COMMODORE 64 ULTIMATE USER'S GUIDE

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QUICK START

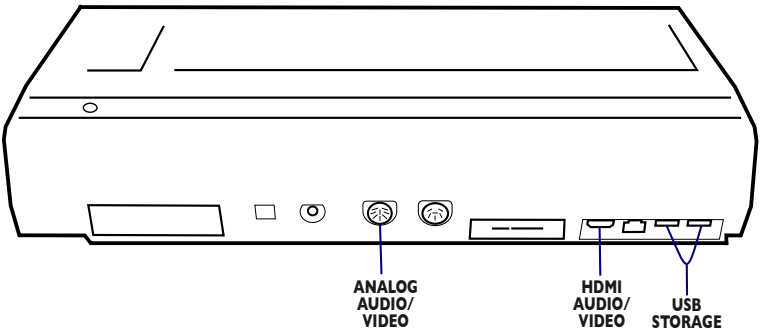
Let's get up and running with your Commodore 64 Ultimate!

Make sure you have:

- Commodore 64 Ultimate computer
- Power supply
- An HDMI® digital display, and HDMI cable (included)
  or
- A composite or S-Video analog display, and 8-pin Commodore A/V cable (available at our website)

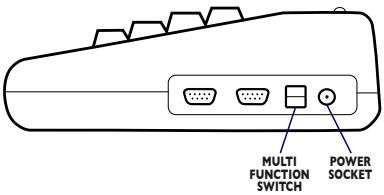
To set up the computer:

Step 1: Use the appropriate video cable to connect the computer to your display.



Step 2: Attach the power connector appropriate for your locale to the power adapter, then connect the adapter to your household power outlet.

Step 3: Connect the power supply to the barrel jack on the right-hand side of the computer.



Step 4: If you have a USB storage device, connect it to either USB storage port.

Step 5: Locate the **Multi Function Switch** on the right-hand side of the computer. Push it upward to switch on the computer.

NOTE: If you are not seeing an image on your display, switch off the computer by holding the Multi Function Switch downward for four seconds. Hold the Commodore key C= and N while switching the computer on again. This temporarily sets the C64U in NTSC video mode, which is required for some displays. See the chapter "Setting Up" for information on how to save this setting.

To **switch off** the C64U, hold the Multi Function Switch downward for four seconds. To **reset** the C64U without switching it off, hold the Multi Function Switch upward for one second.

The Commodore 64 Ultimate works like the original Commodore 64, with modern conveniences. Ultimate features and settings can be accessed from **the C64U Menu**. To open the C64U Menu, press the Multi Function Switch upward momentarily.

The most useful item in the main menu is the **Disk File Browser**. You can use this to browse files on modern storage devices, such as a USB storage device connected to the back-left of the computer.

You can navigate the menu system and file browser using the W, A, S, and D keys, or the Commodore cursor keys.

Press the Multi Function Switch upward to close the menu and return to the **READY** prompt. You can access the C64U Menu at any time, even while a program is running.

FUN THINGS TO TRY!

The best way to learn is to try things. Here are just a few suggestions:

- **Play a game.** Connect your included USB cassette to a USB port, then use the Disk File Browser to find **`GAMES/NTSC & PAL/Bomberland`**. Run the **`.d64`** disk image to start the game.

- **Connect to Wi-Fi.** Select "Wi-Fi Network Setup," then "Select AP from list" to connect to your wireless access point. See chapter 11.

- **Search for a new game.** Select "CommoServe File Search," then enter **`Tenebra 2`** in the "Name" field. Submit the form, then select **`Tenebra 2 (Haplo, 2022)`** from the results. Run the **`.d64`** disk image. See chapter 11. Tip: Don't have a joystick? Turn on keyboard joystick emulation from the C64U Menu.

- **Run a demo.** Try **`DEMOS/Next Level`**. Start with disk "s1."

- **Play some music.** **`MUSIC/MultiSID/The Tuneful Eight`** really shines, using all eight of the C64U's UltiSIDs.

- **Connect to a BBS.** Find **`BBS/UltimateTerm`** on the included USB drive, then run **`UltimateTerm.d64`**. Load the BBS client (option 1), then select a BBS from the list. See chapter 12.

And you're off! Once you've had a look around, return to this Guide for a complete introduction to your new computer.

INTRODUCTION

Congratulations on your purchase of the ultimate version of one of the most beloved computers in the world. You are now the proud owner of a **COMMODORE 64 ULTIMATE**. Commodore is known as **The Friendly Computer** company, and part of being friendly is giving you easy to read, easy to use and easy to understand instruction manuals. The **COMMODORE 64 ULTIMATE USER'S GUIDE** is designed to give you all the information you need to properly set up your equipment, get acquainted with operating the **COMMODORE 64 ULTIMATE**, outline its advanced features in comparison to the original Commodore 64, and give you a simple, fun start at learning to make your own programs.

For those of you who don't want to learn how to program, or who are only interested in the advanced features of the **COMMODORE 64 ULTIMATE**, we've put all the information you need to use Commodore programs from USB storage devices right up front. Later chapters introduce topics such as BASIC programming and more advanced features of the Ultimate.

Let's look at some of the exciting features that are just waiting for you when using a C64U. When it comes to graphics, you've got what was once the most advanced picture maker in the microcomputer industry. **SPRITE GRAPHICS** allow you to design your own pixel based pictures in 4 different colors, just like the ones you see in arcade video games. Using simple programming techniques, you can animate as many as 8 different sprites at one time. You can move your pixel creations anywhere on the screen, even pass one image in front of or behind another. The C64U provides automatic collision detection which instructs the computer to take the action you want when the sprites hit each other.

The Commodore 64 was famous for its built-in music and sound effects that rivaled many well-known music synthesizers of the early 80s. Whilst the original Commodore 64 gave you 3 independent voices, each with a full 9 octave "piano-type" range, the **COMMODORE 64 ULTIMATE** provides as many as 8 emulated SID chips that can operate simultaneously, with 24 independent voices, including the possibility of populating two additional original SID chips on the motherboard. As in the original Commodore 64, you get 4 different waveforms (sawtooth, triangle, variable pulse, and noise), a programmable ADSR (attack, decay, sustain, release) envelope generator, programmable high, low, and bandpass filters for the voices, and variable resonance and volume controls. If you want your music to play back with professional sound reproduction, the

COMMODORE 64 ULTIMATE allows you to connect your audio output to almost any high-quality amplification system.

While we're on the subject of connecting the **COMMODORE 64 ULTIMATE** to other pieces of equipment: your system can be expanded by adding many of the same accessories as the original Commodore 64, known as *peripherals*. Some of your peripheral options include Commodore disk drive storage units such as the VIC 1541, or even the original DATASSETTE recorder, for the programs you make and/or play. You can add a dot matrix printer to give you printed copies of your programs, letters, invoices, etc.

You will find the modern features of the **COMMODORE 64 ULTIMATE** negate the need for most of these peripherals as disk, tape, and cartridge images, sometimes referred to as ROM files, can be utilized instead, accessed via a USB storage device, or via the SD card reader mounted on the Ultimate's motherboard. Printing from various Commodore 64 programs, such as GEOS, can generate output to modern PNG graphics files, which can be transferred to another device for printing on modern printers.

Just as important as all the available hardware is the fact that this **USER'S GUIDE** will help you develop your understanding of computers at a more basic level. Commodore wants you to really enjoy your new **COMMODORE 64 ULTIMATE**. And to have fun, remember: programming is not the kind of thing you can learn in a day. Be patient with yourself as you go through the **USER'S GUIDE**.

The Commodore 64 Ultimate (the "C64U") is a modern interpretation of the best-selling single model of personal computer of all time, the Commodore 64. The C64U adds modern conveniences and connectivity to your Commodore 64 experience, while recreating everything that was great about the original.

We strongly encourage you to seek out the many books, magazine articles, and online resources that have been written about the Commodore 64 over the decades to enhance your Ultimate experience.

Be sure to visit the website of Commodore International for firmware updates, documentation, and more resources for getting the most out of your Commodore 64 Ultimate:

commodore.net

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Ces personnes s'exposent à des crises lorsqu'elles jouent à certains jeux vidéo comportant de telles stimulations, alors même qu'elles n'ont pas d'antécédent médical ou n'ont jamais été sujettes elles-mêmes à des crises d'épilepsie.

Si vous-même ou un membre de votre famille avez déjà présenté des symptômes liés à l'épilepsie (crise ou perte de conscience) en présence de stimulations lumineuses, consultez votre médecin avant toute utilisation.

Les parents se doivent également d'être particulièrement attentifs à leurs enfants lorsqu'ils jouent avec des jeux vidéo.

Si vous-même ou votre enfant présentez un des symptômes suivants : vertige, trouble de la vision, contraction des yeux ou des muscles, trouble de l'orientation, mouvement involontaire ou convulsion, perte momentanée de conscience, il faut cesser immédiatement de jouer et consulter un médecin.

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- Garantire un'adeguata ventilazione.
- Non ci sono parti riparabili dall'utente all'interno. Contattare Commodore per l'assistenza.
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- Fare pause regolari durante l'uso. Utilizzare in una stanza ben illuminata a una distanza di sicurezza.
- California Proposition 65: Questo prodotto può esporvi a sostanze chimiche, tra cui piombo e ftalati, notoriamente cancerogeni o dannosi per l'apparato riproduttivo. Vedere: **`www.P65Warnings.ca.gov`**

Garanzia. Commodore garantisce questo prodotto contro difetti di materiali e fabbricazione per un (1) anno dalla data di acquisto originale. Riparazione, sostituzione o rimborso a discrezione di Commodore. La garanzia esclude la normale usura, l'uso improprio, gli incidenti e le modifiche non autorizzate. I diritti previsti dalla legge a tutela dei consumatori non sono interessati. Prodotto in Cina. Per l'assistenza in garanzia, contattare l'assistenza Commodore: **`commodore.net/contact-us`** Oppure scrivere a: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Licenza software. Il software, il firmware e le ROM Commodore sono concessi in licenza, non venduti. È possibile utilizzare il software solo con l'hardware Commodore. Il reverse engineering, la modifica o la ridistribuzione sono vietati, salvo quanto consentito dalla legge. Alcuni software includono componenti concessi in licenza o open source. Per ulteriori informazioni, visitare: **`commodore.net/licenses`**

Conformità alle normative. Questo dispositivo è conforme alla Parte 15 delle Norme FCC. Il funzionamento è soggetto alle seguenti due condizioni: (1) questo dispositivo non deve causare interferenze dannose e (2) questo dispositivo deve accettare qualsiasi interferenza ricevuta, incluse interferenze che potrebbero causare un funzionamento indesiderato. Questo dispositivo è conforme a ICES-003, CE, UKCA, RCM, RoHS e REACH. Modifiche non autorizzate possono invalidare l'approvazione normativa e l'autorizzazione all'utilizzo del prodotto.

Supporto & Riciclo. Non smaltire con i rifiuti domestici. Per informazioni sul riciclaggio, consultare il simbolo sul prodotto o sulla confezione.

Per i termini di garanzia completi, le istruzioni di assistenza e le dichiarazioni di conformità UE/Regno Unito, visitare: **`commodore.net/compliance`**

Turvallisuus ja terveys

- Käytä vain hyväksyttyä virtalähdettä.
- Pidä poissa vedestä ja liiallisesta kuumuudesta.
- Varmista asianmukainen ilmanvaihto.
- Sisällä ei ole käyttäjän huollettavia osia. Ota yhteyttä Commodoreen huoltoa varten.
- Jotkut ihmiset saattavat saada epileptisiä kohtauksia altistuessaan välkkyville valoille tai visuaalisille kuvioille --- vaikka heillä ei olisi koskaan aiemmin ollut sellaista. Jos sinulla tai jollain perheenjäsenelläsi on epilepsia, ota yhteys lääkäriin ennen tämän tuotteen käyttöä. Lopeta käyttö välittömästi ja hakeudu lääkärin hoitoon, jos sinulla ilmenee huimausta, näön hämärtymistä, tahattomia liikkeitä, tajunnan menetystä tai muita oireita.
- Vanhemmat: valvokaa lasten käyttöä. Pidä säännöllisiä taukoja (10-15 minuuttia tunnissa) ja säädä kirkkautta tarpeen mukaan.
- Pidä säännöllisiä taukoja käytön aikana. Käytä hyvin valaistussa huoneessa turvallisella katseluetäisyydellä.
- Kalifornian lakiehdotus 65: Tämä tuote voi altistaa sinut kemikaaleille, mukaan lukien lyijy ja ftalaatit, joiden tiedetään aiheuttavan syöpää tai lisääntymisterveydelle haitallisia vaikutuksia. Katso: **`www.P65Warnings.ca.gov`**

Takuu. Commodore myöntää tälle tuotteelle yhden (1) vuoden takuun materiaali- ja valmistusvirheiden varalta alkuperäisestä ostopäivästä. Korjaus, vaihto tai hyvitys Commodoren valinnan mukaan. Takuu ei kata normaalia kulumista, väärinkäyttöä, onnettomuuksia tai luvattomia muutoksia. Kuluttajansuojalain mukaiset oikeudet eivät muutu. Valmistettu Kiinassa. Takuupalvelua varten ota yhteyttä Commodoren tukeen: **`commodore.net/contact-us`** Tai kirjoita osoitteeseen: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Ohjelmistolisenssi. Commodoren ohjelmisto, laiteohjelmisto ja ROM-levyt lisensoidaan, niitä ei myydä. Voit käyttää ohjelmistoa vain Commodore-laitteistosi kanssa. Käänteinen suunnittelu, muokkaaminen tai jakelu on kielletty, ellei laki sitä salli. Jotkin ohjelmistot sisältävät lisensoituja tai avoimen lähdekoodin komponentteja. Lisätietoja on osoitteessa: **`commodore.net/licenses`**

Sääntelyvaatimustenmukaisuus. Tämä laite on FCC-sääntöjen osan 15 mukainen. Käyttöön sovelletaan seuraavia kahta ehtoa: (1) tämä laite ei saa aiheuttaa haitallisia häiriöitä ja (2) tämän laitteen on siedettävä kaikki vastaanotetut häiriöt, mukaan lukien häiriöt, jotka voivat aiheuttaa ei-toivottua toimintaa. Tämä laite on ICES-003-, CE-, UKCA-, RCM-, RoHS- ja REACH-standardien mukainen. Luvattomat muutokset voivat mitätöidä viranomaisten hyväksynnän ja oikeutesi käyttää tuotetta.

Tuki & Kierrätys. Älä hävitä kotitalousjätteen mukana. Kierrätystiedot löytyvät tuotteen tai pakkauksen symbolista.

Täydelliset takuuehdot, huolto-ohjeet ja EU:n/UK:n vaatimustenmukaisuusvakuutukset löytyvät osoitteesta: **`commodore.net/compliance`**

Säkerhet och hälsa

- Använd endast godkänd strömförsörjning.
- Förvaras åtskilt från vatten och stark värme.
- Sörj för god ventilation.
- Inga delar inuti som kan repareras av användaren. Kontakta Commodore för service.
- Vissa personer kan uppleva epileptiska anfall när de utsätts för blinkande ljus eller visuella mönster --- även om de aldrig har haft det förut. Om du eller någon i din familj har epilepsi tidigare, rådfråga en läkare innan du använder denna produkt. Sluta använda produkten omedelbart och sök läkarvård om du upplever yrsel, dimsyn, ofrivilliga rörelser, medvetslöshet eller andra symtom.
- Föräldrar: övervaka barns användning. Ta regelbundna pauser (10-15 minuter per timme) och justera ljusstyrkan efter behov.
- Ta regelbundna pauser under användning. Använd i ett väl upplyst rum på säkert avstånd.
- California Prop 65: Denna produkt kan utsätta dig för kemikalier inklusive bly och ftalater, som är kända för att orsaka cancer eller reproduktionsskador. Se: `www.P65Warnings.ca.gov`

Garanti. Commodore garanterar att denna produkt är fri från defekter i material och utförande i ett (1) år från det ursprungliga inköpsdatumet. Reparation, utbyte eller återbetalning sker efter Commodores gottfinnande. Garantin gäller inte normalt slitage, felaktig användning, olyckor eller obehöriga modifieringar. Rättigheter enligt konsumentlagstiftningen påverkas inte. Tillverkad i Kina. För garantiservice, kontakta Commodore Support: `commodore.net/contact-us` Eller skriv till: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Programvarulicens. Commodore-programvara, firmware och ROM-skivor är licensierade, säljs inte. Du får endast använda programvaran med din Commodore-hårdvara. Reverse engineering, modifiering eller omdistribution är förbjuden förutom vad som är tillåtet enligt lag. Viss programvara innehåller licensierade komponenter eller komponenter med öppen källkod. För mer information, besök: `commodore.net/licenses`

Efterlevnad av regelverk. Denna enhet uppfyller del 15 av FCC-reglerna. Användning är föremål för följande två villkor: (1) denna enhet får inte orsaka skadliga störningar, och (2) denna enhet måste acceptera alla mottagna störningar, inklusive störningar som kan orsaka oönskad drift. Denna enhet uppfyller ICES-003, CE, UKCA, RCM, RoHS och REACH. Obehöriga modifieringar kan ogiltigförklara myndighetsgodkännande och din behörighet att använda produkten.

Stöd & Återvinning. Kassera inte med hushållsavfallet. För information om återvinning, se symbolen på produkten eller förpackningen.

För fullständiga garantivillkor, serviceinstruktioner och EU/UK-försäkran om överensstämmelse, besök: `commodore.net/compliance`

Sikkerhet og helse

- Bruk kun godkjent strømforsyning.
- Holdes unna vann og sterk varme.
- Sørg for tilstrekkelig ventilasjon.
- Ingen deler inni som kan repareres av brukeren. Kontakt Commodore for service.
- Noen kan oppleve epileptiske anfall når de utsettes for blinkende lys eller visuelle mønstre --- selv om de aldri har hatt det før. Hvis du eller noen i familien din har en historie med epilepsi, bør du kontakte lege før du bruker dette produktet. Stopp bruken umiddelbart og kontakt lege hvis du opplever svimmelhet, tåkesyn, ufrivillige bevegelser, bevissthetstap eller andre symptomer.
- Foreldre: Overvåk barns bruk. Ta regelmessige pauser (10–15 minutter per time) og juster lysstyrken etter behov.
- Ta regelmessige pauser under bruk. Bruk i et godt opplyst rom med trygg synsavstand.
- California Prop 65: Dette produktet kan utsette deg for kjemikalier, inkludert bly og ftalater, som er kjent for å forårsake kreft eller reproduksjonsskader. Se: `www.P65Warnings.ca.gov`

Garanti. Commodore garanterer at dette produktet er fri for defekter i materialer og utførelse i ett (1) år fra datoen for det opprinnelige kjøpsresultatet. Reparasjon, erstatning eller refusjon er etter Commodores valg. Garantien ekskluderer normal slitasje, misbruk, ulykker og uautoriserte modifikasjoner. Rettigheter under forbrukerloven påvirkes ikke. Laget i Kina. For garantiservice, kontakt Commodore Support: `commodore.net/contact-us` Eller skriv til: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Programvarelisens. Commodore-programvare, fastvare og ROM-er er lisensiert, ikke solgt. Du kan kun bruke programvaren med Commodore-maskinvaren din. Omvendt utvikling, modifisering eller videredistribusjon er forbudt, med mindre det er tillatt ved lov. Noe programvare inneholder lisensierte komponenter eller komponenter med åpen kildekode. For mer informasjon, besøk: `commodore.net/licenses`

Samsvar med forskrifter. Denne enheten er i samsvar med del 15 av FCC-reglene. Bruk er underlagt følgende to betingelser: (1) denne enheten må ikke forårsake skadelig interferens, og (2) denne enheten må godta all mottatt interferens, inkludert interferens som kan forårsake uønsket drift. Denne enheten er i samsvar med ICES-003, CE, UKCA, RCM, RoHS og REACH. Uautoriserte modifikasjoner kan ugyldiggjøre myndighetsgodkjenning og din rett til å bruke produktet.

Støtte & Resirkulering. Ikke kast i husholdningsavfallet. For informasjon om resirkulering, se symbolet på produktet eller emballasjen.

For fullstendige garantivilkår, serviceinstruksjoner og samsvarserklæringer for EU-/UK, besøk: `commodore.net/compliance`

Bezpieczeństwo i higiena pracy

- Używaj wyłącznie zatwierdzonego zasilacza.
- Trzymaj z dala od wody i nadmiernego ciepła.
- Zapewnij odpowiednią wentylację.
- Wewnątrz nie ma części, które mogą być naprawiane przez użytkownika. Skontaktuj się z Commodore w celu naprawy.
- U niektórych osób mogą wystąpić napady padaczkowe po narażeniu na migające światło lub wzorce wizualne --- nawet jeśli nigdy wcześniej ich nie miały. Jeśli Ty lub ktokolwiek z Twojej rodziny choruje na padaczkę, skonsultuj się z lekarzem przed użyciem tego produktu. Natychmiast przerwij używanie i zasięgnij porady lekarza, jeśli wystąpią zawroty głowy, niewyraźne widzenie, mimowolne ruchy, utrata przytomności lub inne objawy.
- Rodzice: kontroluj użytkowanie urządzenia przez dzieci. Rób regularne przerwy (10-15 minut na godzinę) i dostosowuj jasność w razie potrzeby.
- Rób regularne przerwy podczas użytkowania. Używać w dobrze oświetlonym pomieszczeniu, w bezpiecznej odległości.
- California Prop 65: Ten produkt może narazić Cię na działanie substancji chemicznych, w tym ołowiu i ftalanów, o których wiadomo, że powodują raka lub uszkodzenia układu rozrodczego. Patrz: `www.P65Warnings.ca.gov`

Gwarancja. Commodore udziela gwarancji na ten produkt na wady materiałowe i wykonawcze przez jeden (1) rok od daty pierwotnego zakupu detalicznego. Naprawa, wymiana lub zwrot pieniędzy według uznania Commodore. Gwarancja nie obejmuje normalnego zużycia, niewłaściwego użytkowania, wypadków ani nieautoryzowanych modyfikacji. Prawa wynikające z przepisów prawa konsumenckiego pozostają nienaruszone. Wyprodukowano w Chinach. W celu uzyskania serwisu gwarancyjnego skontaktuj się z pomocą techniczną Commodore: `commodore.net/contact-us` lub napisz na adres: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Licencja oprogramowania. Oprogramowanie, oprogramowanie sprzętowe i pamięci ROM firmy Commodore są licencjonowane, a nie sprzedawane. Oprogramowanie można używać wyłącznie ze sprzętem Commodore. Inżynieria wsteczna, modyfikacja lub redystrybucja są zabronione, chyba że zezwala na to prawo. Niektóre oprogramowanie zawiera komponenty licencjonowane lub open source. Aby uzyskać więcej informacji, odwiedź stronę: `commodore.net/licenses`

Zgodność z przepisami. To urządzenie jest zgodne z częścią 15 przepisów FCC. Jego użytkowanie podlega dwóm następującym warunkom: (1) urządzenie nie może powodować szkodliwych zakłóceń oraz (2) urządzenie musi akceptować wszelkie odbierane zakłócenia, w tym zakłócenia, które mogą powodować niepożądane działanie. To urządzenie jest zgodne z ICES-003, CE, UKCA, RCM, RoHS i REACH. Nieautoryzowane modyfikacje mogą unieważnić zatwierdzenie regulacyjne i prawo do korzystania z produktu.

Wsparcie & Recykling. Nie wyrzucać razem z odpadami domowymi. Informacje na temat recyklingu znajdują się na symbolu umieszczonym na produkcie lub opakowaniu.

Pełne warunki gwarancji, instrukcje serwisowe oraz deklaracje zgodności UE/Wielkiej Brytanii można znaleźć na stronie: `commodore.net/compliance`

Seguridad y Salud

- Utilice únicamente una fuente de alimentación aprobada.
- Mantener alejado del agua y del calor excesivo.
- Proporcione una ventilación adecuada.
- No contiene piezas que el usuario pueda reparar. Contacte con Commodore para obtener servicio técnico.
- Algunas personas pueden experimentar ataques epilépticos al exponerse a luces intermitentes o patrones visuales, incluso si nunca los han sufrido. Si usted o algún miembro de su familia tiene antecedentes de epilepsia, consulte a un médico antes de usar este producto. Deje de usarlo inmediatamente y busque atención médica si experimenta mareos, visión borrosa, movimientos involuntarios, pérdida de consciencia u otros síntomas.
- Padres: supervisen el uso de los niños. Tomen descansos regulares (de 10 a 15 minutos por hora) y ajusten el brillo según sea necesario.
- Tomen descansos regulares durante el uso. Úselo en una habitación bien iluminada y a una distancia de visión segura.
- California Prop 65: Este producto puede exponerlo a sustancias químicas, como plomo y ftalatos, que se sabe que causan cáncer o daños reproductivos. Consulte: `www.P65Warnings.ca.gov`

Garantía. Commodore garantiza este producto contra defectos de materiales y mano de obra durante un (1) año a partir de la fecha de compra original. La reparación, el reemplazo o el reembolso son a discreción de Commodore. La garantía excluye el desgaste normal, el mal uso, los accidentes y las modificaciones no autorizadas. Los derechos bajo la ley del consumidor no se ven afectados. Fabricado en China. Para obtener servicio de garantía, comuníquese con el soporte técnico de Commodore: `commodore.net/contact-us` o escriba a: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, EE. UU.

Licencia del software. El software, el firmware y las ROM de Commodore se otorgan bajo licencia, no se venden. Puede usar el software únicamente con su hardware Commodore. La ingeniería inversa, la modificación y la redistribución están prohibidas, salvo en los casos permitidos por la ley. Algunos programas incluyen componentes con licencia o de código abierto. Para obtener más información, visite: `commodore.net/licenses`

Cumplimiento normativo. Este dispositivo cumple con la Parte 15 de las Normas de la FCC. Su funcionamiento está sujeto a las dos condiciones siguientes: (1) este dispositivo no puede causar interferencias perjudiciales y (2) este dispositivo debe aceptar cualquier interferencia recibida, incluidas las que puedan causar un funcionamiento no deseado. Este dispositivo cumple con las normas ICES-003, CE, UKCA, RCM, RoHS y REACH. Las modificaciones no autorizadas pueden anular la aprobación regulatoria y su autorización para operar el producto.

Apoyo & Reciclaje. No lo deseche con la basura doméstica. Para obtener información sobre el reciclaje, consulte el símbolo en el producto o el embalaje.

Para consultar los términos completos de la garantía, las instrucciones de servicio y las Declaraciones de Conformidad UE/RU, visite: `commodore.net/compliance`

Biztonság és egészség

- Csak jóváhagyott tápegységet használjon.
- Tartsa távol víztől és túlzott hőhatástól.
- Biztosítson megfelelő szellőzést.
- A készülék nem tartalmaz felhasználó által szervizelhető alkatrészeket. Szervizelésért forduljon a Commodore-hoz.
- Egyes emberek epilepsziás rohamokat tapasztalhatnak villogó fények vagy vizuális minták hatására --- még akkor is, ha korábban soha nem volt ilyenjük. Ha Önnek vagy családtagjának epilepsziája van, a termék használata előtt konzultáljon orvossal. Azonnal hagyja abba a használatát, és forduljon orvoshoz, ha szédülést, homályos látást, akaratlan mozgásokat, eszméletvesztést vagy egyéb tüneteket tapasztal.
- Szülők: felügyeljék a gyermekek használatát. Rendszeresen tartson szüneteket (óránként 10-15 perc), és szükség szerint állítsa be a fényerőt.
- Használat közben rendszeresen tartson szüneteket. Használja jól megvilágított helyiségben, biztonságos látótávolságban.
- California Prop 65: Ez a termék olyan vegyi anyagoknak teheti ki Önt, beleértve az ólmot és a ftalátokat, amelyekről ismert, hogy rákot vagy reproduktív károsodást okoznak. Lásd: **`www.P65Warnings.ca.gov`**

Garancia. A Commodore az eredeti kiskereskedelmi vásárlás dátumától számított egy (1) évig szavatolja, hogy nem felel meg az anyag- és gyártási hibáknak. A javítás, csere vagy visszatérítés a Commodore belátása szerint történik. A garancia nem vonatkozik a normál kopásra, a nem rendeltetésszerű használatra, a balesetekre és a jogosulatlan módosításokra. A fogyasztóvédelmi törvények szerinti jogokat ez nem érinti. Kínában készült. Garanciális szervizért forduljon a Commodore támogatásához: **`commodore.net/contact-us`** Vagy írjon a következő címre: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Szoftverlicenc. A Commodore szoftver, firmware és ROM-ok licencbe kerülnek, nem kerülnek értékesítésre. A szoftvert csak a Commodore hardverével használhatja. A visszafejtés, módosítás vagy terjesztés tilos, kivéve, ha azt törvény engedélyezi. Egyes szoftverek licencelt vagy nyílt forráskódú összetevőket tartalmaznak. További információkért látogasson el ide: **`commodore.net/licenses`**

Szabályozási megfelelőség. Ez az eszköz megfelel az FCC szabályok 15. részének. A működés a következő két feltételhez kötött: (1) ez az eszköz nem okozhat káros interferenciát, és (2) az eszköznek el kell fogadnia minden interferenciát, beleértve a nem kívánt működést okozó interferenciát is. Ez az eszköz megfelel az ICES-003, CE, UKCA, RCM, RoHS és REACH előírásoknak. A jogosulatlan módosítások érvényteleníthetik a hatósági jóváhagyást és a termék üzemeltetésére vonatkozó jogosultságot.

Támogatás & Újrahasznosítás. Ne dobja a háztartási hulladékkal együtt. Az újrahasznosítási információkért lásd a terméken vagy a csomagoláson található szimbólumot.

A teljes jótállási feltételekért, a szervizelési utasításokért és az EU/UK megfelelőségi nyilatkozatokért látogasson el ide: **`commodore.net/compliance`**

Sikkerhed og sundhed

- Brug kun godkendt strømforsyning.
- Holdes væk fra vand og overdreven varme.
- Sørg for tilstrækkelig ventilation.
- Ingen dele indeni, som brugeren kan servicere. Kontakt Commodore for service.
- Nogle mennesker kan opleve epileptiske anfald, når de udsættes for blinkende lys eller visuelle mønstre --- selvom de aldrig har haft det før. Hvis du eller et medlem af din familie har en historie med epilepsi, skal du kontakte en læge, før du bruger dette produkt. Stop brugen med det samme og søg lægehjælp, hvis du oplever svimmelhed, sløret syn, ufrivillige bevægelser, bevidsthedstab eller andre symptomer.
- Forældre: Overvåg børns brug. Tag regelmæssige pauser (10-15 minutter i timen) og juster lysstyrken efter behov.
- Tag regelmæssige pauser under brug. Brug i et godt oplyst rum i sikker synsafstand.
- California Prop 65: Dette produkt kan udsætte dig for kemikalier, herunder bly og ftalater, der vides at forårsage kræft eller reproduktionsskader. Se: `www.P65Warnings.ca.gov`

Garanti. Commodore garanterer dette produkt mod defekter i materialer og udførelse i et (1) år fra datoen for det oprindelige køb. Reparation, udskiftning eller refusion efter Commodores valg. Garantien udelukker normal slitage, misbrug, ulykker og uautoriserede ændringer. Rettigheder i henhold til forbrugerlovgivningen påvirkes ikke. Fremstillet i Kina. For garantiservice, kontakt Commodore Support: `commodore.net/contact-us` Eller skriv til: Commodore International Corporation, 8 The Green, Ste A, Dover, Kent, DE 19901, USA

Softwarelicens. Commodore-software, firmware og ROM'er er licenseret, ikke solgt. Du må kun bruge softwaren med din Commodore-hardware. Reverse engineering, ændring eller videredistribution er forbudt, medmindre det er tilladt ved lov. Noget software indeholder licenserede eller open source-komponenter. For mere information, besøg: `commodore.net/licenses`

Overholdelse af regler. Denne enhed overholder del 15 af FCC-reglerne. Brug er underlagt følgende to betingelser: (1) denne enhed må ikke forårsage skadelig interferens, og (2) denne enhed skal acceptere enhver modtaget interferens, herunder interferens, der kan forårsage uønsket drift. Denne enhed overholder ICES-003, CE, UKCA, RCM, RoHS og REACH. Uautoriserede ændringer kan ugyldiggøre den lovgivningsmæssige godkendelse og din tilladelse til at betjene produktet.

Support & Genbrug. Bortskaf ikke med husholdningsaffald. For information om genbrug, se symbolet på produktet eller emballagen.

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CHAPTER 1

SETTING UP

- Unpacking and Connecting the Commodore 64 Ultimate
- Installing and Switching On the C64U
- The Multi Function Switch
- Configuring the C64U
- Typing Commands

UNPACKING AND CONNECTING THE COMMODORE 64 ULTIMATE

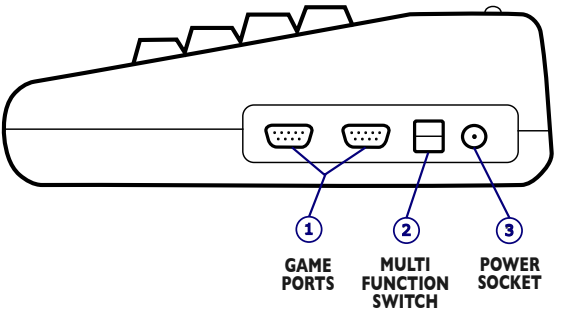
The following step-by-step instructions show you how to connect the Commodore 64 Ultimate to your HDMI display and make sure everything is working properly.

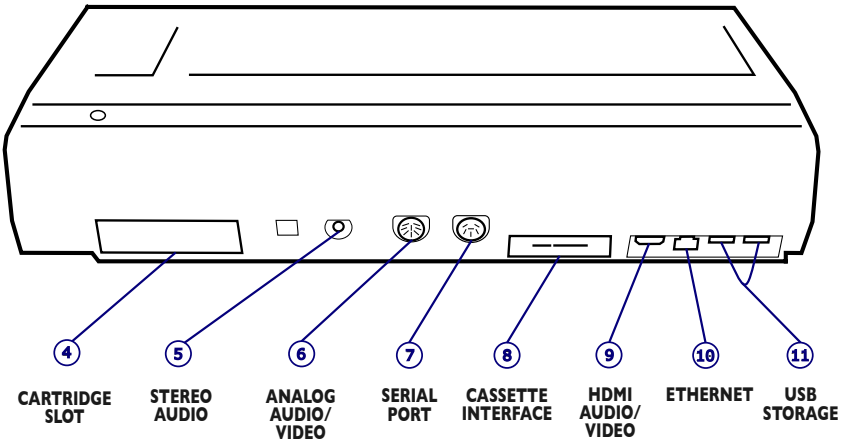
Your box contains the following:

- Commodore 64 Ultimate
- Power supply, with power connectors for each locale
- HDMI cable
- USB storage device

If any items are missing, visit the Commodore International website to contact customer support: **`commodore.net`**

First, let's take a look at the arrangement of the various connections on the computer and how each functions.





Side Panel Connections

1. **Control (Game) ports.** Each game port can accept a joystick or game controller paddle set, or a Commodore 64-compatible mouse or mouse adapter.
2. **Multi Function Switch.** This switches the C64U on or off, and provides access to the C64U Menu and other functions.
3. **Power socket.** The free end of the cable from the power supply is attached here to supply power to the Commodore 64 Ultimate.

Rear Connections

4. **Cartridge slot.** The rectangular slot to the left (when viewed from the back) accepts Commodore 64 or C64U program or game cartridges.
5. **Audio output.** You can connect optional speakers to this standard 3.5mm stereo audio jack. The C64U also supports optical S/PDIF audio output through the same port. This is a line-level output and cannot be used with headphones.
6. **Commodore 64 video output.** Use an 8-pin Commodore video cable (available from our website) to connect the C64U to composite or S-Video displays, such as vintage CRT monitors or 4:3 flat panel displays. This is not needed when using an HDMI display.
7. **IEC serial port.** Connect IEC serial devices such as original Commodore disk drives, modern drive emulator devices, or printer interfaces. (See chapter 10.)
8. **Cassette interface.** An original Commodore Datassette recorder or compatible device can be attached for loading and saving programs on cassette tape.
9. **HDMI® video output.** Connect an HDMI digital video display, with built-in audio. HDMI video output uses a 16:9 aspect ratio, 1080p HD.
10. **Ethernet.** The C64U can connect to your local network via Ethernet cable, or via Wi-Fi.
11. **USB storage** (2x). Use these USB-A ports to connect USB storage devices containing disk images, tape images, cartridge files, system ROMs, and firmware updates.

The C64U does not have a Commodore 64-style user port (IEEE-488 interface) on the back side. Instead, an optional user port adapter (sold separately) can be connected to the mainboard. See chapter 10.

NOTE: The C64U's case is designed to resemble the Commodore 64, including some unusual port labels pressed into the plastic along the back. "MEMORY EXPANSION" is another name for the cartridge slot, because cartridges contain memory chips that connect to the Commodore 64 memory system. "H-L" and "RF" refer to ways the Commodore 64 connects to vintage television sets; the C64U does not provide these ports, and instead provides a stereo audio output jack. The label "USER PORT" appears above the HDMI port, Ethernet port, and USB ports, because this is the location of the user port on the Commodore 64. We just couldn't resist keeping the original labels.

INSTALLING AND SWITCHING ON THE C64U

To set up the computer with an HDMI display:

1. Connect the computer to the display with the HDMI cable to the HDMI port on the back-left of the computer.
2. Connect the power supply to the barrel jack on the right-hand side of the computer.
3. Attach the power connector appropriate for your locale to the power adapter, then connect it to your main power.

The HDMI connection provides a 1080p HD digital signal, with a 16:9 aspect ratio. To change the size of the image as it appears on your HDMI display, use your display's built-in options. Usually these are found in the display's on-screen settings menu, and are often called "Aspect Ratio" or similar.

Alternatively, you can use an 8-pin Commodore A/V cable to connect the C64U to an analog display that supports a composite or S-Video connection. This connection provides an analog video signal, with a 4:3 aspect ratio. The analog A/V port is on the back of the computer. Take care to identify the A/V port and the serial IEC port: they have similar shapes but different pins.

Locate the Multi Function switch on the right-hand side of the computer. Push it in either direction to switch on the computer. The C64U's power light illuminates, and an image appears on the display.

THE MULTI FUNCTION SWITCH

The Multi Function Switch is a rocker switch that can be pressed or held either upward or downward. It has the following features:

To do this...	Multi Function Switch operation
Switch on (when off)	Press either upward or downward
Switch off (when on)	Hold downward for 4 seconds
Reset (when not in menu)	Hold upward for 1 second, then release
Toggle C64U Menu	Press upward

CONFIGURING THE C64U

The Commodore 64 Ultimate is *extremely* configurable, for the ultimate experience. The following are just a few options you might consider adjusting for now. Additional options will be described later in this Guide.

You can browse and modify all configuration options in the C64U Menu. To access the menu, press upward on the Multi Function Switch.

The C64U Menu is accessible at all times while using your C64U, even when a Commodore 64 program is running. Pressing upward on the Multi Function Switch pauses the program that is running, then displays the menu. When you exit the menu, the program will resume. (You can use this to pause any game if you need a break.)

You can navigate the menu with the keyboard, as follows:

- Use the W and S keys to move the selection up and down.
- Use D to open the selected sub-menu, and A to return to the parent menu.
- Press RETURN to select an option or action. In some cases, this opens a pop-up menu to change a setting or offer additional actions.
- Press RUN/STOP to exit a pop-up menu, return to a parent menu, or exit the C64U main menu. (To make a hasty exit, press RUN/STOP repeatedly.)

If you're already familiar with the Commodore 64 cursor keys, these can also be used to navigate menus. If you're not already familiar, you will be introduced to them in chapter 3.

If you change an option, the C64U Menu prompts you to save your changes when you attempt to exit the menu. Press Y or N to confirm or skip saving the settings. Some options do not take effect until you exit the menu.

Safe Mode

If you accidentally change a setting that is incompatible with your display or otherwise prevents your ability to access the menu, you can restart the computer in *safe mode*. This mode temporarily resets all settings to their defaults.

To enter safe mode:

1. Hold the Multi Function Switch downward for 4 seconds to switch off the computer.
2. Press and hold the RESTORE key.
3. Switch on the computer: press the Multi Function Switch upward.

To save the restored settings to flash memory, make any change, exit the menu, then save the settings when prompted. Safe mode will only change the saved settings when asked to do so.

The Tool Menu

The Tool menu provides several useful actions, available anywhere within the C64U Menu. To open the Tool menu, press F1. To exit the Tool menu without selecting an option, press RUN/STOP.

PAL vs. NTSC

When the original Commodore 64 was released, different countries used competing technical standards for analog video signals displayed on televisions and computer monitors. Commodore made versions of its computers for two different standards, and sold them in the countries where those standards were used: **NTSC** in North America and Japan, and **PAL** in Europe, the United Kingdom, Australia, and New Zealand.

Most modern digital displays support both NTSC and PAL image sizes and refresh rates. If you have an older digital display, or if you are using an analog display with a Commodore 64 video cable, you may need to switch the video mode to one that is compatible with your display.

There's another reason to switch video modes: Some Commodore 64 software only runs correctly in one mode or the other. Some games will run in either mode, but the game or music will play at the wrong speed, due to how the program uses the computer's refresh rate to synchronize timed events. A few games will crash or not run at all if the computer is in a mode it doesn't expect.

You can choose the video mode temporarily while switching on the computer:

To start in this mode...	Hold these keys...
NTSC	C= N
PAL	C= P

To switch the C64U video mode setting and save it for future sessions:

1. Open the C64U Menu.
2. Select "Video Setup."
3. Select the "System Mode" option (press RETURN).
4. In the pop-up menu, select "PAL" or "NTSC." (Other options support unusual combinations of video encoding and refresh rate.)
5. Press RUN/STOP to switch video modes. If the display is no longer working, switch off the computer, then switch it on again to return to the previously selected video mode.
6. Press Y to save the setting.

Most software runs correctly in PAL mode, while some titles require NTSC. If your display supports PAL mode, it is useful to make this your default setting. You can always change it later.

HDMI Scan Lines

Cathode ray tube (CRT) displays use a raster beam to draw the image onto a phosphor coating many times per second, moving the beam horizontally in tiny rows. This method of producing an image causes tiny gaps to appear between the rows, known as *scan lines*. Modern LCD flat panel displays do not show gaps between the rows, and anyone used to seeing Commodore 64 images on a CRT may notice the difference. The Commodore 64 Ultimate can simulate the scan lines on an HDMI display.

To enable or disable HDMI scan lines:

1. Open the C64U Nenu.
2. Select "Video Setup."
3. Select the "HDMI Scan lines" option (move the selection down, then press RETURN).
4. Select "Disabled" or "Enabled," as you prefer.
5. Exit the menu to apply the setting, then press Y to save it.

Built-in Speaker

The Commodore 64 Ultimate has a built-in speaker inside the computer. This speaker has two functions: it plays sound effects and music generated by a program, and it simulates the sounds of using a vintage disk drive when working with digital disk images. (It is common to rely on disk drive noises to confirm that the computer is busy loading or saving data, when the computer otherwise doesn't look like it's doing anything.)

You can disable the built-in speaker for quieter operation.

1. Open the C64U Menu.
2. Select "Audio Setup."
3. Select "Speaker Mixer."
4. Select the "Speaker Enable" option (press RETURN).
5. Select "Disabled" or "Enabled," as you prefer.
6. Exit the menu to apply the setting, then press Y to save it.

Sound generated by programs will continue to play through HDMI displays or the audio jack. Simulated drive noises only play through the built-in speaker, and only when it is enabled.

RAM Expansion Unit

The original Commodore 64 provided up to 64 kilobytes of memory for program use. This memory could be expanded using a RAM Expansion Unit (REU), a separate device connected to the Commodore 64's expansion port. Some programs use the REU for faster operation or large temporary storage.

The C64U provides an emulation of an REU to support running such programs. It is disabled by default to avoid confusing programs that are not expecting an REU to be connected. To enable the REU:

1. Open the C64U Menu.
2. Select "Memory & ROMs."
3. Select "RAM Expansion Unit."
4. Select "Disabled" or "Enabled," as you prefer.
5. Exit the menu to apply the setting, then press Y to save it.

Joystick Swap

Many Commodore 64 games require that a joystick be connected to the second game port (port 2). Others only work with the joystick connected to port 1. Commodore gamers are familiar with needing to move the joystick between the ports when switching games.

To make this easier, the Commodore 64 Ultimate can swap the identities of the two game ports, so you can continue playing without hassling with the cable connections.

To swap the joystick port assignments in the configuration:

1. Open the C64U Menu.
2. Select "Joystick & Controllers."
3. Select "Joystick Input."
4. Select "Normal" or "Swapped," as you prefer.
5. Exit the menu to apply the setting, then press Y to save it.

Troubleshooting Software

The Commodore 64 Ultimate can behave like a Commodore 64 with common peripherals attached. Some of these features, such as the PAL or NTSC video mode or the RAM Expansion Unit (REU), can cause some Commodore 64 programs to behave incorrectly, because those programs were not written to be compatible with the equivalent hardware.

If a Commodore 64 program does not appear to be behaving correctly, try changing C64U settings, such as the following:

- Change the video mode from PAL to NTSC, or from NTSC to PAL.
- Disable the RAM Expansion Unit.
- If you have installed JiffyDOS ROM files, switch back to the stock Commodore 64 ROMs.
- Disconnect unused IEC peripherals, such as external disk drives.
- Disable virtual disk drive B: from the C64U Menu, select "Disk Drive B Options," then ensure "Drive" is "Disabled."
- Disable the Software IEC feature: from the C64U Menu, open the Tool menu (press F1). Select "Software IEC." If the action "Turn Off" is available, select it.

- Disable the printer emulation feature: from the C64U Menu, open the Tool menu (press F1). Select "Printer." If the action "Turn Off" is available, select it.

TYPING COMMANDS

When you switch on the Commodore 64 Ultimate (without a cartridge attached), it starts the Commodore 64 command prompt: a blinking cursor at a **READY** prompt. This prompt is your Commodore saying it is ready to receive your commands.

```
READY.
```

Let's try giving it a command. Type the following text, then press the RETURN key:

```
PRINT "HELLO COMMODORE 64 ULTIMATE!"
```

You'll get a complete introduction to the Commodore 64 keyboard in chapter 3. For now, notice a few things:

- When you type a letter, it appears in uppercase, as shown here. In the default uppercase letter mode, you do not need to hold SHIFT to type an uppercase letter. (There is also a lowercase letter mode, which we will discuss later.)
- To type the double-quote mark, hold SHIFT and press 2. The Commodore 64 keyboard has minor differences from a modern PC keyboard.
- If you type an incorrect character, press INST DEL to delete it.

When you press RETURN with the cursor anywhere on the line with your command, the C64U performs your command. In this case, it performs a command to PRINT a phrase onto the screen. The phrase appears just below the command, followed by a fresh **READY** prompt.

```
PRINT "HELLO COMMODORE 64 ULTIMATE!"
HELLO COMMODORE 64 ULTIMATE!

READY.
```

If you get into a state that you do not understand while typing commands, hold the RUN/STOP key then press the RESTORE key. The screen clears, and the C64U displays a new **READY** prompt so you can try again. You will learn more about controlling the cursor in chapter 3.

CHAPTER 2

THE C64U FILE BROWSER

- The Disk File Browser
- Updating the C64U Firmware
- Using Disk Images
- Using Cartridge ROM Files
- Using Tape Images
- Using PRG and T64 Files
- Playing SID Music Files
- File Operations

THE DISK FILE BROWSER

The original Commodore 64 connected to other devices for loading and storing (saving) programs and data, such as floppy disk drives and the Commodore Datassette drive. You can connect your Commodore 64 Ultimate to such devices for the same purpose, if you have them. (See chapter 10.)

The Commodore 64 Ultimate also offers modern data storage options, including USB storage devices or an SD card formatted for a modern computer with the FAT-32 or exFAT filesystem.[1] Here are just some of the things you can do with files on USB storage or an SD card:

- Store disk or tape image files that replicate the experience of using floppy disks or cassettes.
- Store cartridge ROM files that replicate the experience of attaching cartridge modules.
- Update the C64U firmware.
- Play Commodore 64 SID music files using the built-in SID player.

You use the C64U Disk File Browser to access files on modern storage devices.

To start the Disk File Browser:

1. Open the C64U Menu: press the Multi Function Switch upward. The menu appears.
2. The first entry, "Disk File Browser," is selected. Press RETURN. The Disk File Browser starts.

[1] You can install an SD memory card by opening the case and locating the SD card holder on the mainboard. You can connect a USB storage device to one of the external USB ports on the back, or to an internal USB port on the mainboard.

As with the C64U Menu, you can use the W and S keys to move the selection up and down, and press RETURN to open a pop-up menu with actions for the item. You can also use D and A to navigate into and out of each storage container, such as a storage device, folder, or disk image. You can return to the C64U Menu with the A key from the top level of the Disk File Browser.

Try this:

1. Connect a USB storage device to a USB port on the back of the computer.
2. Start the Disk File Browser.
3. Locate the USB storage device in the list (such as **Usb1**). Use the S key to select it.
4. Press the D key to open the USB storage device. A list of files on the device is shown.
5. Press the A key to return to the device list.

You can navigate a long list of files with these handy shortcuts:

- F3 : Go up one page.
- F5 : Go down one page.
- SHIFT + a letter : Jump to the next entry starting with the given letter.

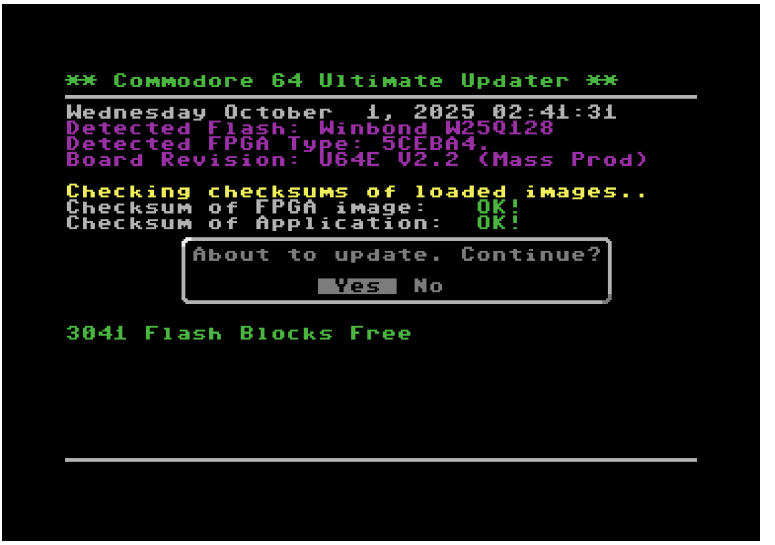
UPDATING THE C64U FIRMWARE

Your Commodore 64 Ultimate uses *firmware* to power the menus and operating system. Keeping this firmware up to date ensures that you have the latest features and fixes. You can download firmware updates from the Commodore website, and install it using the Disk File Browser.

1. On your PC, visit the Commodore International website: **`commodore.net/downloads`**
2. Download the Commodore 64 Ultimate firmware. The file is a **`.zip`** archive. Expand the archive to access the firmware update files.
3. Connect a USB storage device to your PC. Copy the firmware update file to the storage device. Eject the device from your PC.
4. Connect the USB storage device to the C64U.
5. Start the Disk File Browser, then navigate to the USB storage device.

6. Locate the firmware update file, select it, then press RETURN. The pop-up menu opens with the "Run Update" action selected. Press RETURN to start the update, and follow the prompts.

Do not switch off or disconnect power from your C64U while the update is in progress. The C64U will switch off automatically at the end of the update. Switch it back on again to continue using your computer.



USING DISK IMAGES

Back in the day, the most common way to store Commodore 64 programs and data was on 5-1/4" magnetic floppy disks, using a floppy disk drive such as the Commodore 1541 or 1571, or on 3-1/2" disks using the Commodore 1581. There are no manufacturers of floppy disk drives or media still active today.

Today, it is more convenient to use *disk images*, files that contain the same data as a floppy disk, with a modern storage device that replicates the experience of a floppy disk drive. Commodore enthusiasts have archived thousands of original Commodore 64 programs as disk images that you can download from the Internet. When you buy a newly published Commodore 64 game, it often comes in the form of a disk image file (or cartridge ROM file, discussed later in this chapter). You can also create empty disk image files to store your own programs and data.

The Commodore 64 Ultimate can use disk images stored on a USB storage device or SD card. The Ultimate provides two virtual disk drives, labelled

drive A and drive B. You use the Disk File Browser to locate a disk image file, and *mount* the file to a virtual drive to make it accessible to the Commodore 64 Ultimate. You can then use the disk image like you would a floppy disk, with Commodore 64 disk commands and programs.

The C64U supports the following disk image types:

File type	Equivalent media
.d64	1541 5-1/4″ floppy disk, 170 KB
.d71	1571 5-1/4″ floppy disk, 340 KB
.d81	1581 3-1/2″ floppy disk, 800 KB
.g64	1541 5-1/4″ floppy disk, raw GCR-encoded
.g71	1571 5-1/4″ floppy disk, raw GCR-encoded
.dnp	CMD hard drive (various sizes)

Mount a Disk Image

To mount a disk image:

1. Start the Disk File Browser.
2. Locate the disk image file on the connected USB storage device or SD card.
3. With the disk image selected, press RETURN to open the pop-up action menu.
4. Select "Mount Disk," then press RETURN. The Disk File Browser mounts the disk in virtual drive A.
5. Exit the menu: press the Multi Function Switch upward, or press RUN/STOP repeatedly.

By default, virtual drive A is configured as unit number 8, the unit number for the primary Commodore 64 disk drive. You can use the Commodore 64 **LOAD** command to load programs, or get a listing of the file directory. For example, to list the files on the mounted disk, enter these commands:

```
LOAD "$",8
LIST
```

The display would look something like this, depending on the contents of the disk image:

```
LOAD "$",8

SEARCHING FOR $
LOADING
READY.
LIST

0 "DISK NAME        " 00 ID
99     "PROGRAM FILE     " PRG
5      "DATA FILE        " SEQ
320 BLOCKS FREE.
READY.
```

(Don't worry if you're not familiar with Commodore disk commands yet. This will be discussed in later chapters.)

The loading process will appear to pause at the word **LOADING**. If you have the C64U's internal speaker enabled, it will make sounds similar to the

noise of a whirring disk drive while data is being loaded into memory. The C64U power light will also change color during this process.

Run a Disk Image

The Disk File Browser offers another action that is convenient for running most programs from disk, such as a game distributed as a disk image. With a disk image of a professional program disk, instead of "Mount Disk," select "Run Disk." This action mounts the disk, switches to Commodore 64 mode, then automatically runs the following commands:

```
LOAD "*",8,1
RUN
```

These commands are frequently used to launch published software titles such as games or productivity software. The command **`LOAD "*",8,1`** loads the first program on the disk in the drive connected as unit 8, in this case the disk image in virtual drive A. (The **`,1`** tells **`LOAD`** to read part of the file to determine how to store the program in memory.) The command **`RUN`** starts the program.

Not all program disks will work with "Run Disk," but most will.

Running Multi-Disk Programs

Some programs are distributed on multiple disk images, similar to how they were originally distributed on multiple floppy disks. At some point in the process of using the program, the program will prompt to insert one of the other floppy disks. You can use the Disk File Browser to swap disk images while the program is running.

When the program prompts for a new disk, press upward on the Multi Function Switch. This pauses the program. Start the Disk File Browser, navigate to the disk image for the disk that the program is requesting, then select "Mount Disk." The C64U mounts the new disk image in the virtual drive, then resumes execution of the Commodore 64 program. Continue to use the program with the new disk.

Create an Empty Disk Image

Disk images are an excellent way to store your own Commodore 64 programs and data. You can use the Disk File Browser to create new disk images for your own use.

To create a disk image:

1. Start the Disk File Browser.
2. Navigate to the location on the storage device where you wish to create the disk image.
3. Open the Tool menu: press F1.
4. Select "Create," then press RETURN. The pop-up action menu opens with a list. Select an image type, such as "D81 Image."
5. When prompted, enter a name for the disk image. The C64U creates the disk image, and after a moment, it appears in the Disk File Browser.

You can now mount your disk image to start using it.

NOTE: If the "Create" action does not open a pop-up menu, make sure you have navigated the Disk File Browser to a location on a storage device where a file can be created.

You can also use the "Create" action to create directories (folders) on the storage device. Use this to organize your disk images.

USING CARTRIDGE ROM FILES

Many Commodore 64 games and programs are distributed as cartridges, small boxes of electronics that connect to the expansion port in the back-right of the computer. In most cases, the cartridge is program data on a ROM chip. Commodore enthusiasts have archived these programs as cartridge ROM files (`.crt`), and some new titles are distributed as cartridges ROM files as well. The Commodore 64 Ultimate can load and run cartridge image files.

To run a cartridge ROM file:

1. Open the C64U Menu, then start the Disk File Browser.
2. Locate the cartridge ROM file, then press RETURN to open the pop-up action menu.
3. Select "Run Cart."

The C64U resets, then starts the program as if the cartridge is inserted in the expansion port.

The C64U will behave as if the cartridge is connected, even after performing a reset with the Multi Function Switch. To disconnect the cartridge ROM:

1. Open the C64U Menu.
2. Open the Tool menu: press F1.
3. Select "C64 Machine."
4. Select "Reboot C64." This is similar to switching the C64U off then on again.

Most cartridge ROM files are in the common 8 KB, 16 KB, or UltiMax formats. In addition to these, the C64U supports cartridge ROM files in the following formats:

Action Replay	Westermann	EasyFlash
KCS Power Cartridge	Final Cartridge I	Retro Replay
Final Cartridge III	Magic Formel	EXOS
Simons Basic	C64 Game System	Pagefox
Ocean type 1	Zaxxon	Kingsoft Business Basic
Super Games	Magic Desk, Domark, HES	GMod2
Atomic Power	Super Snapshot 5	Blackbox V8, V3, V4
Epyx Fastload	COMAL 80	

Installing a Cartridge ROM in Flash Memory

In some cases, it is useful to configure the Commodore 64 Ultimate to behave as if a cartridge ROM is attached, such that the ROM is active after resetting the computer. This is especially useful for utility cartridges that augment the behavior of the computer, such as BASIC extensions. You can install a cartridge ROM in flash memory to enable this effect.

To install a cartridge ROM in flash memory:

1. Navigate to the CRT file.
2. Press RETURN to open the pop-up action menu.
3. Select "Copy to Flash."

Switch off the computer, then switch it back on again. The program of the cartridge ROM takes effect.

To remove the cartridge ROM from flash memory:

1. Open the C64U Menu. Select "Memory & ROMs."
2. Select "Cartridge."

3. Select “None.”
4. Exit the menu, then save settings to flash memory when prompted.

USING TAPE IMAGES

Older Commodore 64 software was originally distributed on cassette tape, for use with the Commodore Datassette drive. Commodore enthusiasts have archived these cassette tapes as tape image files (**`.tap`**). The Commodore 64 Ultimate provides a virtual Datassette for use with tape image files.

To load and run the first program on a tape image:

1. Open the C64U Menu, then start the Disk File Browser.
2. Locate the tape image file, then press RETURN to open the pop-up action menu.
3. Select “Run Tape.”

Similar to “Run Disk,” this returns to Commodore 64 mode, then performs the commands to load a program from tape, and simulates the tape playback. This is sufficient for most programs distributed as tape image files.

If you’d like to fully recreate the experience of using a Datasette, you can use the other pop-up actions to simulate starting tape playback at the appropriate time. The sequence is as follows:

1. At the **`READY`** prompt, enter this command (without anything after it): **`LOAD`**
2. The Commodore 64 replies with: **`PRESS PLAY ON TAPE`**
3. Open the C64U Menu, then start the Disk File Browser. Locate the tape image file, then press RETURN to open the pop-up action menu.
4. Select “Start Tape.” The C64U returns to Commodore 64 mode, and the screen goes blank for a moment while it reads the tape.
5. The computer will say **`FOUND (PROGRAM NAME)`** on the screen. Press the C= key to load this program. (Some programs will run automatically without this step.)

The Disk File Browser does not have a way to create tape image files. We recommend using disk images instead.

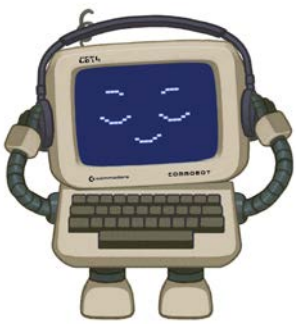
USING PRG AND T64 FILES

With respect to Commodore software, a file with a **`.prg`** extension represents a single Commodore program file. As long as the program does not need to be run from a floppy disk (or disk image), you can run such a program stored directly on the USB storage device or SD card, from the Disk File Browser.

You may also find a file format with the **`.t64`** extension. A T64 file contains one or more programs that can also be run from the Disk File Browser.

Neither of these file types behave as a floppy disk or a cassette tape, and they cannot be written to. When you select a PRG program or a program from a T64 file, the C64U simply resets the computer, copies the program into memory, and runs it. These file types take up less space than disk images, because they do not need to make room for empty space as on a disk.

PLAYING SID MUSIC FILES



The Commodore 64 has a long heritage of music composed for its SID sound synthesizer chip, published as title and background music for games, or to accompany demos and animations. To preserve this heritage, Commodore enthusiasts developed *SID files*, a file format that captures the part of the program that plays this music, so that it can be played in a jukebox-style music player application.

The Commodore 64 Ultimate includes a built-in music player capable of playing SID files (**`.sid`**).

To play a SID music file from storage:

1. Open the C64U Menu, then start the Disk File Browser.
2. Locate the SID music file, then press RETURN to open the pop-up action menu.
3. Select "Play Main Tune," or select a song from the list if the SID file contains multiple songs.

You can control the *C-64 Ultimate SID Player* with the following keys:

Key	Function
←	Fast forward
1 - 0	Select a tune 1 - 10
+	Play next tune
-	Play previous tune
RUN/STOP	Return to the Disk File Browser
SPACE	Pause or resume

The High Voltage SID Collection (HVSC) is a large collection of SID music files from throughout Commodore 64 history. Visit their website: `www.hvsc.c64.org`

FILE OPERATIONS

You can perform common operations on files stored on any storage device accessible from the Disk File Browser.

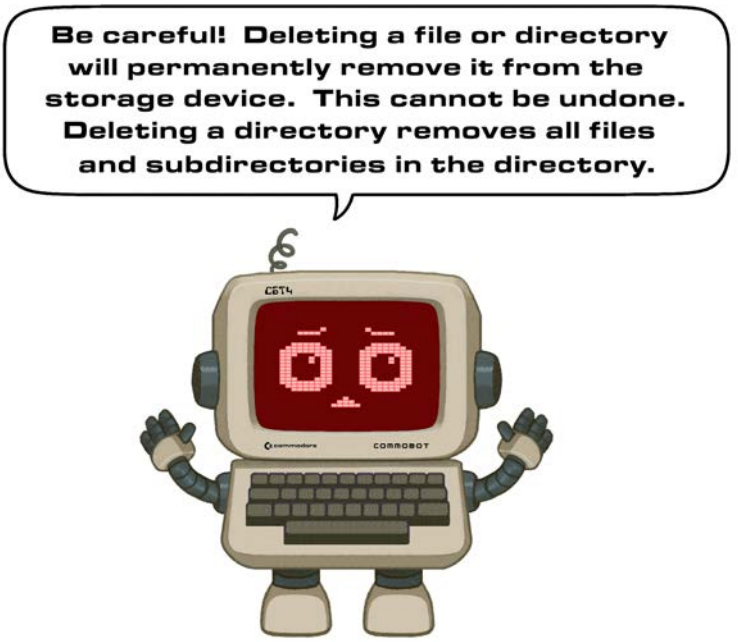
Rename and Delete

To rename a file or directory:

1. Navigate to the file or directory to rename.
2. Press RETURN. The pop-up action menu opens.
3. Select "Rename." When prompted, enter the new name.

To delete a file or directory:

1. Navigate to the file or directory to rename.
2. Press RETURN. The pop-up action menu opens.
3. Select "Delete." When prompted, confirm the operation (RETURN or Y).



Copy

To copy a file or directory:

1. Navigate to the file or directory to copy.
2. Hold C= then press C (for "Copy"). Acknowledge the dialog (press RETURN).
3. Navigate to the location where you want the copy to reside.
4. Hold C= then press V. A new file or directory is created with the same contents.

You can copy a file or directory between directories, or between different storage devices. Copying a directory copies all files and subdirectories in the directory.

To copy multiple files or directories in a single operation:

1. Navigate to the location where items to copy reside.
2. Move the selection to a file or directory to copy. Press SPACE. A diamond appears next to the filename to indicate it is selected for copying.
3. Repeat for every file or directory to select.
4. Hold C then press C (for "Copy"). Acknowledge the dialog (press RETURN).
5. Navigate to the location where you want the copy to reside.
6. Hold C then press V. All selected items are copied.

Create a Directory

You can create an empty directory (folder) on any storage device.

To create a directory:

1. Navigate to the location where the new directory will reside.
2. Open the Tool menu: press F1.
3. Select "Create."
4. Select "Directory."
5. When prompted, enter the name of the directory to create.

CHAPTER 3

GETTING STARTED

- The Keyboard
- Back to Normal
- Loading and Saving Programs
- PRINT and Calculations
- Precedence
- Combining Things

THE KEYBOARD

Now that you've got everything set up and adjusted, please take a few moments to familiarize yourself with the keyboard which is your most important means of communication with the Commodore 64 Ultimate.

You will find the keyboard similar to a standard typewriter keyboard. There are, however, a number of new keys which control specialized functions. What follows is a brief description of the various keys and how they function. The detailed operation of each key will be covered in later sections.

RETURN

The RETURN key signals the computer to look at the information that you typed and enters that information into memory.

SHIFT

The SHIFT key works like that on a standard typewriter. Many keys are capable of displaying two letters or symbols and two graphic characters. In the "upper/lower case" mode the SHIFT key gives you standard upper case characters. In the "upper case/graphic" mode the SHIFT key will display the graphic character on the right hand side of the front part of the key.

In the case of special function keys, the SHIFT key will give you the function marked on the front of the key.

Editing

No one is perfect, and the Commodore 64 takes that into account. A number of editing keys let you correct typing mistakes and move information around on the screen.

CRSR

There are two keys marked CRSR (CuRSoR), one with up and down arrows ⇑CRSR⇓ the other with left and right arrows ⇐CRSR⇒. You can use these keys to move the cursor up and down or left and right. In the unshifted mode, the CRSR keys will let you move the cursor down and to the right. Using the SHIFT key and CRSR keys allows the cursor to be moved either up or to the left. The cursor keys have a special repeat feature that keeps the cursor moving until you release the key.

INST/DEL

If you hit the INST/DEL key, the cursor will move back a space, erasing (DELeting) the previous character you typed. If you're in the middle of a line, the character to the left is deleted and the characters to the right automatically move together to close up the space.

A SHIFTed INST/DEL allows you to INSerT information on a line. For example, if you noticed a typing mistake in the beginning of a line — perhaps you left out part of a name — you could use the ⇐CRSR⇒ key to move back to the error and then hit SHIFT INST/DEL to insert a space. Then just type in the missing letter.

CLR/HOME

CLR/HOME positions the cursor at the "HOME" position of the screen, which is the upper left-hand corner. A SHIFTed CLR/HOME will clear the screen and place the cursor in the home position.

RESTORE

RESTORE has different functions depending on the program that is running. In many cases, you can use it to interrupt a running program, clear

the screen, and restore the state of operation to a command prompt. To do this, hold RUN/STOP then press RESTORE.

Function Keys

The four function keys on the right side of the keyboard are used by programs for various purposes. Their behavior depends on the program. You can write your own programs that can be controlled by the user pressing these keys.

You can use the function keys to perform actions in the C64U Menu.

CTRL

The CTRL key, which stands for ConTRoL, allows you to set colors, and perform other specialized functions. You hold the CTRL key down while depressing another designated key to get a control function.

RUN/STOP

Normally, depressing the key will stop the execution of a BASIC program. It signals the computer to STOP doing something. Using the RUN/STOP

key in the shifted mode automatically loads a program from tape, which was the style at the time.

C= Commodore Key

The Commodore key C= performs a number of functions. First, it allows you to move between the text and graphic display modes.

When the computer is first turned on, it is in the Upper Case/Graphic mode, that is, everything you type is in upper case letters. As was mentioned, using the SHIFT key in this mode will display the graphic on the right side of the keys.

If you hold down the C= key and press the SHIFT key, the display will change to upper and lower case. Now, if you hold down the C= key and any other key with a graphic symbol, the graphic shown on the left side of the key will be displayed.

To get back into the upper case/graphic mode hold down the C= key and press the SHIFT key again.

The second function of the C= key is to allow you access to a second set of eight text colors. By holding down the C= key and any of the number keys, any text now typed will be in the alternate color available from the key you depressed. Chapter 6 lists the text colors available from each key.

BACK TO NORMAL

Now that you've had a chance to look over the keyboard, let's explore some of the Commodore 64's many capabilities.

Hold SHIFT and press CLR/HOME. The screen should clear and the cursor will be positioned in the "home" spot (upper left-hand corner of the screen).

Now, simultaneously hold C= and the 7 key. This sets the text color back to light blue. There is one more step needed to get everything back to normal. Hold CTRL and 0 (Zero not Oh!). If the cursor was in "reversed" mode, this sets the mode back to normal.

TIP:

Now that you've done things the hard way, there is a simple way to reset the machine to the normal display. First press the RUN/STOP key and then press the RESTORE key. RUN/STOP must always be held down in order to use the RESTORE key function.

This will clear the screen and return everything to normal. If there is a program in the computer, it will be left untouched. This is a good sequence to remember, especially if you do a lot of programming.

LOADING AND SAVING PROGRAMS

One of the most important features of the Commodore 64 is the ability to save and load programs to and from a floppy disk. This capability allows you to save the programs you write for use at a later time, or purchase prewritten programs to use with the Commodore 64.

We discussed how to mount, run, and create disk images in chapter 2. When a disk image is connected to a Commodore 64 Ultimate virtual drive, that disk image behaves like a floppy disk in a physical disk drive.

If you have a vintage 5-1/4" floppy disk drive such as the VIC 1541, you can use it with the Commodore 64 Ultimate, connected to the IEC serial port. Carefully insert the pre-programmed disk so that the label on the disk is facing up and is closest to you. Look for a little notch on the disk (it might be covered with a little piece of tape). If you're inserting the disk properly the notch will be on the left side. Once the disk is inside close the protective gate by pushing down on the lever.

The computer refers to the disk drive (virtual or otherwise) using a *unit number*. The most common unit number for a single disk drive is 8. You will use this unit number with commands that perform disk operations. It is possible to connect multiple disk drives simultaneously, including up to two C64U virtual drives. Additional drives use unit numbers 9 and above. Unit numbers must be configured with the drive itself. For information on configuring a physical disk drive with the C64U, see chapter 10.

Loading Programs from Disk

A floppy disk contains a set of files, each with a name. A file can be a program file or a data file. To load and run a program, type:

```
LOAD "PROGRAM NAME",8
```

and hit the RETURN key. The disk will make noise and your screen will say:

```
SEARCHING FOR PROGRAM NAME
LOADING
READY.
```

When READY appears and the cursor is blinking, just type RUN. The program starts.

Some program disks expect you to use a program name of *****, the asterisk character. This tells the disk drive to load the first file on the disk, which professionally produced program disks have set up to be the program you should run. It is also common to follow the **LOAD** command with **,8,1**, to give the program full control over how it is loaded into memory.

```
LOAD "*",8,1

SEARCHING FOR *
LOADING
READY.
RUN
```

NOTE: When you load a new program into the computer's memory, any instructions that were in the computer previously will be erased. Make sure you save a program you're working on before loading a new one. Once a program has been loaded, you can RUN it, LIST it, or make changes and re-save the new version.

Saving Programs to Disk

Soon, you will be writing your own programs in BASIC. When you do, you can (and should!) save them to disk for later retrieval. You will find it is a good practice to save your program frequently as you work, so when the computer needs to be reset, you can pick up where you left off.

To save a BASIC program to disk, type:

```
SAVE "PROGRAM NAME",8
```

After you press RETURN the disk will start to turn and the computer will respond with:

```
SAVING PROGRAM NAME
READY.
```

When saving a program in this way, the disk drive will report an error if you are using the name of a program that already exists on the disk. This prevents accidental data loss. If you are sure you want to replace the file, type `@:` inside the quote marks, just before the filename:

```
SAVE "@:PROGRAM NAME",8
```

Another good practice is to keep old versions of your program on the disk while you are working, using different filenames. Only replace the file if you are sure you don't need the previous version.

NOTE: Older physical floppy disk drives had flaws with the save-with-replace mechanism that can lead to data loss. This is not an issue when using disk images.

Listing the Files on a Disk

A disk stores a list of its files in a *directory*. You can view the *directory listing* by LOADing a special file named `"$"`, then issuing the LIST command:

```
LOAD "$",8

SEARCHING FOR $
LOADING
READY.
LIST
```

If the list of files is long, you can slow down the listing by holding down the CTRL key, or you can interrupt it by pressing RUN/STOP.

NOTE: LOADing the directory listing overwrites the program in memory, if any. Be sure to save any work in progress before loading the directory listing. Also, be sure to enter the NEW command to clear program memory before starting a new program.

PRINT AND CALCULATIONS

Now that you've gotten through a couple of the more difficult operations you need in order to keep the programs you like, let's start making some programs for you to save.

Try typing the following exactly as shown:

```
PRINT "COMMODORE 64"
COMMODORE 64
```

TYPE THIS LINE AND HIT RETURN

COMPUTER TYPED

If you make a typing mistake, use the INST/DEL key to erase the character immediately to the left of the cursor. You can delete as many characters as necessary.

Let's see what went on in the example above. First, you instructed (commanded) the computer to PRINT whatever was inside the quote marks. By hitting RETURN you told the computer to do what you instructed and COMMODORE 64 was printed on the screen.

When you use the PRINT statement in this form, whatever is enclosed in quotes is printed exactly as you typed it.

If the computer responded with:

```
?SYNTAX ERROR
```

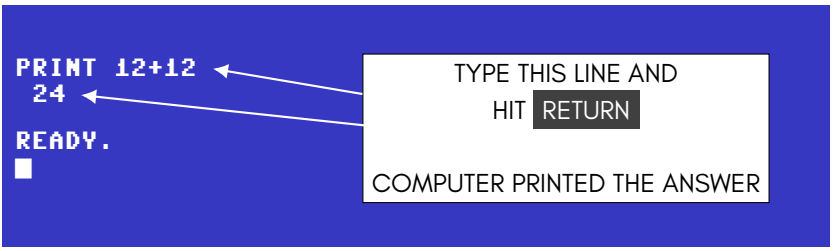
ask yourself if you made a mistake in typing, or forgot the quote marks. The computer is precise and expects instructions to be given in a specific form.

But don't get worried; just remember to enter things as we present them in the examples and you'll get along great with the Commodore 64.

Remember, you can't hurt the computer by typing on it, and the best way to learn BASIC is to try different things and see what happens.

PRINT is one of the most useful and powerful commands in the BASIC language. With it, you can display just about anything you wish, including graphics and results of computations.

For example, try the following. Clear the screen by holding down the SHIFT key and CLR/HOME key and type (be sure to use the **1** key for one, not a letter **I**):



What you've discovered is that the Commodore 64 is a calculator in its basic form. The result of "24" was calculated and printed automatically. In fact, you can also perform subtraction, multiplication, division, exponentiation, and advanced math functions such as calculating square roots, etc. And you're not limited to a single calculation on a line, but more on that later.

Note that in the above form, PRINT behaved differently from the first example. In this case, a value or result of a calculation is printed, rather than the exact message you entered because the quote marks were omitted.

Addition

The plus sign (+) signals addition: we instructed the computer to print the result of 12 added to 12. Other arithmetic operations take a similar form to addition. Remember to always hit RETURN after typing PRINT and the calculation.

Subtraction

To subtract, use the conventional minus (-) sign. Type:

Multiplication

If you wanted to multiply 12 times 12, use the asterisk (*) to represent multiplication. You would type:

```
PRINT 12*12
 144
```

HIT RETURN

Division

Division uses the familiar **/** symbol. For example, to divide 144 by 12, type:

```
PRINT 144/12
 12
```

HIT RETURN

Exponentation

In a like fashion, you can easily raise a number to a power (this is the same as multiplying a number by itself a specified number of times). The ↑ (Up arrow) signifies exponentiation.

```
PRINT 12↑5
 248832
```

This is the same as typing:

```
PRINT 12*12*12*12*12
 248832
```

TIP:

BASIC has a number of shortcut ways of doing things. One such way is abbreviating BASIC commands (or keywords). A **?** can be used in place of PRINT, for example. As we go on you'll be presented with many commands; Appendix B shows the abbreviations for each and what will be displayed on the screen when you type the abbreviated form.

The last example brings up another important point: many calculations may be performed on the same line, and they can be of mixed types.

You could calculate this problem (**?** replaces the word PRINT):

```
? 3 + 5 - 7 + 2
 3
```

THIS ? REPLACES THE WORD PRINT

Up to this point we've just used small numbers and simple examples. However, the Commodore 64 is capable of more complex calculations. You could, for example, add a number of large figures together. Try this, but don't use any commas, or you'll get an error:

```
? 123.45 + 345.78 + 7895.687
 8364.917
```

That looks fine, but now try this:

```
? 12123123.45 + 345.78 + 7895.687
 12131364.9
```

If you took the time to add this up by hand, you would get a different result.

What's going on here? Even though the computer has a lot of power, there's a limit to the numbers it can handle. The Commodore 64 can work

with numbers containing 10 digits. However when a number is printed, only nine digits are displayed.

So in our example, the result was "rounded" to fit in the proper range. The Commodore 64 rounds up when the next digit is five or more; it rounds down when the next digit is four or less.

Numbers between 0.01 and 999,999,999 are printed using standard notation. Numbers outside this range are printed using scientific notation.

Scientific notation is just a process of expressing a very large or small number as a power of 10.

If you type:

```
? 123000000000000000
 1.23E+17
```

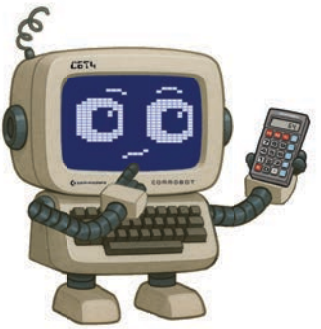
This is the same as **`1.23 * 10↑17`** and is used just to keep things tidy.

There is a limit to the numbers the computer can handle, even in scientific notation. These limits are:

Largest: ± 1.70141183E+38
Smallest (different from zero): ± 2.93873588-39

PRECEDENCE

If you tried to perform some mixed calculations different from the examples we showed earlier, you might not have gotten the results that you expected. The reason is that the computer performs calculations in a certain order.



In this calculation:

```
20 + 8/2
```

you can't tell whether the answer should be 24 or 14 until you know in which order to perform the calculations. If you add 20 to 8 divided by 2 (or 4), then the result is 24. But, if you add 20 plus 8 and then divide by 2 the answer is 14. Try the example and see what result you get.

The reason you got 24 is because the Commodore 64 performs calculations left to right according to the following:

First:	-	minus sign indicating negative numbers
Second:	↑	exponentiation, left to right
Third:	* /	multiplication and division, left to right
Fourth:	+ -	addition and subtraction, left to right

Follow along according to the order of precedence, and you will see that in the above example the division was performed first and then the addition to get a result of 24.

Make up some problems of your own and see if you can follow along and predict the results according to the rules set down above.

There's also an easy way to alter the precedence process by using parentheses to set off which operations you want performed first.

For example, if you want to divide 35 by 5 plus 2 you type:

```
? 35 / 5 + 2
 9
```

you will get 35 divided by 5 with 2 added to the answer, which is not what you intended at all. To get what you really wanted, try this:

```
? 35 / (5 + 2)
 5
```

What happens now is that the computer evaluates what is contained in the parentheses first. If there are parentheses within parentheses, the innermost parentheses are evaluated first.

Where there are a number of parentheses on a line, such as:

```
? (12 + 9) * (6 + 1)
 147
```

the computer evaluates them left to right. Here 21 would be multiplied by 7 for the result of 147.

COMBINING THINGS

Even though we've spent a lot of time in areas that might not seem very important, the details presented here will make more sense once you start to program, and will prove invaluable.

To give you an idea how things fit in place, consider the following: how could you combine the two types of print statements we've examined so far to print something more meaningful on the screen?

We know that by enclosing something within quote marks prints that information on the screen exactly as it was entered, and by using math operators, calculations can be performed. So why not combine the two types of PRINT statements like this:

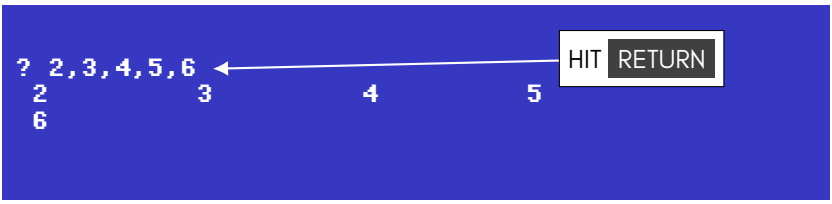
SEMICOLON MEANS NO SPACE

```
? "5 * 9=";5 * 9
 5 * 9 = 45
```

Even though this might seem a bit redundant, what we've done is simply use both types of print statements together. The first part prints "5 * 9 =" exactly as it was typed. The second part does the actual work and prints the result, with the semicolon separating the message part of the statement from the actual calculation.

You can separate the parts of a mixed print statement with punctuation for various formats. Try a comma in place of the semicolon and see what happens.

For the curious, the semicolon causes the next part of the statement to be printed immediately after the previous part, without any spaces. The comma does something different. Even though it is an acceptable separator, it spaces things out more. If you type:



the numbers will be printed across the screen and down on to the next line.

The Commodore 64's display is organized into 4 areas of 10 columns each. The comma tabs each result into the next available area. Since we asked for more information to be printed than would fit on one line, (we tried to fit five 10-column areas on one line) the last item was moved down to the next line.

The basic difference between the comma and semicolon in formatting PRINT statements can be used to our advantage when creating more complex displays: it will allow us to create some sophisticated results very easily.

CHAPTER 4

BEGINNING BASIC PROGRAMMING

- The Next Step
- Quote Mode
- Editing Tips
- Variables
- IF...THEN
- FOR...NEXT Loops

THE NEXT STEP

Up to now we've performed some simple operations by entering a single line of instructions into the computer. Once RETURN was depressed, the operation that we specified was performed immediately. This is called the IMMEDIATE or CALCULATOR mode.

But to accomplish anything significant, we must be able to have the computer operate with more than a single line statement. A number of statements combined together is called a PROGRAM and allows you to use the full power of the Commodore 64.

To see how easy it is to write your first Commodore 64 program, try this:

Clear the screen by holding the SHIFT key, and then depressing the CLR/HOME key.

Type NEW and press RETURN. (This just clears out any numbers that might have been left in the computer from your experimenting.)

Now type the following exactly as shown (remember to hit RETURN each line):

```
10 ?"COMMODORE 64"
20 GOTO 10
```

Now, type RUN and hit RETURN — watch what happens. Your screen will come alive with COMMODORE 64. After you've finished watching the display, hit RUN/STOP to stop the program.

A number of important concepts were introduced in this short program that are the basis for all programming.

Notice that here we preceded each statement with a number. This LINE number tells the computer in what order to work with each statement. These numbers are also a reference point, in case the program needs to get back to a particular line. Line numbers can be any whole number (integer) value between 0 - 63,999.

```
10 PRINT "COMMODORE 64"
```

STATEMENT

LINE NUMBER

```
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64

BREAK IN 10
READY.
```

It is good programming practice to number lines in increments of 10, in case you need to insert some statements later on.

Besides PRINT, our program also used another BASIC command, GOTO. This instructs the computer to go directly to a particular line and perform it, then continue from that point.

```
10 PRINT "COMMODORE 64"
20 GOTO 10
```

In our example, the program prints the message in line 10, goes to the next line (20), which instructs it to go back to line 10 and print the message over again. Then the cycle repeats. Since we didn't give the computer a way out of this loop, the program will cycle endlessly, until we physically stop it with the RUN/STOP key.

Once you've stopped the program, type: LIST. Your program will be displayed, intact, because it's still in the computer's memory. Notice, too, that the computer converted the ? into PRINT for you. The program can now be changed, saved, or run again.

Another important difference between typing something in the immediate mode and writing a program is that once you execute and clear the screen of an immediate statement, it's lost. However, you can always get a program back by just typing LIST.

By the way, when it comes to abbreviations, remember that the computer may run out of space on a line if you use too many. A line of a BASIC program can have up to 79 characters, and abbreviations get expanded to their full length after you enter the line.

QUOTE MODE

Consider the command in the first line of the program:

```
PRINT "COMMODORE 64"
```

This instructs the Commodore 64 to print the message inside the double-quote marks (`"..."`). This phrase surrounded by quotes is known as a *string*. Specifically, the **PRINT** command prints the string as if you typed those characters at the location of the cursor.

Many of the key combinations described in the previous chapter manipulate the cursor or the screen in various ways. When you use a cursor key, it moves the cursor. When you select a color, it changes the color of the cursor and the text that it types. When you hold SHIFT and press CLR/HOME, it clears the screen and moves the cursor to the top left corner.

The Commodore 64 lets you "print" these effects as well, just as if you typed them. To do this, the screen editor notices when you start a quoted phrase by typing a double-quote mark, then switches to a special entry mode called *quote mode*. In this mode, when you type a key combination that normally manipulates the cursor or the string, the cursor actually types a special symbol that represents that key combination. When you type the closing double-quote mark, the screen editor returns to its normal typing mode.

Try this: hold SHIFT and press CLR/HOME. The screen clears immediately. Don't worry: if you entered the short program above, it is still in memory. (Type **LIST** and press RETURN to see it.)

Now try this: type the following, but do *not* press RETURN:

```
PRINT "
```

Because you typed a double-quote, the editor is now in quote mode.

Next, hold SHIFT and press CLR/HOME. Instead of clearing the screen, the editor prints a heart symbol in a box.

Finally, type the rest of this phrase, but do no press RETURN:

```
COMMODORE 64"
```

Because you typed another quote mark, the editor is no longer in quote mode. The command appears like this on the screen:

```
PRINT "▚COMMODORE 64"
```

Finally, press RETURN to execute the command. The Commodore 64 prints the message as you typed it: it clears the screen and moves the cursor to the top-left corner as if typing SHIFT + CLR/HOME, then prints the message.

Quote mode lets you include cursor manipulation commands in your programs, entered just as if you typed them directly to the screen. We'll use quote mode for programs later in this Guide. It's worth noticing it now, because it is easy to accidentally type a cursor control key while in quote mode, causing symbols to appear. If you type a cursor command you did not intend while in quote mode, use INST/DEL to delete it. (INST/DEL is one of several keys that do not emit commands in quote mode. RETURN is another one.)

EDITING TIPS

If you make a mistake on a line, you have a number of editing options:

1. You can retype a line anytime, and the computer will automatically substitute the new line for the old one.
2. An unwanted line can be erased by simply typing the line number and RETURN.
3. You can also easily edit an existing line, using the cursor keys and editing keys.

Suppose you made a typing mistake in a line of the example. To correct it without retyping the entire line, try this:

Type **LIST**, then using the SHIFT and ⇧CRSR⇩ keys together move the cursor up until it is positioned on the line that needs to be changed.

Now, use the cursor-right key to move the cursor to the character you want to change, typing the change over the old character. Now hit RETURN and the corrected line will replace the old one.

If you need more space on the line, position the cursor where the space is needed and hit SHIFT and INST/DEL at the same time and a space

will open up. Now just type in the additional information and hit RETURN. Likewise, you can delete unwanted characters by placing the cursor to the right of the unwanted character and hitting the INST/DEL key.

To verify that changes were entered, type **LIST** again, and the corrected program will be displayed! And lines don't have to be entered in numerical order. The computer will automatically place them in the proper sequence.

Try editing our sample program on page 52 by changing line 10 and adding a comma to the end of the line. Then RUN the program again.[1]

```
10 PRINT "COMMODORE",
```

VARIABLES

Variables are some of the most used features of any programming language, because variables can represent much more information in the computer. Understanding how variables operate will make computing easier and allow us to accomplish feats that would not be possible otherwise.

```
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE
COMMODORE   COMMODORE   COMMODORE   COMMODORE

BREAK IN 10
READY.
```

Imagine a number of boxes within the computer that can each hold a number or a string of text characters. Each of these boxes is to be labeled with a name that we choose. That name is called a variable and represents the information in the respective box.

For example, if we say:

[1] Don't forget to move the cursor past line 20 before you run the program.

```
10 X% = 15
20 X = 23.5
30 X$ = "THE SUM OF X%+X = "
```

The computer might represent the variables like this:

```
X%      15

X       23.5

X$      THE SUM OF X%+X =
```

A variable name represents the box, or memory location, where the current value of the variable is stored. As you can see, we can assign either an integer number, floating point number, or a text string to a variable.

The % symbol following a variable name indicates the variable will represent an integer number. The following are valid integer variable names:

```
A%
X%
A1%
NM%
```

The '$' following the variable name indicates the variable will represent a text string. The following are examples of string variables:

```
A$
X$
M1$
```

Floating point variables follow the same format, with the type indicator:

```
A1
X
Y
MI
```

In assigning a name to a variable there are a few things to keep in mind. First, a variable name can have one or two characters. The first character

must be an alphabetic character from A to Z; the second character can be either alphabetic or numeric (in the range 0 to 9). A third character can be included to indicate the type of variable (integer or text string), % or $.

You can use variable names having more than two alphabetic characters, but only the first two are recognized by the computer. So PA and PARTNO are the same and would refer to the same variable box.

The last rule for variable names is simple: they can't contain any BASIC keywords (reserved words) such as GOTO, RUN, etc. Refer back to Appendix B for a complete list of BASIC reserved words.

To see how variables can be put to work, type in the complete program that we introduced earlier and RUN it. Remember to hit RETURN after each line in the program.

```
NEW

10 X% = 15
20 X = 23.5
30 X$ = "THE SUM OF X% + X ="
40 PRINT "X% ="; X%, "X ="; X
50 PRINT X$; X% + X
```

If you did everything as shown, you should get the following result printed on the screen:

```
RUN
X% = 15 X = 23.5
THE SUM OF X% + X = 38.5

READY.
```

We've put together all the tricks learned so far to format the display as you see it and print the sum of the two variables.

In lines 10 and 20 we assigned an integer value to X% and assigned a floating point value to X. This puts the number associated with the variable in its box. In line 30, we assigned a text string to X$. Line 40 combines the two types of PRINT statements to print a message and the actual value of X% and X. Line 50 prints the text string assigned to X$ and the sum of X% and X.

Note that even though X is used as part of each variable name, the identifiers % and $ make X%, X, and X$ unique, thus representing three distinct variables.

But variables are much more powerful. If you change their value, the new value replaces the original value in the same box. This allows you to write a statement like:

```
X = X + 1
```

This would never be accepted in normal algebra, but is one of the most used concepts in programming. It means: take the current value of X, add one to it and place the new sum into the box representing X.

IF...THEN

Armed with the ability to easily update the value of variables, we can now try a program such as:

```
NEW

10 CT = 0
20 ?"COMMODORE 64"
30 CT = CT + 1
40 IF CT < 5 THEN 20
50 END

RUN
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
```

What we've done is introduce two new BASIC commands, and provided some control over our runaway little print program introduced at the start of this chapter.

IF...THEN adds some logic to the program. It says IF a condition holds true THEN do something. IF the condition no longer holds true, THEN do the next line in the program.

A number of conditions can be set up in using an IF...THEN statement:

SYMBOL	MEANING
<	Less Than
>	Greater Than
=	Equal To
<>	Not Equal To
>=	Greater Than or Equal To
<=	Less Than or Equal To

The use of any one of these conditions is simple, yet surprisingly powerful.

```
10 CT = 0
20 ?"COMMODORE 64"
30 CT = CT + 1
40 IF CT < 5 THEN 20
↓
50 END
```

In the sample program, we've set up a "loop" that has some constraints placed on it by saying: IF a value is less than some number THEN do something.

Line 10 sets CT (CounT) equal to 0. Line 20 prints our message. Line 30 adds one to the variable CT. This line counts how many times we do the loop. Each time the loop is executed, CT goes up by one.

Line 40 is our control line. If CT is less than 5, meaning we've executed the loop less than 5 times, the program goes back to line 20 and prints again. When CT becomes equal to 5 — indicating five COMMODORE 64's were printed — the program goes to line 50, which signals to END the program.

Try the program and see what we mean. By changing the CT limit in line 40 you can have any number of lines printed.

IF...THEN has a multitude of other uses, which we'll see in future examples.

FOR...NEXT LOOPS

There is a simpler, and preferred way to accomplish what we did in the previous example by using a FOR...NEXT loop. Consider the following:

```
NEW

10 FOR CT = 1 TO 5
20 PRINT "COMMODORE 64"
30 NEXT CT

RUN
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
COMMODORE 64
```

As you can see, the program has become much smaller and more direct.

CT starts at 1 in line 10. Then, line 20 does some printing. In Line 30 CT is incremented by 1. The NEXT statement in line 30 automatically sends the program back to line 10 where the FOR part of the FOR...NEXT statement is located. This process will continue until CT reaches the limit you entered.

The variable used in a FOR...NEXT loop can be incremented by smaller amounts than 1, if needed.

Try this:

```
NEW

10 FOR NB = 1 TO 10 STEP .5
20 PRINT NB,
30 NEXT NB

RUN
1          1.5          2          2.5
3          3.5          4          4.5
5          5.5          6          6.5
7          7.5          8          8.5
9          9.5          10
```

If you enter and run this program, you'll see the numbers from 1 to 10, incremented by .5, printed across the display.

All we're doing here is printing the values that NB assumes as it goes through the loop.

You can even specify whether the variable is increasing or decreasing. Substitute the following for line 10:

```
10 FOR NB = 10 to 1 STEP -.5
```

and watch the opposite occur, as NB goes from 10 to 1 in descending order.

CHAPTER 5

ADVANCED BASIC

- Introduction
- Simple Animation
- INPUT
- GET
- Random Numbers and Other Functions
- Guessing Game
- Your Roll
- Random Graphics

INTRODUCTION

The next few chapters have been written for people who have become relatively familiar with the BASIC programming language and the concepts necessary to write more advanced programs.

For those of you who are just starting to learn how to program, you may find some of the information a bit too technical to understand completely. But take heart...because for these two fun chapters, SPRITE GRAPHICS and CREATING SOUND, we've set up some simple examples that are written for the new user. The examples will give you a good idea of how to use the sophisticated sound and graphics capabilities available on your Commodore 64.

If you are already familiar with BASIC programming, these chapters will help you get started with advanced BASIC programming techniques. More detailed information can be found in the COMMODORE 64 PROGRAMMER'S REFERENCE GUIDE (1982).

SIMPLE ANIMATION

Let's exercise some of the Commodore 64's graphic capabilities by putting together what we've seen so far, together with a few new concepts. If you're ambitious, type in the following program and see what happens. You will notice that within the print statements we can also include cursor controls and screen commands. When you see something like {CRSR LEFT} in a program listing, hold the SHIFT key and hit the CRSR LEFT/RIGHT key. The screen will show the graphic representation of a cursor left (two vertical reversed bars). In the same way, pressing SHIFT and CLR/HOME shows as a reversed heart.

```
NEW

10 REM BOUNCING BALL
20 PRINT "{CLR/HOME}"
25 FOR X = 1 TO 10 : PRINT "{CRSR DOWN}": NEXT
30 FOR BL = 1 TO 40
40 PRINT" ●{CRSR LEFT}";: REM (● is a SHIFT-Q)
50 FOR TM = 1 TO 5
60 NEXT TM
70 NEXT BL
75 REM MOVE BALL RIGHT TO LEFT
80 FOR BL = 40 TO 1 STEP -1
90 PRINT" {CRSR LEFT}{CRSR LEFT}●{CRSR LEFT}";
100 FOR TM = 1 TO 5
110 NEXT TM
120 NEXT BL
130 GOTO 20
```

: INDICATES NEW COMMAND

THESE SPACES ARE INTENTIONAL

TIP:

All words in this text will be completed on one line. However, as long as you don't hit RETURN your 64 will automatically move to the next line even in the middle of a word.

The program will display a bouncing ball moving from left to right, and back again, across the screen.

If we look at the program closely, you can see how this feat was accomplished.

```
10 REM BOUNCING BALL
20 PRINT "{CLR/HOME}"
25 FOR X = 1 TO 10 : PRINT "{CRSR DOWN}": NEXT
30 FOR BL = 1 TO 40
40 PRINT" ●{CRSR LEFT}";:REM (● is a SHIFT-Q)
50 FOR TM = 1 TO 5
60 NEXT TM
70 NEXT BL
75 REM MOVE BALL RIGHT TO LEFT
80 FOR BL = 40 TO 1 STEP -1
90 PRINT" {CRSR LEFT}{CRSR LEFT}●{CRSR LEFT}";
100 FOR TM = 1 TO 5
110 NEXT TM
120 NEXT BL
130 GOTO 20
```

Line 10 is a REMark that just tells what the program does; it has no effect on the program itself. Line 20 clears the screen of any information.

Line 25 PRINTs 10 cursor-down commands. This just positions the ball in the middle of the screen. If line 25 was eliminated the ball would move across the top line of the screen.

Line 30 sets up a loop for moving the ball the 40 columns from the left to right.

Line 40 does a lot of work. It first prints a space to erase the previous ball positions, then it prints the ball, and finally it performs a cursor-left to get everything ready to erase the current ball position again.

The loop set up in lines 50 and 60 slows the ball down a bit by delaying the program. Without it, the ball would move too fast to see.

Line 70 completes the loop that prints balls on the screen, set up in line 30. Each time the loop is executed, the ball moves another space to the right. As you notice from the illustration, we have set up a loop within a loop.

This is perfectly acceptable. The only time you get in trouble is when the loops cross over each other. It's helpful in writing programs to check yourself as illustrated here to make sure the logic of a loop is correct.

To see what would happen if you cross a loop, reverse the statements in lines 60 and 70. You will get an error because the computer gets confused and cannot figure out what's going on.

Lines 80 through 120 just reverse the steps in the first part of the program, and move the ball from right to left. Line 90 is slightly different from line 40 because the ball is moving in the opposite direction (we have to erase the ball to the right and move to the left).

And when that's all done the program goes back to line 20 to start the whole process over again. Pretty neat! To stop the program hold down RUN/STOP and hit RESTORE.

For a variation on the program, edit line 40 to read:

```
40 PRINT "●";
```

TO MAKE THE ● HOLD THE SHIFT KEY DOWN AND HIT THE LETTER "Q."

Run the program and see what happens now. Because we left out the cursor control, each ball remains on the screen until erased by the ball moving right to left in the second part of the program.

INPUT

Up to now, everything within a program has been set before it is run. Once the program was started, nothing could be changed. INPUT allows us to pass new information to a program as it is running and have that new information acted upon.

To get an idea of how INPUT works, type NEW RETURN and enter this short program:

```
10 INPUT A$
20 PRINT "YOU TYPED: ";A$
30 PRINT
40 GOTO 10

RUN
? COMMODORE 64
YOU TYPED: COMMODORE 64
```

YOU TYPED

COMPUTER RESPONDED

What happens when you run this program is simple. A question mark will appear, indicating that the computer is waiting for you to type something. Enter any character, or group of characters, from the keyboard and hit RETURN. The computer will then respond with "YOU TYPED: " followed by the information you entered.

This may seem very elementary, but imagine what you can have the computer do with any information you enter.

You can INPUT either numeric or string variables, and even have the INPUT statement prompt the user with a message. The format of INPUT is:

```
INPUT "PROMPT MESSAGE";VARIABLE
```

PROMPT MESSAGE MUST BE 38 CHARACTERS OR LESS.

Or, just:

```
INPUT VARIABLE
```

NOTE: To get out of this program hold down the RUN/STOP and RESTORE keys.

The following program is not only useful, but demonstrates a lot of what has been presented so far, including the new input statement.

```
NEW

1 REM TEMPERATURE CONVERSION PROGRAM
5 PRINT "{CLR/HOME}"
10 PRINT "CONVERT FROM FAHRENHEIT OR CELSIUS
   (F/C)": INPUT A$
20 IF A$ = "" THEN 10
30 IF A$ = "F" THEN 100
40 IF A$ <> "C" THEN 10
50 INPUT "ENTER DEGREES CELSIUS: ";C
60 F = (C*9)/5+32
70 PRINT C; " DEG. CELSIUS = "; F; " DEG.
   FAHRENHEIT"
80 PRINT
90 GOTO 10
100 INPUT "ENTER DEGREES FAHRENHEIT: ";F
110 C = (F-32)*5/9
120 PRINT F; " DEG. FAHRENHEIT = "; C;
    " DEG. CELSIUS"
130 PRINT
140 GOTO 10
```

NO SPACE HERE

DON'T FORGET TO HIT RETURN

If you enter and run this program, you'll see INPUT in action.

Line 10 uses the input statement to not only gather information, but also print our prompt. Also notice that we can ask for either a number or a string (by using a numeric or string variable).

Lines 20, 30 and 40 do some checks on what is typed in. In line 20, if nothing is entered (just RETURN is hit), then the program goes back to line 10 and requests the input again. In line 30, if F is typed, you know the user wants to convert a temperature in degrees Fahrenheit to Celsius, so the program branches to the part that does that conversion.

Line 40 does one more check. We know there are only two valid choices the user can enter. To get to line 40, the user must have typed some character other than F. Now, a check is made to see if that character is a C; if not, the program requests input again.

This may seem like a lot of detail, but it is good programming practice. A user not familiar with the program can become very frustrated if it does something strange because a mistake was made entering information.

Once we determine what type of conversion to perform, the program does the calculation and prints out the temperature entered and the converted temperature.

The calculation is just straight math, using the established formula for temperature conversion. After the calculation is finished and answer printed, the program loops back and starts over.

After running, the screen might look like this:

```
CONVERT FROM FAHRENHEIT OR CELSIUS (F/C)

? F
ENTER DEGREES FAHRENHEIT: ? 32
32 DEG. FAHRENHEIT = 0 DEG. CELSIUS

CONVERT FROM FAHRENHEIT OR CELSIUS (F/C)

?
```

After running the program, make sure to save it on disk or tape. This program, as well as others presented throughout this Guide, can form the base of your program library.

GET

GET allows you to input one character at a time from the keyboard without hitting RETURN. This really speeds entering data in many applications. Whatever key is hit is assigned to the variable you specify with GET.

The following routine illustrates how GET works:

```
NEW
1 PRINT "{CLR/HOME}"
10 GET A$: IF A$ = "" THEN 10
20 PRINT A$;
30 GOTO 10
```

NO SPACE HERE

If you RUN the program, the screen will clear and each time you hit a key, line 20 will print it on the display, and then GET another character. It is

important to note that the character entered will not be displayed unless you specifically PRINT it to the screen, as we've done here.

The second statement on line 10 is also important. GET continually works, even if no key is pressed (unlike INPUT that waits for a response), so the second part of this line continually checks the keyboard until a key is hit.

See what happens if the second part of line 10 is eliminated.

To stop this program you can hit the RUN/STOP and RESTORE keys.

The first part of the temperature conversion program could easily be rewritten to use GET. LOAD the temperature conversion program, and modify lines 10, 20 and 40 as shown:

```
10 PRINT "CONVERT FROM FAHRENHEIT OR CELSIUS (F/C)"
20 GET A$: IF A$ = "" THEN 10
40 IF A$ <> "C" THEN 20
```

NO SPACE HERE

This modification will make the program operate smoother, as nothing will happen unless the user types in one of the desired responses to select the type of conversion.

Once this change is made, make sure you save the new version of the program.

RANDOM NUMBERS AND OTHER FUNCTIONS

The Commodore 64 contains a number of functions that are used to perform special operations. Functions could be thought of as built-in programs included in BASIC. But rather than typing in a number of statements each time you need to perform a specialized calculation, you just type the command for the desired function and the computer does the rest.

Many times when designing a game or educational program, you need to generate a random number, to simulate the throw of dice, for example. You could certainly write a program that would generate these numbers, but an easier way is to call upon the RaNDom number function.

To see what RND actually does, try this short program:

```
NEW

10 FOR X = 1 TO 10
20 PRINT RND(1),
30 NEXT
```

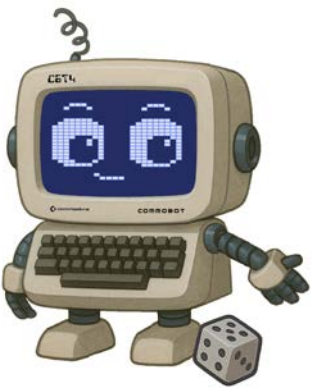
IF YOU LEAVE OUT THE COMMA YOUR LIST OF NUMBERS WILL APPEAR AS 1 COLUMN

After running the program, you will see a display like this:

```
.789280697          .664673958
.256373663          .0123442287
.682952381          .9058727922
.402343724          .87930926
.158209063          .245596701
```

Your numbers don't match? Well, if they did we would all be in trouble, as they should be completely random!

Try running the program a few more times to verify that the results are always different. Even if the numbers don't follow any pattern, you should start to notice that some things remain the same every time the program is run.



First, the results are always between 0 and 1, but never equal to 0 or 1. This will certainly never do if we want to simulate the random toss of dice, since we're looking for numbers between 1 and 6.

The other important feature to look for is that we are dealing with real numbers (with decimal places). This could also be a problem since whole (integer) numbers are often needed.

There are a number of simple ways to produce numbers from the RND function in the range desired.

Replace line 20 with the following and run the program again:

```
20 PRINT 6*RND(1),

RUN


3.60563664 4.53660853
5.47238963 2.40850227
3.19265054 4.39547668
3.16331095 5.50620749
1.32527884 4.17090293
```

That cured the problem of not having results larger than 1, but we still have the decimal part of the result to deal with. Now, another function can be called upon.

The INTeger function converts real numbers into integer values.

Once more, replace line 20 with the following and run the program to see the effect of the change:

```
20 PRINT INT(6*RND(1)),
RUN

2          3          1          0
2          4          5          5
0          1
```

That took care of a lot, getting us closer to our original goal of generating random numbers between 1 and 6. If you examine closely what we generated this last time, you'll find that the results range from 0 to 5, only.

As a last step, add a one to the statement, as follows:

```
20 PRINT INT(6*RND(1))+1,
```

Now, we have achieved the desired results.

In general, you can place a number, variable, or any BASIC expression within the parentheses of the INT function. Depending on the range desired, you just multiply the upper limit by the RND function. For example, to generate random numbers between 1 and 25, you could type:

```
20 PRINT INT(25*RND(1))+1
```

The general formula for generating a set of random numbers in a certain range is:

```
NUMBER=INT(LOWER LIMIT+(UPPER - LOWER+1)*RND(1))
```

GUESSING GAME

Since we've gone to some lengths to understand random numbers, why not put this information to use? The following game not only illustrates a good use of random numbers, but also introduces some additional programming theory.

In running this program, a random number, NM, will be generated.

```
NEW

1 REM NUMBER GUESSING GAME
2 PRINT "{CLR/HOME}"
5 INPUT "ENTER UPPER LIMIT FOR GUESS ";LI
10 NM = INT(LI*RND(1))+1
15 CN = 0
20 PRINT "I'VE GOT THE NUMBER.":PRINT
30 INPUT "WHAT'S YOUR GUESS"; GU
35 CN = CN + 1
40 IF GU > NM THEN PRINT "MY NUMBER IS LOWER"
   : PRINT : GOTO 30
50 IF GU < NM THEN PRINT "MY NUMBER IS HIGHER"
   : PRINT : GOTO 30
60 PRINT "GREAT! YOU GOT MY NUMBER"
65 PRINT "IN ONLY "; CN ;"GUESSES.":PRINT
70 PRINT "DO YOU WANT TO TRY ANOTHER (Y/N)?";
80 GET AN$ : IF AN$="" THEN 80
90 IF RN$ = "Y" THEN 2
100 IF AN$ <> "N" THEN 70
110 END
```

; INDICATES NO SPACE AFTER QUOTATION MARK

You can specify how large the number will be at the start of the program. Then, it's up to you to guess what the number is.

A sample run follows along with an explanation:

```
ENTER UPPER LIMIT FOR GUESS? 25
I'VE GOT THE NUMBER.

WHAT'S YOUR GUESS? 15
MY NUMBER IS HIGHER

WHAT'S YOUR GUESS? 20
MY NUMBER IS HIGHER

WHAT'S YOUR GUESS? 23
GREAT! YOU GOT MY NUMBER
IN ONLY 3 GUESSES

DO YOU WANT ANOTHER TRY (Y/N)
```

IF/THEN statements compare your guess to the number generated. Depending on your guess, the program tells you whether your guess was higher or lower than the random number generated.

From the formula given for determining random number range, see if you can add a few lines to the program that allow the user to also specify the lower range of numbers generated.

Each time you make a guess, CN is incremented by 1 to keep track of the number of guesses. In using the program, see if you can use good reasoning to guess a number in the least number of tries.

When you get the right answer, the program prints out the "GREAT! YOU GOT MY NUMBER" message, along with the number of tries it took.

You can then start the process over again. Remember, the program generates a new random number each time.

PROGRAMMING TIPS:

In lines 40 and 50, a colon is used to separate multiple statements on a single line. This not only saves typing, but in long programs will conserve memory space.

Also notice in the IF/THEN statements on the same two lines, we instructed the computer to PRINT something, rather than immediately branching to some other point in the program.

The last point illustrates the reason behind using line numbers in increments of 10: we originally wrote Guessing Game without the feature that counts your guesses. We were able to add that feature by entering the lines numbered 15, 35, and 65, after all of the other lines had been entered. BASIC inserted the lines into the program in line number order. This made it easy to change the program without reentering any of the other lines.

YOUR ROLL

The following program simulates the throw of two dice. You can enjoy it as it stands, or use it as part of a larger game.

```
5 PRINT "CARE TO TRY YOUR LUCK?"
10 PRINT "RED DICE = " ;INT(6*RND(1))+1
20 PRINT "WHITE DICE = " ;INT(6*RND(1))+1
30 PRINT "HIT SPACE BAR FOR ANOTHER ROLL ":PRINT
40 GET A$: IF A$ = "" THEN 40
50 IF A$ = CHR$(32) THEN 10
```

Care to try your luck?

From what you've learned about random numbers and BASIC, see if you can follow what is going on.

RANDOM GRAPHICS

As a final note on random numbers, and as an introduction to designing graphics, take a moment to enter and run this neat little program:

```
10 PRINT "{CLR/HOME}"
20 PRINT CHR$(205.5 + RND(1));
40 GOTO 20
```

As you may have expected, line 20 is the key here. Another function, CHR$ (Character String), gives you a character, based on a standard code number from 0 to 255. Every character the Commodore 64 can print is encoded this way (see Appendix D).

To quickly find out the code for any character, just type:

```
PRINT ASC("X")
```

where X is the character you're checking (this can be any printable character, including graphics). The response is the code for the character you typed. As you probably figured out, "ASC" is another function, which returns the standard "ASCII" code for the character you typed.

You can now print that character by typing:

```
PRINT CHR$(X)
```

If you try typing:

```
PRINT CHR$ (205); CHR$(206)
```

you will see the two right side graphic characters on the M and N keys. These are the two characters that the program is using for the maze.

By using the formula 205.5 + RND (1) the computer will pick a random number between 205.5 and 206.5. There is a fifty-fifty chance of the number being above or below 206. CHR$ ignores any fractional values, so half the time the character with code 205 is printed and the remaining time code 206 is displayed.

If you'd like to experiment with this program, try changing 205.5 by adding or subtracting a couple tenths from it. This will give either character a greater chance of being selected.

CHAPTER 6

ADVANCED COLOR AND GRAPHIC COMMANDS

- Color and Graphics
- PRINTing Colors
- Color CHR$ Codes
- PEEKs and POKEs
- Screen Graphics
- Screen Memory Map
- Color Memory Map
- More Bouncing Balls

COLOR AND GRAPHICS

Up to now we've explored some of the sophisticated computing capabilities of the Commodore 64. But one of its most fascinating features is an outstanding ability to produce color and graphics.

You've seen a quick example of graphics in the "bouncing ball" and "maze" programs. But these only touched on the power you command. A number of new concepts will be introduced in this section to explain graphic and color programming and show how you can create your own games and advanced animation.

Because we've concentrated on the computing capabilities of the machine, all the displays we've generated so far were a single color (light blue text on a dark blue background, with a light blue border).

In this chapter we'll see how to add color to programs and control all those strange graphic symbols on the keyboard.

PRINTING COLORS

As you type, the cursor prints characters to the display in one of the available colors. You can change cursor text color by holding the CTRL key and one of the color keys. This works fine in the immediate mode, but what happens if you want to incorporate color changes in your programs?

When we showed the "bouncing ball" program, you saw how keyboard commands, like cursor movement, could be incorporated within PRINT statements. In a like way, you can also add text color changes to your programs.

You have a full range of 16 text colors to work with. Using the CTRL key and a number key, the following colors are available:

1	2	3	4	5	6	7	8
Black	White	Red	Cyan	Purple	Green	Blue	Yellow

If you hold down the C= key along with the appropriate number key, these additional eight colors can be used:

1	2	3	4	5	6	7	8
Orange	Brown	Light Red	Gray 1	Gray 2	Light Green	Light Blue	Gray 3

Type NEW, and experiment with the following. Hold down the CTRL key and at the same time hit the 1 key. Next, hit the R key without holding down the CTRL key. Now, while again depressing the CTRL key at the same time hit the 2 key. Release the CTRL key and hit the A key. Move through the numbers, alternating with the letters, and type out the word RAINBOW as follows:

```
10 PRINT" R A I N B O W"
          ↑ ↑ ↑ ↑ ↑ ↑ ↑
```

CTRL 1 2 3 4 5 6 7

```
RUN
RAINBOW
```

Just as cursor controls show as graphic characters within the quote marks of print statements, color controls are also represented as graphic characters.

In the previous example, when you held down CTRL and typed 3 a "£" was displayed. CTRL 7 displayed a "←". Each color control will display its unique graphic code when used in this way. The table shows the graphic representations of each printable color control.

KEYBOARD	COLOR	DISPLAY	KEYBOARD	COLOR	DISPLAY
CTRL 1	BLACK		C= 1	ORANGE	
CTRL 2	WHITE		C= 2	BROWN	
CTRL 3	RED		C= 3	LT. RED	
CTRL 4	CYAN		C= 4	GRAY 1	
CTRL 5	PURPLE		C= 5	GRAY 2	
CTRL 6	GREEN		C= 6	LT. GREEN	
CTRL 7	BLUE		C= 7	LT. BLUE	
CTRL 8	YELLOW		C= 8	GRAY 3	

Even though the PRINT statement may look a bit strange on the screen, when you RUN the program, only the text will be displayed. And it will automatically change colors according to the color controls you placed in the print statement.

Try a few examples of your own, mixing any number of colors within a single PRINT statement. Remember, too, you can use the second set of text colors by using the Commodore key and the number keys.

TIP:

You will notice after running a program with color or mode (reverse) changes, that the "READY" prompt and any additional text you type is the same as the last color or mode change. To get back to the normal display, remember to depress: RUN/STOP and RESTORE.

COLOR CHR$ CODES

Take a brief look at Appendix D, then turn back to this section.

You may have noticed in looking over the list of CHR$ codes in Appendix D that each color (as well as most other keyboard controls, such as cursor movement) has a unique code. These codes can be printed directly to obtain the same results as typing CTRL and the appropriate key within the PRINT statement. For example, try this:

```
NEW
10 PRINT CHR$(147) : REM CLR/HOME
20 PRINT CHR$(30);"CHR$(30) CHANGES ME TO?"
RUN
CHR$(30) CHANGES ME TO?
```

The text should now be green. In many cases, using the CHR$ function will be much easier, especially if you want to experiment with changing colors. The following program is a different way to get a rainbow of colors. Since there are a number of lines that are similar (40 - 110) use the editing keys to save a lot of typing. See the notes after the listing to refresh your memory on the editing procedures.

```
NEW

1 REM AUTOMATIC COLOR BARS
5 PRINT CHR$(147) : REM CHR$(147)=CLR/HOME
10 PRINT CHR$(18); "      " ;:REM REVERSE BAR
20 CL = INT(8*RND(1))+1
30 ON CL GOTO 40,50,60,70,80,90,100,110
40 PRINT CHR$(5);: GOTO 10
50 PRINT CHR$(28);: GOTO 10
60 PRINT CHR$(30);: GOTO 10
70 PRINT CHR$(31);: GOTO 10
```

```
80 PRINT CHR$(144);: GOTO 10
90 PRINT CHR$(156);: GOTO 10
100 PRINT CHR$(158);: GOTO 10
110 PRINT CHR$(159);: GOTO 10
```

Type lines 5 through 40 normally. Your display should look like this:

```
1 REM AUTOMATIC COLOR BARS
5 PRINT CHR$(147) : REM CHR$(147)=CLR/HOME
10 PRINT CHR$(18); "      ";:REM REVERSE BAR
20 CL = INT(8*RND(1))+1
30 ON CL GOTO 40,50,60,70,80,90,100,110
40 PRINT CHR$(5);: GOTO 10
```

Editing Notes

Use the CRSR-UP key to position the cursor on line 40. Then type 5 over the 4 of 40. Next, use the CRSR-RIGHT key to move over to the 5 in the CHR$ parentheses. Hit SHIFT INST/DEL to open up a space and type '28'. Now just hit RETURN with the cursor anywhere on the line.

The display should now look like this:

```
1 REM AUTOMATIC COLOR BARS
5 PRINT CHR$(147) : REM CHR$(147)=CLR/HOME
10 PRINT CHR$(18); "      ";:REM REVERSE BAR
20 CL = INT(8*RND(1))+1
30 ON CL GOTO 40,50,60,70,80,90,100,110
50 PRINT CHR$(28);: GOTO 10
```

Don't worry. Line 40 is still there. LIST the program and see. Using the same procedure, continue to modify the last line with a new line number and CHR$ code until all the remaining lines have been entered. See, we told you the editing keys would come in handy. As a final check, list the entire program to make sure all the lines were entered properly before you RUN it.

Here is a short explanation of what's going on.

You've probably figured out most of the color bar program by now except for some strange new statement in line 30. But let's quickly see what the whole program actually does. Line 5 prints the CHR$ code for CLR/HOME.

Line 10 turns reverse type on and prints 5 spaces, which turn out to be a bar, since they're reversed. The first time through the program the bar will be light blue, the normal text color.

Line 20 uses our workhorse, the random function to select a random color between 1 and 8.

Line 30 contains a variation of the IF...THEN statement which is called ON...GOTO. ON...GOTO allows the program to choose from a list of line numbers to go to. If the variable (in this case CL) has a value of 1, the first line number is the one chosen (here 40). If the value is 2, the second number in the list is used, etc.

Lines 40-110 just convert our random key colors to the appropriate CHR$ code for that color and return the program to line 10 to PRINT a section of the bar in that color. Then the whole process starts over again.

See if you can figure out how to produce 16 random numbers, expand ON...GOTO to handle them, and add the remaining CHR$ codes to display the remaining 8 colors.

PEEKS AND POKES

No, we're not talking about jabbing the computer, but we will be able to "look around" inside the machine and "stick" things in there.

Just as variables could be thought of as a representation of "boxes" within the machine where you placed your information, you can also think of some specially defined "boxes" within the computer that represent specific memory locations.

The Commodore 64 looks at these memory locations to see what the screen's background and border color should be, what characters are to be displayed on the screen — and where — and a host of other tasks.

By placing, "POKEing," a different value into the proper memory location, we can change colors, define and move objects, and even create music.

These memory locations could be represented like this:

53280	53281	53282	53283
X	Y		
BORDER COLOR	BACKGROUND COLOR		

These are just four memory locations, two of which control the screen and background colors. Try typing this:

POKE 53281,7 RETURN

The background color of the screen will change to yellow because we placed the value '7' — for yellow — in the location that controls the background color of the screen.

Try POKEing different values into the background color location, and see what results you get. You can POKE any value between 0 and 255, but only 0 through 15 will work.

The actual values to POKE for each color are:

0	BLACK	8	ORANGE
1	WHITE	9	BROWN
2	RED	10	Light RED
3	CYAN	11	GRAY 1
4	PURPLE	12	GRAY 2
5	GREEN	13	Light GREEN
6	BLUE	14	Light BLUE
7	YELLOW	15	GRAY 3

Can you think of a way to display the various background and border combinations? The following may be of some help:

```
NEW

10 FOR BA = 0 TO 15
20 FOR BO = 0 TO 15
30 POKE 53280, BA
40 POKE 53281, BO
50 FOR X = 1 TO 2000 : NEXT X
60 NEXT BO: NEXT BA

RUN
```

Two simple loops were set up to POKE various values to change the background and border colors. The delay loop in line 50 just slows things down a bit.

For the curious, try:

```
? PEEK (53280) AND 15
```

You should get a value of 15. This is the last value BO was given and makes sense because both the background and border colors are GRAY (value 15) after the program is run.

By entering AND 15 you eliminate all other values except 0 - 15, because of the way the color codes are stored in the computer. Normally you would expect to find the same value that was last POKEd in the location. In general, PEEK lets us examine a specific location and see what value is present there. Can you think of a one line addition to the program that will display the value of BA and BO as the program runs? How about this?

```
25 PRINT CHR$(147); "BORDER = ";PEEK (53280) AND 15,
   "BACKGROUND = "; PEEK (53281) AND 15
```

SCREEN GRAPHICS

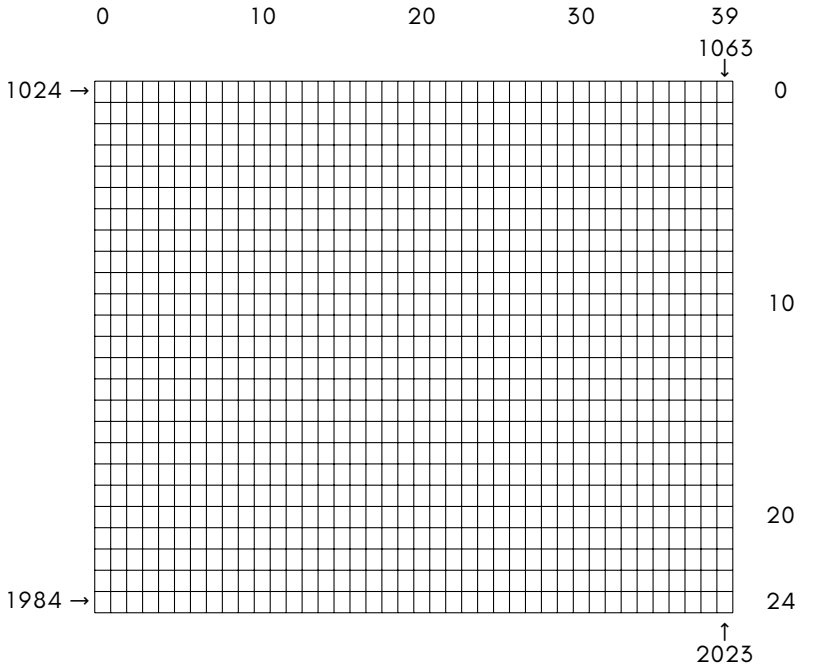
In all the printing of information that you've done so far, the computer normally handled information in a sequential fashion: one character is printed after the next, starting from the current cursor position (except where you asked for a new line, or used the ', ' in PRINT formatting).

To PRINT data in a particular spot you can start from a known place on the screen and PRINT the proper number of cursor controls to format the display. But just as there are certain spots in the Commodore 64's memory to control color, there are also locations that you can use to directly control each location on the screen.

SCREEN MEMORY MAP

Since the computer's screen is capable of holding 1000 characters (40 columns by 25 lines) there are 1000 memory locations set aside to handle what is placed on screen. The layout of the screen could be thought of as a grid, with each square representing a memory location.

And since each location in memory can contain a number from 0 to 255, there are 256 possible values for each memory location. These values represent the different characters the Commodore 64 can display (see Appendix C). By POKEing the value for a character in the appropriate screen memory location, that character will be displayed in the proper position.



Screen memory in the Commodore 64 normally begins at memory location 1024, and ends at location 2023. Location 1024 is the upper left corner of the screen. Location 1025 is the position of the next character to the right of that, and so on across the row. Location 1063 is the right-most position of the first row. The next location following the last character on a row is the first character on the next row down.

Now, let's say that you're controlling a ball bouncing on the screen. The ball is in the middle of the screen, column 20, row 12. The formula for calculation of the memory on the screen is:

COLUMN

POINT = 1024 + X + 40*Y

ROW

where X is the column and Y is the row.

Therefore, the memory location of the ball is

COLUMN

1024 + 20 + (480) = 1524

ROW (40*12)

Clear the screen with SHIFT and CLR/HOME and type:

```
POKE 1524,81
POKE 55796,1
```

COLOR

LOCATION

COLOR MEMORY MAP

A ball appears in the middle of the screen! You have placed a character directly into screen memory without using the PRINT statement. The ball that appeared was white. However there is a way to change the color of an object on the screen by altering another range of memory. Type:

LOCATION

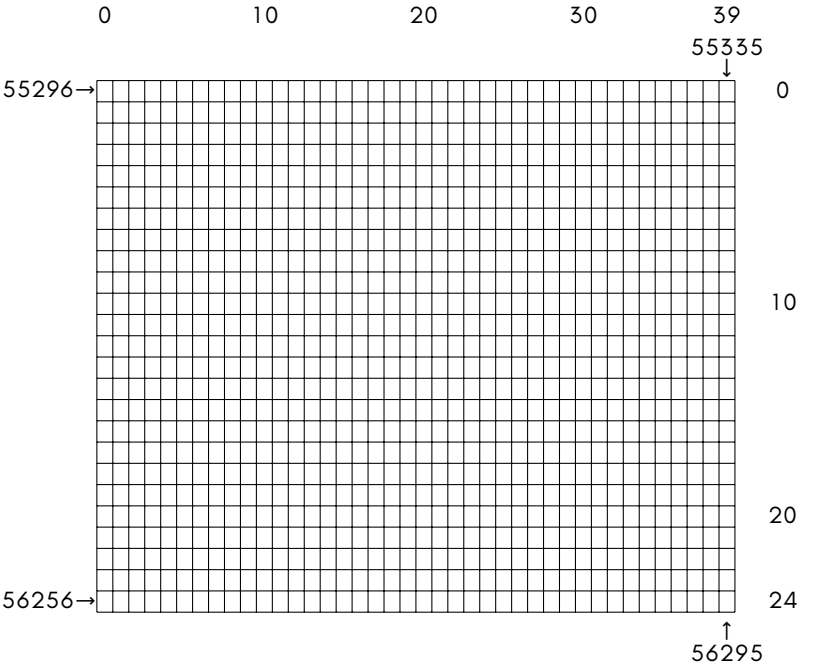
```
POKE 55796,2
```

COLOR

The ball's color changes to red. For every spot on the Commodore 64's screen there are two memory locations, one for the character code, and the other for the color code. The color memory map begins at location 55296 (top left-hand corner), and continues on for 1000 locations. The same color codes, from 0 to 15, that we used to change border and background colors can be used here to directly change character colors.

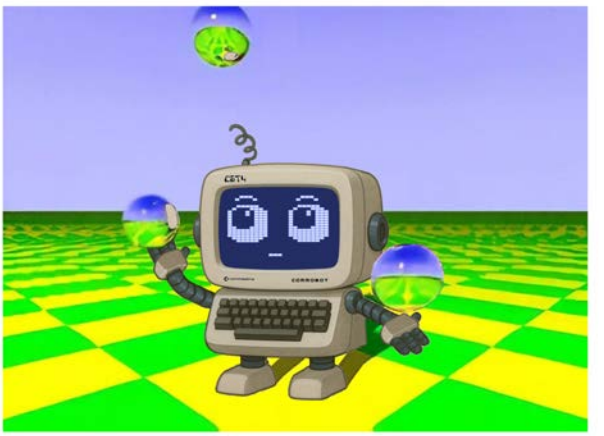
The formula we used for calculating screen memory locations can be modified to give the locations to POKE color codes. The new formula is:

COLOR PRINT = 55296 + X + 40*Y



MORE BOUNCING BALLS

Here's a revised bouncing ball program that prints directly on the screen with POKEs, rather than using cursor controls within PRINT statements. As you will see after running the program, it is much more flexible than the earlier program, and will lead up to programming much more sophisticated animation.



Where have I seen this before?

```
NEW

10 PRINT "{CLR/HOME}"
20 POKE 53280,7 : POKE 53281,13
30 X = 1 : Y = 1
40 DX = 1 : DY = 1
50 POKE 1024 + X + (40*Y),81
60 FOR T = 1 TO 10 : NEXT
70 POKE 1024 + X + (40*Y),32
80 X = X + DX
90 IF X <= 0 OR X >= 39 THEN DX = -DX
100 Y = Y + DY
110 IF Y <= 0 OR Y >= 24 THEN DY = -DY
120 GOTO 50
```

Line 10 clears the screen, and line 20 sets the background to light green with a yellow border.

The X and Y variables in line 30 keep track of the current row and column position of the ball. The DX and DY variables in line 40 are the horizontal and vertical direction of the ball's movement. When a +1 is added to the X value, the ball is moved to the right; when -1 is added, the ball moves to the left. A +1 added to Y moves the ball down a row; a -1 added to Y moves the ball up a row.

Line 50 puts the ball on the screen at the current cursor position. Line 60 is the familiar delay loop, leaving the ball on the screen just long enough to see it.

Line 70 erases the ball by putting a space (code 32) where the ball was on the screen.

Line 80 adds the direction factor to X. Line 90 tests to see if the ball has reached one of the side walls, reversing the direction if there's a bounce. Lines 100 and 110 do the same thing for the top and bottom walls.

Line 120 sends the program back to display and moves the ball again.

By changing the code in line 50 from 81 to another character code, you can change the ball to any other character. If you change DX or DY to 0 the ball will bounce straight instead of diagonally.

We can also add a little more intelligence. So far the only thing you checked for is the X and Y values getting out-of-bounds for the screen. Add the following lines to the program:

```
21 FOR L = 1 TO 10
25 POKE 1024 + INT(RND(1)*1000), 166
27 NEXT L
85 IF PEEK(1024 + X + (40*Y)) = 166 THEN DX = -DX : GOTO 80
105 IF PEEK(1024 + X + (40*Y)) = 166 THEN DY = -DY : GOTO 100
```

SCREEN CODE

Lines 21 to 27 put 10 blocks on the screen in random positions. Lines 85 and 105 check (PEEK) to see if the ball is about to bounce into a block, and change the ball's direction if so.

CHAPTER 7

SPRITE GRAPHICS

- Introduction to Sprites
- Sprite Creation
- Additional Notes on Sprites
- Binary Arithmetic

INTRODUCTION TO SPRITES

In previous chapters dealing with graphics we saw that graphic symbols could be used in PRINT statements to create animations and add chartlike appearances to our displays.

A way was also shown to POKE character codes in specific screen memory locations. This would then place the appropriate characters directly on the screen in the right spot.

Creating animation in both these cases requires a lot of work because objects must be created from existing graphic symbols. Moving the object requires a number of program statements to keep track of the object and move it to a new spot. And, because of the limitation of using graphic symbols, the shape and resolution of the object might not be as good as required.

Using sprites in animated sequences eliminates a lot of these problems. A sprite is a high-resolution programmable object that can be made into just about any shape — through BASIC commands. The object can be easily moved around the screen by simply telling the computer the position the sprite should be moved to. The computer takes care of the rest.

And sprites have much more power than just that. Their color can be changed; you can tell if one object collides with another; they can be made to go in front and behind another; and they can be easily expanded in size, just for starters.

The penalty for all this is minimal. However, using sprites requires knowing some more details about how the Commodore 64 operates and how numbers are handled within the computer. It's not as difficult as it sounds though. Just follow the examples and you'll be making your own sprites do amazing things in no time.

SPRITE CREATION

Sprites are controlled by a separate picture-maker in the Commodore 64. This picture-maker handles the video display. It does all the hard work of creating and keeping track of characters and graphics, creating colors, and moving around.

This display circuit has 46 different "ON/OFF" locations which act like internal memory locations. Each of these locations breaks down into a series of 8 blocks. And each block can either be "on" or "off". We'll get into more detail about this later. By POKEing the appropriate decimal value in the proper memory location you can control the formation and movement of your sprite creations.

In addition to accessing many of the picture-making locations we will also be using some of the Commodore 64's main memory to store information (data) that defines the sprites. Finally, 8 memory locations directly after the screen memory will be used to tell the computer exactly which memory area each sprite will get its data from.

As we go through some examples, the process will be very straightforward, and you'll get the hang of it.

So let's get on with creating some sprite graphics. A sprite object is 24 dots wide by 21 dots long. Up to 8 sprites can be controlled at a time. Sprites are displayed in a special independent 320 dot wide by 200 dot high area. However, you can use your sprite with any mode, high- resolution, low-resolution, text etc.

Say you want to create a balloon and have it float around the sky. The balloon could be designed as in the 24 by 21 grid below.

The next step is to convert the graphic design into data the computer can use. Get a piece of data or graph paper and set up a sample grid that is 21 spaces down and 24 spaces across. Across the top write 128, 64, 32, 16, 8, 4, 2, 1, three times (as shown) for each of the 24 squares. Number down the left side of the grid 1 – 21 for each row. Write the word DATA at the end of each row. Now fill the grid with any design or use the balloon that we have. It's easiest to outline the shape first and then go back and fill in the grid.

Now if you think of all the squares you filled as "on" then substitute a 1 for each filled square. For the squares that aren't filled in, they're "off" so put a zero.

Starting on the first row, you need to convert the dots into 3 separate pieces of data the computer can read. Each set of 8 squares is equal to one piece of data called a byte in our balloon. Working from the left, the first 8 squares are blank, or 0, so the value for that series of numbers is 0.

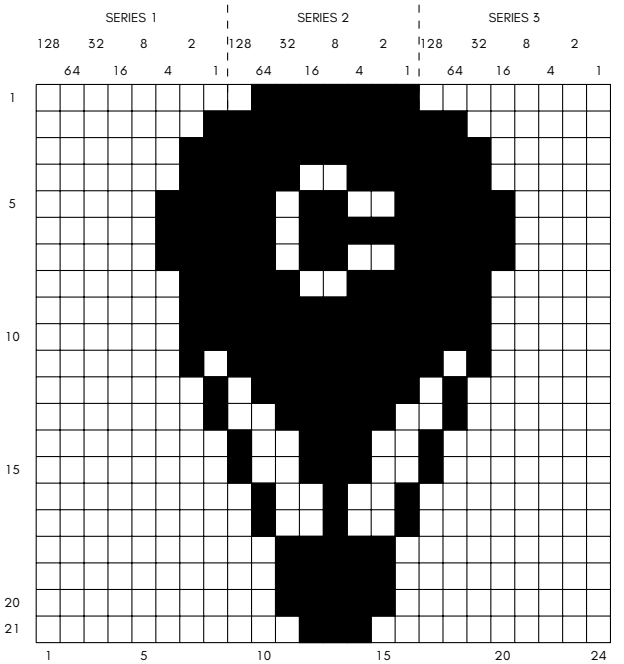
The middle series looks like this (again a 1 indicates a dot, 0 is a space):

128	64	32	16	8	4	2	1
0	1	1	1	1	1	1	1
↑	↑	↑	↑	↑	↑	↑	↑

0 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 127

The third series on the first row also contains blanks, so it too equals zero. Thus the data for the first line is:

DATA 0, 127, 0



The series that make up row two are calculated like this:

Series 1:	0	0	0	0	0	0	0	1	
	↑	↑	↑	↑	↑	↑	↑	↑	
	0 +	0 +	0 +	0 +	0 +	0 +	0 +	1	= 1
Series 2:	1	1	1	1	1	1	1	1	
	↑	↑	↑	↑	↑	↑	↑	↑	
	128 +	64 +	32 +	16 +	8 +	4 +	2 +	1	= 255
Series 3:	1	1	0	0	0	0	0	0	
	↑	↑	↑	↑	↑	↑	↑	↑	
	128 +	64 +	0 +	0 +	0 +	0 +	0 +	0	= 192

For row 2, the data would be:

DATA 1, 255, 192

In the same way, the 3 series that make up each remaining row would be converted into their decimal value. Take the time to do the remainder of the conversion in this example.

Now that you have the data for the object, how can it be put to use? Type in the following program and see what happens.

```
1 REM UP, UP, AND AWAY!
```

```
5 PRINT CHR$(147)
10 V = 53248 : REM START OF DISPLAY CHIP
11 POKE V+21,4 : REM ENABLE SPRITE 2
12 POKE 2042,13 : REM SPRITE 2 DATA FROM 13TH BLK
20 FOR N = 0 TO 62 : READ Q : POKE 832+N,Q : NEXT
30 FOR X = 0 TO 200
40 POKE V+4,X : REM UPDATE X COORDINATES
50 POKE V+5,X : REM UPDATE Y COORDINATES
60 NEXT X
70 GOTO 30
200 DATA 0,127,0,1,255,192,3,255,224,3,231,224
210 DATA 7,217,240,7,223,240,7,217,240,3,231,224
220 DATA 3,255,224,3,255,224,2,255,160,1,127,64
230 DATA 1,62,64,0,156,128,0,156,128,0,73,0,0,73,0
240 DATA 0,62,0,0,62,0,0,62,0,0,28,0
```

If you typed everything correctly, your balloon is smoothly flying across the sky.

In order to understand what happened, first you need to know what picture-making locations control the functions you need. These locations, called "registers", could be illustrated in this manner:

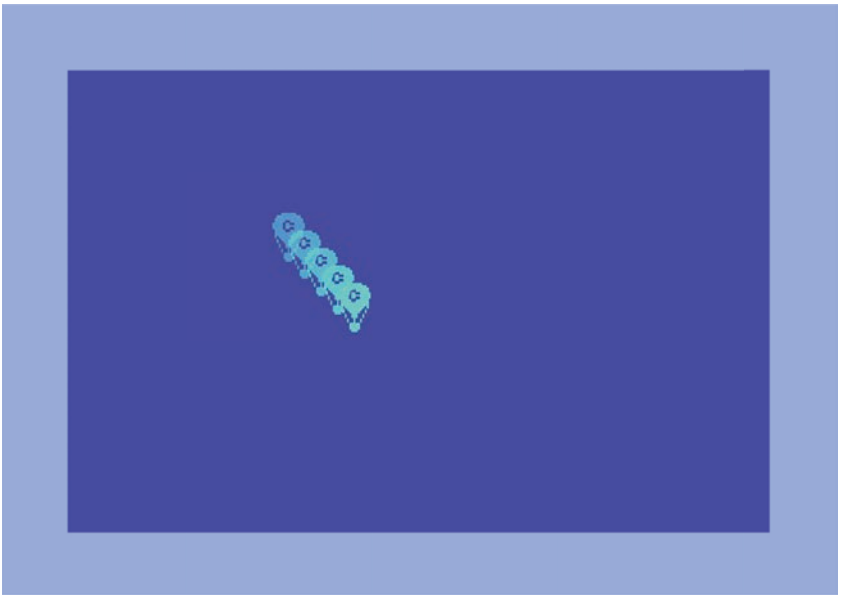
Registers	*Description*
0	X coordinate of sprite 0
1	Y coordinate of sprite 0
2 - 15	Paired like 0 and 1 for sprites 1 - 7
16	Most significant bit - X coordinate
21	Sprite appear: 1=appear 0=disappear
29	Expand sprite in "X" direction
23	Expand sprite in "Y" direction
39 - 46	Sprite 0 - 7 color

In addition to this information you need to know from which 64 bytes section sprites will get their data (1 byte is not used).

The data is handled by 8 locations directly after screen memory:

	2040	2041	2042	2043	2044	2045	2046	2047
	↑	↑	↑	↑	↑	↑	↑	↑
SPRITE	0	1	2	3	4	5	6	7

Now let's outline the exact procedure to get things moving and finally write a program.



There are only a few things necessary to actually create and move an object.

1. Make the proper sprite(s) appear on the screen by POKEing into location 21 a 1 for the bit which turns on the sprite.
2. Set sprite pointer (locations 2040 - 2047) to where sprite data should be read from.
3. POKE actual data into memory.
4. Through a loop, update X and Y coordinates to move sprite around.
5. You can, optionally, expand the object, change colors, or perform a variety of special functions. Using location 29 to expand your sprite in the "X" direction and location 23 in the "Y" direction.

There are only a few items in the program that might not be familiar from the discussion so far.

In line 10:

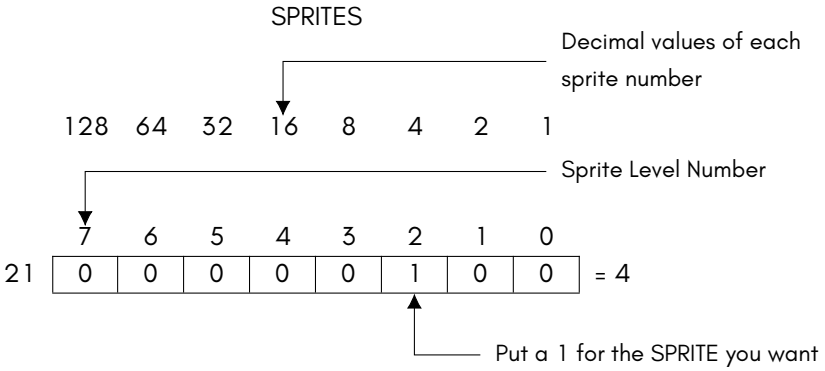
V=53248

sets V to the starting memory location of the video chip. In this way, we just increase V by the memory number to get the actual memory location. The register numbers are the ones given on the sprite register map.

In line 11:

```
POKE V+21,4
```

makes sprite 2 appear by placing a 4 in what is called the "sprite enable register" (21) to turn on sprite 2. Think of it like this:



Each sprite level is represented in section 21 of the sprite memory and 4 happens to be sprite level 2. If you were using level 3 you would put a 1 in sprite 3 which has a value of 8. In fact if you used both sprites 2 and 3 you would put a 1 in both 4 and 8. You would then add the numbers together just like you did with the DATA on your graph paper. So, turning on sprites 2 and 3 would be represented as V+21,12.

In line 12:

```
POKE 2042,13
```

instructs the computer to get the data for sprite 2 (location 2042) from the 13th area of memory. You know from making your sprite that it takes up 63 sections of memory. You may not have realised it, but those numbers you put across the top of your grid equal what is known as 3 bytes of the computer. In other words, each collection of the following numbers: 128, 64, 32, 16, 8, 4, 2, 1 equals 1 byte of computer memory. Therefore with the 21 rows of your grid times the 3 bytes of each row, each sprite takes up 63 bytes of memory.

```
20 FOR N = 0 TO 62 : READ Q : POKE 832+N,Q:NEXT
```

1 WHOLE SPRITE

This line handles the actual sprite creation. The 63 bytes of data that represent the sprite you created are READ in through the loop and POKEd into the 13th block of memory. This starts at location 832.

```
30 FOR X = 0 TO 200
40 POKE V+4, X
50 POKE V+5, X
```

SPRITE 2'S X COORDINATE

SPRITE 2'S Y COORDINATE

If you remember from school the X coordinate represents an object's horizontal movement across the screen and the Y coordinate represents the sprite's vertical movement across the screen. Therefore as the values of X change in line 30 from 0 to 200 (one number at a time) the sprite moves across the screen DOWN and TO THE RIGHT one space for each number. The numbers are READ by the computer fast enough to make the movement appear to be continuous, instead of 1 step at a time. If you need more details take a look at the register map in Appendix K.

When you get into moving multiple objects, it would be impossible for one memory section to update the locations of all 8 objects. Therefore each sprite has its own set of 2 memory locations to make it move on the screen.

Line 70 starts the cycle over again, after one pass on the screen. The remainder of the program is the data for the balloon. Sure looks different on the screen, doesn't it?

Now try adding the following line:

```
25 POKE V+23,4:POKE V+29,4:REM EXPAND
```

and RUN the program again. The balloon has expanded to twice the original size! What we did was simple. By POKEing 4 (again to indicate sprite 2) into memory sections 23 and 29, sprite 2 was expanded in the X and Y direction.

It's important to note that the sprite will appear in the upper left-hand corner of the object. When expanding an object in either direction, the starting point remains the same.

For some added excitement, make the following changes:

```
11 POKE V+21,12
12 POKE 2042,13:POKE 2043,13
30 FOR X = 1 TO 190
45 POKE V+6,X
55 POKE V+7,190-X
```

A second sprite (number 3) has been turned on by POKEing 12 into the memory location that makes the sprite appear (V+21). The 12 turns sprites 3 and 2 on (00001100 = 12).

The added lines 45 and 55 move sprite 3 around by POKEing values into sprite 3's X and Y coordinate locations (V+6 and V+7).

Want to fill the sky with even more action? Try making these additions:

28 IS REALLY 4 (SPRITE 2) + 8 (SPRITE 3) + 16 (SPRITE 4)

```
11 POKE V+21,28
12 POKE 2042,13:POKE 2043,13:POKE 2044,13
25 POKE V+23,12:POKE V+29,12
48 POKE V+8,X
58 POKE V+9,100
```

In line 11 this time, another sprite (4) was made to appear by POKEing 28 into the appropriate "on" location of the sprite memory section. Now sprites 2 – 4 are on (00011100 = 28).

Line 12 indicates that sprite 4 will get its data from the same memory area (13th 63 section area) as the other sprites by POKEing 2044,13.

In line 25, sprites 2 and 3 are expanded by POKEing 12 (sprites 2 and 3 on) into the X and Y direction expanded memory locations (V+23 and V+29).

Line 48 moves sprite 3 along the X axis. Line 58 positions sprite 3 halfway down the screen, at location 100. Because this value does not change, like it did before with X=0 to 200, sprite 3 just moves horizontally.

ADDITIONAL NOTES ON SPRITES

Now that you've experimented with sprites, a few more words are in order. First, you can change a sprite's color to any of the standard 16 color codes (0 - 15) that were used to change character color. These can be found in chapter 6 or in Appendix E.

For example, to change sprite 1 to light green, type: POKE V+40,13 (be sure to set V = 53248).

You may have noticed in using the example sprite programs that the object never moved to the right-hand edge of the screen. This was because the screen is 320 dots wide and the X direction register can only hold a value up to 255. How then can you get an object to move across the entire screen?

There is a location on the memory map that has not been mentioned yet. Location 16 (of the map) controls something called the "Most Significant Bit" (MSB) of the sprite's X direction location. In effect, this allows you to move the sprite to a horizontal spot between 256 and 320.

The MSB of X register works like this: after the sprite has been moved to X location 255, place a value into memory location 16 representing the sprite you want to move. For example, to get sprite 2 to move into horizontal locations 256 - 320, POKE the value for sprite 2 (which is 4) into memory location 16:

```
POKE V+16,4
```

Now start from 0 again in the usual X direction register for sprite 2 (which is in location 4 of the map). Since you are only moving another 64 spaces, X locations would only range between 0 and 63 this time.

This whole concept is best illustrated with a version of the original sprite 1 program:

```
5 PRINT CHR$(147)
10 V = 53248:POKE V+21,4:POKE 2042,13
20 FOR N = 0 TO 62:READ Q:POKE 832+N,Q:NEXT
25 POKE V+5,100
30 FOR X = 0 TO 255
40 POKE V+4,X
50 NEXT
```

```
60 POKE V+16,4
70 FOR X = 0 TO 63
80 POKE V+4,X
90 NEXT
100 POKE V+16,0
110 GOTO 30
200 DATA 0,127,0,1,255,192,3,255,224,3,231,224
210 DATA 7,217,240,7,223,240,7,217,240,3,231,224
220 DATA 3,255,224,3,255,224,2,255,160,1,127,64
230 DATA 1,62,64,0,156,128,0,156,128,0,73,0,0,73,0
240 DATA 0,62,0,0,62,0,0,62,0,0,28,0
```

Line 60 sets the most significant bit for sprite 2. Line 70 starts moving the standard X direction location, moving sprite 2 the rest of the way across the screen.

Line 100 is important because it "turns off" the MSB so that the sprite can start moving from the left edge of the screen again.

To define multiple sprites, you may need additional blocks for the sprite data. You can use some of BASIC's RAM by moving BASIC. Before typing or loading your program type:

```
POKE44,16:POKE16*256,0:NEW
```

Now you can use blocks 32 to 41 (locations 2048 through 4095) to store sprite data.

BINARY ARITHMETIC

It is beyond the scope of this introductory Guide to go into details of how the computer handles numbers. We will, however, provide you with a good base for understanding the process and get you started on sophisticated animation.

But, before you get too involved we have to define a few terms:

BIT — This is the smallest amount of information a computer can store. Think of a BIT as a switch that is either "on" or "off". When a BIT is "on" it has a value of 1; when a BIT is "off" it has a value of 0.

After BIT, the next level is BYTE.

BYTE — This is defined as a series of BITS. Since a BYTE is made up of 8 BITS, you can actually have a total of 256 different combinations of BITS. In other words, you can have all 8 bits "off" so your BYTE will look like this:

128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	0

and its value will be 0. All BITS "on" is:

128	64	32	16	8	4	2	1
1	1	1	1	1	1	1	1

which is 128+64+32+16+8+4+2+1 = 255.

The next step up is called a REGISTER.

REGISTER — Defined as a block of BYTES strung together. But in this case each REGISTER is really only 1 BYTE long. A series of REGISTERS makes up a REGISTER MAP. REGISTER MAPS are charts like the one you looked at to make your balloon sprite. Each REGISTER controls a different function, like turning on the sprite is really called the ENABLE REGISTER. Making the sprite longer is the EXPAND X REGISTER, while making the sprite wider is the EXPAND Y REGISTER. Keep in mind that a REGISTER is a BYTE that performs a specific task.

Now let's move on to the rest of BINARY ARITHMETIC.

Binary to Decimal Conversion

Decimal Value								
128	**64**	**32**	**16**	**8**	**4**	**2**	**1**	
0	0	0	0	0	0	0	1	2↑0
0	0	0	0	0	0	1	0	2↑1
0	0	0	0	0	1	0	0	2↑2
0	0	0	0	1	0	0	0	2↑3
0	0	0	1	0	0	0	0	2↑4
0	0	1	0	0	0	0	0	2↑5
0	1	0	0	0	0	0	0	2↑6
1	0	0	0	0	0	0	0	2↑7

Using combinations of all 8 BITS, you can obtain any decimal value from 0 to 255. Do you start to see why when we POKEd character or color values into memory locations the values had to be in the 0 - 255 range? Each memory location can hold a BYTE of information.

Any possible combination of 8 0's and 1's will convert to a unique decimal value between 0 – 255. If all places contain a 1 then the value of the BYTE equals 255. All zeros equal a byte value of zero; "00000011" equals 3, and so on. This will be the basis for creating data that represents sprites and manipulating them. As just one example, if this BYTE grouping represented part of a sprite (0 is a space, 1 is a colored area):

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	1	1	1	1	1	1

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255

Then we would POKE 255 into the appropriate memory location to represent that part of the object.

TIP:

To save you the trouble of converting binary numbers into decimal values — we'll need to do that a lot — the following program will do the work for you. It's a good idea to enter and save the program for future use.

```
5 REM BINARY TO DECIMAL CONVERTER
10 INPUT "ENTER 8-BIT BINARY NUMBER: ";A$
12 IF LEN(A$) <> 8 THEN PRINT "8 BITS PLEASE..." : GOTO 10
15 TL = 0 : C = 0
20 FOR X = 8 TO 1 STEP-1 : C = C+1
30 TL = TL + VAL(MID$(A$,C,1))*2↑(X-1)
40 NEXT X
50 PRINT A$;"BINARY ";" = ";TL; " DECIMAL"
60 GOTO 10
```

This program takes your binary number, which was entered as a string, and looks at each character in the string, from left to right (the MID$ function). The variable C indicates what character to work on as the program goes through the loop.

The VAL function, in line 30, returns the actual value of the character. Since we are dealing with numeric characters, the value is the same as the character. For example, if the first part of A$ is 1 then the value would also be 1.

The final part of line 30 multiplies the value of the current character by the proper power of 2. Since the first value is in the 27 place, in the example, TL would first equal 1 times 128 or 128. If the BIT is zero then the value for that place would also be zero.

This process is repeated for all 8 characters as TL keeps track of the running total decimal value of the binary number.

CHAPTER 8

CREATING SOUND

- Using Sound If You're Not a Computer Programmer
- Structure of a Sound Program
- Sample Sound Program
- Making Music on Your Commodore 64
- Important Sound Settings
- Playing a Song on the Commodore 64
- Creating Sound Effects
- Sample Sound Effects to Try

USING SOUND IF YOU'RE NOT A COMPUTER PROGRAMMER

Most programmers use computer sound for two purposes: making music and generating sound effects. Before getting into the intricacies of programming sound, let's take a quick look at how a typical sound program is structured...and give you a short sound program you can experiment with.

STRUCTURE OF A SOUND PROGRAM

To begin with there are 5 settings which you should know in order to generate sound on your Commodore 64: **VOLUME**, **ATTACK/DECAY**, **SUSTAIN/RELEASE** (**ADSR**), **WAVEFORM CONTROL** and **HIGH FREQUENCY/LOW FREQUENCY**. The first 3 settings are usually set ONCE at the beginning of your program. The high and low frequency settings must be set for EACH NOTE you play. The waveform control starts and stops each note.

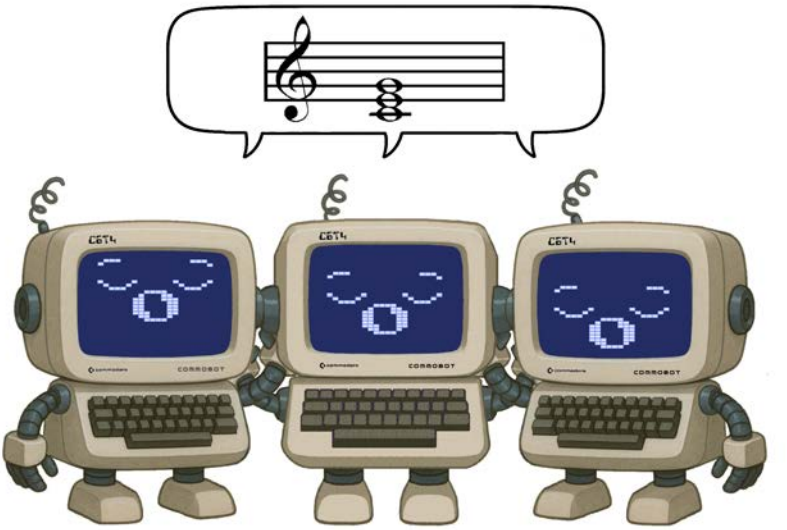
SAMPLE SOUND PROGRAM

Before you start you have to choose a **VOICE**. There are 3 voices. Each voice requires different sound setting numbers for Waveform, etc. You can play 1, 2, or 3 voices together but our sample uses only **VOICE NUMBER 1**. Type in this program line by line...be sure to hit the RETURN key after each line:

`5 FOR L = 54272 TO 54296 : POKE L,0 : NEXT`	First clear sound chip.
`10 POKE 54296,15` `20 POKE 54277,190`	Set **VOLUME** at highest setting. Set **ATTACK/DECAY** rates to define how fast a note rises to and falls from its peak volume level (0 to 255).
`30 POKE 54278,248`	Set **SUSTAIN/RELEASE** to define level to prolong note and rate to release it.

40 POKE 54273,17 : POKE 54272,37	Find the note/tone you want to play in the **TABLE OF MUSICAL NOTES** in Appendix J and enter the **HIGH FREQUENCY** and **LOW FREQUENCY** values for than note (each note requires 2 POKEs).
50 POKE 54276,17	Start **WAVEFORM** with one of the 4 standard settings (17, 33, 65 or 129).
60 FOR T = 1 TO 250 : NEXT	Enter a time loop to set the **DURATION** of the note to be played (a quarter note is approx. "250" but may vary since a longer program can affect the timing).
70 POKE 54276,16	Turn off note.

To hear the note you just created, type the word RUN and then hit the hit RETURN key. To view the program type the word LIST and RETURN. To change it, retype the lines you want to alter.



The Three SID Voices

MAKING MUSIC ON YOUR COMMODORE 64

You don't have to be a musician to make music on your Commodore 64! All you need to know are a few simple numbers which tell your computer how loud to set the volume, which notes to play, how long to play them, etc. But first...here's a program which gives you a quick demonstration of the Commodore 64's incredible music capabilities, using only ONE of your computer's 3 separate voices.

Type the word NEW and hit RETURN to erase your previous program, then enter this program, type the word RUN and hit the RETURN key.

5 REM MUSICAL SCALE	Title of program.
7 FOR L = 54272 TO 54296 : POKE L,0 : NEXT	
10 POKE 54296,15	Sets volume at highest setting (15).
20 POKE 54277,9	Sets Attack/Decay Sustain/Release level (each note).
30 POKE 54276,17	Determines waveform (type of sound).
40 FOR T = 1 TO 300 : NEXT	Duration (how long) each note plays.
50 READ A	Reads first number in line 110 DATA.
60 READ B	Reads second number in line 110 DATA.
70 IF B = -1 THEN END	Ends when it READs -1 in line 900.

80 POKE 54273,A : POKE 54272,B	POKEs the first number from DATA in line 110 (A = 17) as HIGH FREQUENCY and second number (B = 37) as LOW FREQUENCY. Next time program loops around it READs A as 19 and B as 63, and so on, and POKEs these numbers into the HIGH and LOW FREQUENCY locations. The number 54273 = HIGH FREQUENCY for VOICE 1 and 54272 = LOW FREQUENCY for VOICE 1.
85 POKE 54276,17	Start note.
90 FOR T = 1 TO 250 : NEXT : POKE 54276,16	Let it play then stop note.
95 FOR T = 1 TO 50 : NEXT	Time for release.
100 GOTO 20	Loops back to reset CONTROL and play new note.
110 DATA 17, 37, 19, 63, 21, 154, 22, 227 **120 DATA 25, 177, 28, 214, 32, 94, 34, 175**	Musical note values from note value chart in Appendix J. Each pair of numbers represents one note. For example, 17 and 37 represent "C" of the 4th octave, 19 and 63 represent "D" and so on.
900 DATA -1, -1	When program reaches -1 it turns off HIGH/LOW FREQUENCY settings and ENDs as instructed in line 70.

To change the sound to a "harpsichord," change line 85 to read **POKE 54276,33** and line 90 to read **FOR T = 1 TO 250 : NEXT : POKE 54276,32** and RUN the program again. (To change the line hit the RUN/STOP key to stop the program, type the word LIST and hit RETURN, then retype the program line you want to change; the new line will auto-

matically replace the old one). What we did here is change the "waveform" from a "triangular" shaped sound wave to a "sawtooth" wave. Changing the WAVEFORM can drastically change the sound produced by the Commodore 64...but...waveform is only one of several settings you can change to make different musical tones and sound effects! You can also change the ATTACK/DECAY rate of each note...for example, to change from a "harpsichord" sound to a more "banjo" sound try changing lines 20 and 30 to read:

```
20 POKE 54277,3          Sets no sustain for banjo effect
30 POKE 54278,0
```

As you've just seen, you can make your Commodore 64 sound like different musical instruments. Let's take a closer look at how each sound setting works.

IMPORTANT SOUND SETTINGS

1. VOLUME — To turn on the volume and set it to the highest level, type: **POKE 54296,15**. The volume setting ranges from 0 to 15 but you'll use 15 most of the time. To turn "off" the volume, type:

```
POKE 54296,0
```

You only have to set the volume ONCE at the beginning of your program, since the same setting activates all 3 of the Commodore 64's voices. (Changing the volume during a musical note or sound effect can produce interesting results but is beyond the scope of this introduction.)

2. ADSR and WAVEFORM CONTROL SETTING — You've already seen how changing the waveform can change the sound effect from "xylophone" to "harpsichord." Each VOICE has its own WAVEFORM CONTROL SETTING which lets you define 4 different types of waveforms: Triangle, Sawtooth, Pulse (Square) and Noise. The CONTROL also activates the Commodore

64's ADSR feature, but we'll come back to this in a moment. A sample waveform start setting looks like this:

```
POKE 54276,17
```

where the first number (54276) represents the control setting for VOICE 1 and the second number (17) represents the start for a triangular waveform. The settings for each VOICE and WAVEFORM combination are shown in the table below:

ADSR AND WAVEFORM CONTROL SETTINGS

	CONTROL	Note Start/Stop Numbers			
	REGISTER	TRIANGLE	SAWTOOTH	PULSE	NOISE
VOICE 1	54276	17/16	33/32	65/44	129/128
VOICE 2	54283	17/16	33/32	65/44	129/128
VOICE 3	54290	17/16	33/32	65/44	129/128

Although the control registers are different for each voice the waveform settings are the same for each type of waveform. To see how this works, look at lines 85 and 90 in the musical scale program. In this program, immediately after setting the frequency in line 80, we set the CONTROL SETTING for VOICE 1 in line 85 by POKEing 54276,17. This turned on the CONTROL for VOICE 1 and set it to a TRIANGLE WAVEFORM (17). In line 90 we POKE 54276,16, stopping the note. Later, we changed the waveform start setting from 17 to 33 to create a SAWTOOTH WAVEFORM and this gave the scale a "harpsichord" effect. See how the CONTROL SETTING and WAVEFORM interact? Setting the waveform is similar to setting the volume, except each voice has its own setting and instead of POKEing volume levels we're defining waveforms. Next, we'll look at another aspect of sound...the ADSR feature.

3. ATTACK/DECAY SETTING — As we mentioned before, the ADSR CONTROL SETTING not only defines the waveform but it also activates the **ADSR**, or **ATTACK/DECAY/SUSTAIN/RELEASE** feature of the Commodore 64. We'll begin by looking at the ATTACK/DECAY setting. The following chart shows the various ATTACK and DECAY levels for each voice. If you're not familiar with the concepts of sound attack and decay, you might think of "attack" as the rate at which a note/sound arises to its maximum volume. The DECAY is the rate at which the note/sound falls from its highest volume level back to the SUSTAIN level. The following chart shows the ATTACK/DECAY setting for each voice, and the numbers for each attack and decay setting.

Note that YOU MUST COMBINE ATTACK AND DECAY SETTINGS BY ADDING THEM UP AND ENTERING THE TOTAL. For example, you can set a HIGH ATTACK rate and a low DECAY rate by adding the high attack number (64) to the low decay number (1). The total (65) will tell the computer to set the high attack rate and low decay rate. You can also increase the attack rates by adding them together (128 + 64 + 32 + 16 = MAX. ATTACK RATE of 240.)

ATTACK/DECAY RATE SETTINGS

	ATTACK/DECAY SETTING	HIGH ATTACK	MED ATTACK	LOW ATTACK	LOWEST ATTACK	HIGH DECAY	MED DECAY	LOW DECAY	LOWEST DECAY
VOICE 1	54277	128	64	32	16	8	4	2	1
VOICE 2	54284	128	64	32	16	8	4	2	1
VOICE 3	54291	128	64	32	16	8	4	2	1

If you set an attack rate with no decay, the decay is automatically zero, and vice-versa. For example if you POKE 54277,64 you set a medium attack rate with zero decay for VOICE 1. If you POKE 54277,66 you set a medium attack rate and a low decay rate (because 66 = 64 + 2 and sets BOTH settings). You can also add up several attack values, or several decay values. For example, you can add a low attack (32) and a medium attack (64) for combined attack rate of 96, then add a medium decay of 4 and...presto...POKE 54277,100.

At this point a sample program will better illustrate the effect. Type the word NEW, hit RETURN and type this program in and RUN it:

`5 FORL=54272TO54296:POKEL,0:NEXT`	Duration the note plays
`10 PRINT"HIT ANY KEY"`	Screen message
`20 POKE54296,15`	Set volume at highest level
`30 POKE54277,64`	Set Attack/Decay
`40 POKE54273,17:POKE54272,37`	POKE one note into VOICE 1
`50 GETK$:IFK$=""THEN50`	Check the keyboard.
`60 POKE54276,17:FORT=1TO200:NEXT`	Set Waveform control (triangle).

70 POKE54276,16:FORT=1TO50:NEXT	Turn off settings.
80 GOTO 20	Loop back and do it again.

Here, we're using VOICE 1 to create one note at a time...with a MEDIUM ATTACK RATE and ZERO DECAY. The Key like is line 40. POKEing the ATTACK/DECAY setting with the number 64 activates a MEDIUM attack rate. The result sounds like someone bouncing a ball in an oil drum. Now for the fun part. Hit the RUN/STOP key to stop the program, then type the word LIST and hit RETURN. Now type this line and hit RETURN (the new line 30 automatically replaces the old line 30):

```
30 POKE 54277,190
```

Type the word RUN and hit RETURN to see how it sounds. What we've done here is combine several attack and decay settings. The settings are: **HIGH ATTACK (128) + LOW ATTACK (32) + LOWEST ATTACK (16) + HIGH DECAY (8) + MEDIUM DECAY (4) + LOW DECAY (2)** = 190.

This effect sounds like the noise an "Oboe" or other "reed" instrument might make. If you'd like to experiment, try changing the waveform and attack/decay numbers in the musical scale example to see how an "oboe" sounds. Thus...you can see that changing the attack/decay rates can be used to create different types of sound effects.

4. SUSTAIN RELEASE SETTING — Like Attack/Decay, the SUSTAIN/RELEASE setting is activated by the ADSR/WAVEFORM Control. SUSTAIN/RELEASE lets you "extend" (SUSTAIN) a portion of a particular sound, like the "sustain pedal" on a piano or organ which lets you prolong a note. Any note or sound can be sustained at any one of 16 levels. The SUSTAIN/RELEASE setting may be used with a FOR...NEXT loop to determine how long the note will be held at SUSTAIN volume before being released. The following chart shows the numbers you have to POKE to reach different SUSTAIN/RELEASE rates:

SUSTAIN/RELEASE RATE SETTINGS

SUSTAIN/RELEASE CONTROL	SETTING	HIGH SUS	MED SUS	LOW SUS	LOWEST SUS	HIGH REL	MED REL	LOW REL	LOWEST REL
VOICE 1	54278	128	64	32	16	8	4	2	1
VOICE 2	54285	128	64	32	16	8	4	2	1
VOICE 3	54292	128	64	32	16	8	4	2	1

As an example, if you're using VOICE 1, you can set a HIGH SUSTAIN LEVEL by typing: POKE 54278,128 or you could combine a HIGH SUSTAIN LEVEL with a LOW RELEASE RATE by adding 128 + 2 and then POKE 54278,130. Here's the same sample program we used in the ATTACK/DECAY section above...with a SUSTAIN/RELEASE feature added. Notice the difference in sounds:

`5 FORL=54272TO54296:POKEL,0:NEXT`	Duration the note plays.
`10 POKE54296,15`	Set volume at highest level.
`20 POKE54277,64`	Set Attack/Decay.
`30 POKE54278,128`	Set SUSTAIN/RELEASE.
`40 POKE54273,17:POKE 54272,37`	POKE one note into VOICE 1
`50 PRINT"HIT ANY KEY"`	Screen message.
`60 GETK$:IFK$=""THEN60`	Check the keyboard.
`70 POKE54276,17:FORT=1TO200:NEXT`	Set Waveform control (triangle).
`80 POKE54276,16:FORT=1TO50:NEXT`	Turn off settings.
`90 GOTO60`	Loop back and do it again.

In line 30, we tell the computer to SUSTAIN the note at a HIGH SUSTAIN LEVEL (128 from the chart above)...after which the tone is released in line 80. You can vary the duration of a note by changing the "count" in line 70. To see the effect of using the release function try changing line 30 to POKE 54278,89 (SUSTAIN = 80, RELEASE = 9).

5. CHOOSING VOICES AND SETTING HIGH/LOW FREQUENCY SOUND VALUES — Each individual note on the Commodore 64 requires TWO SEPARATE POKE COMMANDS...one for HIGH FREQUENCY and one for LOW FREQUENCY. The MUSICAL NOTE VALUE table in Appendix J shows the corresponding POKEs you need to play any note in the Commodore 64's

8 octave range. The HIGH and LOW FREQUENCY POKE commands are different for each voice you use — this allows you to program all 3 voices independently to create 3-voice music or exotic sound effects.

The HIGH and LOW FREQUENCY POKE commands for each voice are shown in the chart below, which also contains the NOTE VALUES for the middle (fifth) octave.

VOICE NUMBER POKE		SAMPLE MUSICAL NOTES — FIFTH OCTAVE													
& FREQUENCY	**NUMBER**	**C**	**C#**	**D**	**D#**	**E**	**F**	**F#**	**G**	**G#**	**A**	**A#**	**B**	**C**	**C#**
VOICE 1 HIGH	55273	34	36	38	40	43	45	48	51	54	57	61	64	68	72
VOICE 1 LOW	55273	75	85	126	200	52	198	127	97	111	172	126	188	149	169
VOICE 2 HIGH	54280	34	36	38	40	43	45	48	51	54	57	61	64	68	72
VOICE 2 LOW	54279	75	85	126	200	52	198	127	97	111	172	126	188	149	169
VOICE 3 HIGH	54287	34	36	38	40	43	45	48	51	54	57	61	64	68	72
VOICE 3 LOW	54286	75	85	126	200	52	198	127	97	111	172	126	188	149	169

As you can see, there are 2 settings for each voice, a HIGH FREQUENCY setting and a LOW FREQUENCY setting. To play a musical note, you must POKE a value into the HIGH FREQUENCY location and POKE another value into the LOW FREQUENCY location. Using the settings in our VOICE/FREQUENCY/NOTE VALUE table, here's the setting that plays a C note from the fifth octave (VOICE 1):

```
POKE54273,34:POKE54272,75
```

The same note on VOICE 2 would be:

```
POKE54280,34:POKE54279,75
```

Used in a program, it looks like this:

`5 FORL=54272TO54296:POKEL,0:NEXT`	Duration the note plays.
`10 V=54296:W=54276:A=54277:` `S=54278:H=54273:L=54272`	Set numbers equal to letters.
`20 POKEV,15:POKEA,190:POKES,8`	Poke volume, waveform, attack/decay.
`30 POKEH,34:POKEL,7`	POKE hi/lo freq. notes
`40 POKEW,33:FORT=1TO200:NEXT`	Start note, let it play.
`50 POKEW,32`	Stop note.

PLAYING A SONG ON THE COMMODORE 64

The following program can be used to compose or play a song (using VOICE 1). There are two important lessons in this program: first, note how we abbreviate all the long control numbers in the first line of the program...after that, we can use the letter W for "Waveform" instead of the number 54276.

The second lesson concerns the way we use the DATA. This program is set up to let you enter 3 numbers for each note: the HIGH FREQUENCY NOTE VALUE, the LOW FREQUENCY NOTE VALUE, and the DURATION THE NOTE WILL BE PLAYED.

For this song, we used a duration "count" of 125 for an eighth note, 250 for a quarter note, 375 for a dotted quarter note, 500 for a half note and 1000 for a whole note. These number values can be increased or decreased to match a particular tempo, or your own musical taste.

To see how a song gets entered, look at line 110. We entered 34 and 75 as our HIGH and LOW FREQUENCY settings to play a "C" note (from the sample scale shown previously) and then the number 250 for a quarter note. So the first note in our song is a quarter note C. The second note is also a quarter note, this time the note is "E"...and so on to the end of our tune. You can enter almost any song this way, adding as many DATA statement lines as you need. You can continue the note and duration numbers from one line to the next but each line must begin with the word DATA. DATA -1,-1,-1 should be the last line in your program. This line "ends" the song.

Type the word NEW to erase your previous program and type in the following program, then type RUN to hear the song.

Michael Row the Boat Ashore — 1 Measure

```
10 FORL=54272TO54296:POKEL,0:NEXT
20 V=54296:W=54276:A=54277:HF=54273:LF=54272:S= 54278:
PH=54275:PL=54274
30 POKEV,15:POKEA,88:POKEPH,15:POKEPL,15:POKES,89
40 READH:IFH=-1THENEND
50 READL
60 READD
70 POKEHF,H:POKELF,L:POKEW,65
```

```
80 FORT=1TOD:NEXT:POKEW,64
85 FORT=1TO50:NEXT
90 GOTO10
100 DATA34,75,250,43,52,250,51,97,275,43,52,125,51,97
105 DATA250,57,172,250
110 DATA51,97,500,0,0,125,43,52,250,51,97,250,57,172
115 DATA1000,51,97,500
120 DATA-1,-1,-1
```

CREATING SOUND EFFECTS

Unlike music, sound effects are more often tied to a specific programming "action" such as the explosion made by an astro-fighter as it crashes through a barrier in a space game...or the warning buzzer in a business program that tells the user he's about to erase his disk by mistake.

You have a wide range of options available if you want to create different sound effects. Here are 11 programming ideas which might help you get started experimenting with sound effects.

1. Change the volume while a note is playing, for example to create an "echo" effect.
2. Vary between two notes rapidly to create a sound "tremor".
3. Waveform...try different settings for each voice.
4. ATTACK/DECAY...alter the rate a sound rises towards its "peak" volume and the rate it diminishes from that peak.
5. SUSTAIN/RELEASE...change sustain to volume of a sound effect, and the rate it diminishes from that volume.

6. Multivoice effects...playing more than one voice at the same time, each voice independently controlled, or one voice playing longer or shorter than the another, or serving as an "echo" or response to a first note.

7. Changing notes on the scale, or changing octaves, using the values in the MUSICAL NOTES VALUE table.

8. Use the Square Waveform and different Pulse settings to create different effects.

9. Use the Noise Waveform to generate "white noise" for accenting tonal sound effects or creating explosions, gunshots or footsteps. The same musical notes that create music can also be used with the Noise Waveform to create different types of white noise.

10. Combine several HIGH/LOW-FREQUENCIES in rapid succession across different octaves.

11. Filter...try the extra POKE settings in Appendix J.

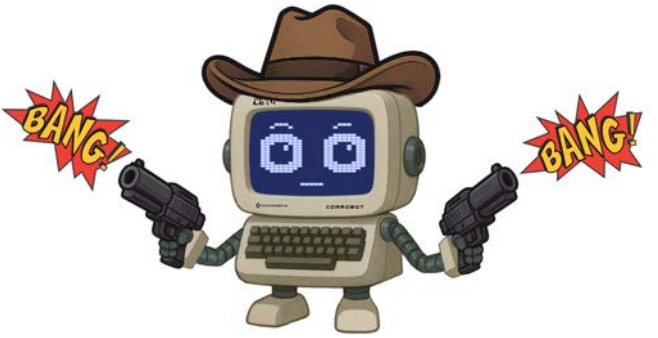
SAMPLE SOUND EFFECTS TO TRY

The following programs may be added to almost any BASIC program. They are included to give you some programming ideas and demonstrate the Commodore 64's sound effect range.

Notice the programming shortcut we're using in line 10. We can abbreviate those long, cumbersome sound setting numbers by defining them as easy-to-use letters (numeric variables). Line 10 simply means that these easy-to-remember LETTERS can be used instead of those long numbers. Here, V = Volume, W = Waveform, A = Attack/Decay, H = High Frequency (VOICE 1), L = Low Frequency (VOICE 1), HP = High- Pulse (VOICE 1), LP = Low-Pulse (VOICE 1). We then use these letters instead of numbers in our program...making our program shorter, typing faster, and the sound settings easier to remember and spot.

Doll Crying

```
10 V=54296:W=54276:A=54277:H=54273:L=54272:
HP=54275:LP=54274
20 FORI=54272TO54296:POKEI,0:NEXT
30 POKEHP,15:POKELP,40
40 POKEV,15:POKEW,65:POKEA,15
50 FORX=200TO5STEP-2:POKEH,40:POKEL,X:NEXT
60 FORX=150TO5STEP-2:POKEH,40:POKEL,X:NEXT
70 POKEW,0
```



Shooting Sound

```
10 V=54296:W=54276:A=54277:H=54273:L=54272
20 FORI=54272TO54296:POKEI,0:NEXT
30 FORX=15TO0STEP-1:POKEV,X:POKEW,129:POKEA,15
40 POKEH,40:POKEL,200:NEXT
50 POKEW,128:POKEA,0
```

CHAPTER 9

ADVANCED DATA HANDLING

- READ and DATA
- Averages
- Subscripted Variables
- Dimension
- Simulated Dice Roll with Arrays
- Two-Dimensional Arrays

READ AND DATA

You've seen how to assign values to variables directly within the program (A = 2), and how to assign different values while the program is running — through the INPUT statement.

There are many times, though, when neither one of these ways will quite fit the job you're trying to do, especially if it involves a lot of information.

Try this short program:

```
10 READ X
20 PRINT "X IS NOW:";X
30 GOTO 10
40 DATA 1, 34, 10.5, 16, 234.56

RUN

X IS NOW: 1
X IS NOW: 34
X IS NOW: 10.5
X IS NOW: 16
X IS NOW: 234.56

?OUT OF DATA ERROR IN 10
READY.
```

In line 10, the computer READs one value from the DATA statement and assigns that value to X. Each time through the loop the next value in the DATA statement is read and that value assigned to X, and PRINTed. A pointer in the computer itself keeps track of which value is to be used next:

Pointer
↓
40 DATA 1, 34, 10.5, 16, 234.56

When all the values have been used, and the computer executed the loop again, looking for another value, the OUT OF DATA error was displayed because there were no more values to READ.

It is important to follow the format of the DATA statement precisely:

40 DATA 1, 34, 10.5, 16, 234.56

↑ Comma separates each item

↑ No comma

Data statements can contain integer numbers, real numbers (234.65) or numbers expressed in scientific notation. But you can't READ other variables, or have arithmetic operations in DATA lines. This would be incorrect:

```
40 DATA A, 23/56, 2*5
```

You can, however, use a string variable in a READ statement and then place string information in the DATA line. The following is acceptable:

```
NEW

10 FOR X = 1 TO 3
15 READ A$
20 PRINT "A$ IS NOW:";A$ 30 NEXT
40 DATA THIS, IS, FUN

RUN

A$ IS NOW: THIS
A$ IS NOW: IS
A$ IS NOW: FUN

READY.
```

Notice that this time, the READ statement was placed inside a FOR...NEXT loop. This loop was then executed to match the number of values in the data statement.

In many cases you will change the number of values in the DATA statement each time the program is run. A way to avoid counting the number of values and still avoid an OUT OF DATA ERROR is to place a "FLAG" as the last value in the DATA line. This would be a value that your data would never equal, such as a negative number or a very large or small number. When that value is READ the program will branch to the next part.

There is a way to reuse the same DATA later in the program by RESTOREing the data pointer to the beginning of the data list. Add line 50 to the previous program:

```
50 GOTO 10
```

You will still get the OUT OF DATA error because as the program branches back to line 10 to reread the data, the data pointer indicates all the data has been used. Now, add:

and RUN the program again. The data pointer has been RESTOREd and the data can be READ continuously.

AVERAGES

The following program illustrates a practical use of READ and DATA, by reading in a set of numbers and calculating their average.

```
NEW

5 T = 0 : CT = 0
10 READ X
20 IF X = -1 THEN 50 : REM CHECK FOR FLAG
25 CT = CT + 1
30 T = T + X : REM UPDATE TOTAL
40 GOTO 10
50 PRINT "THERE WERE"; CT;"VALUES READ"
60 PRINT "TOTAL =";T
70 PRINT "AVERAGE =";T/CT
80 DATA 75, 80, 62, 91, 87, 93, 78, -1

RUN
THERE WERE 7 VALUES READ
TOTAL = 566
AVERAGE = 80.8571429
READY.
```

Line 5 sets CT, the CounTer, and T, Total, equal to zero. Line 10 READs a value and assigns the value to X. Line 20 checks to see if the value is our flag (here a -1). If the value READ is part of the valid DATA, CT is incremented by 1 and X is added to the total.

When the flag is READ, the program branches to line 50 which PRINTs the number of values read. Line 60 PRINTs the total, and line 70 divides the total by the number of values to get the average.

By using a flag at the end of the DATA, you can place any number of values in DATA statements — which may stretch over several lines — without worrying about counting the number of values entered.

Another variation of the READ statement involves assigning information from the some DATA line to different variables. This information can even be a mixture of string data and numeric values. You can do all this in the

following program that will READ a name, some scores — say bowling — and print the name, scores, and the average score:

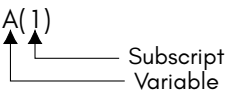
```
NEW

10 READ N$,A,B,C
20 PRINT N$;"'S SCORES WERE:";A;B;C
30 PRINT "AND THE AVERAGE IS:";(A+B+C)/3
40 PRINT:GOTO 10
50 DATA MIKE,190,185,165,DICK,225,245,190
60 DATA JOHN,155,185,205,LUKE,160,179,187

RUN

MIKE'S SCORES WERE: 190 185 165
AND THE AVERAGE IS: 180

DICK'S SCORES WERE: 225 245 190
AND THE AVERAGE IS: 220

JOHN'S SCORES WERE: 155 185 205
AND THE AVERAGE IS: 181.666667

LUKE'S SCORES WERE: 160 179 187
AND THE AVERAGE IS: 175.333333
```

In running the program, the DATA statements were set up in the some order that the READ statement expected the information: a name (a string), then three values. In other words N$ the first time through gets the DATA "MIKE", A in the READ corresponds to 190 in the data statement, "B" to 185 and "C" to 165. The process is then repeated in that order for the remainder of the information. (Dick and his scores, John and his scores, and Luke and his scores.)

SUBSCRIPTED VARIABLES

In the past we've used only simple BASIC variables, such as A, A$, and NU to represent values. These were a single letter followed by a letter or single digit. In any of the programs that you would write, it is doubtful that we would have a need for more variable names than possible with all the combinations of letters or numbers available. But you are limited in the way variables are used with programs.

Now let's introduce the concept of subscripted variables.



This would be said: A sub 1. A subscripted variable consists of a letter followed by a subscript enclosed within parentheses. Please note the difference between A, Al, and A(1). Each is unique. Only A(1) is a subscripted variable.

Subscripted variables, like simple variables, name a memory location within the computer. Think of subscripted variables as boxes to store information, just like simple variables:

A(0)	
A(1)	
A(2)	
A(3)	
A(4)	

If you wrote:

```
10 A(0) = 25: A(3) = 55 : A(4) = -45.3
```

Then memory would look like this:

A(0)	25
A(1)	
A(2)	
A(3)	55
A(4)	-45.3

This group of subscripted variables is also called an array. In this case, a one-dimensional array. Later on, we'll introduce multidimensional arrays.

Subscripts can also be more complex to include other variables, or computations. The following are valid subscripted variables:

A(X) A(X+ 1) A(2+1) A(1 * 3)

The expressions within the parentheses are evaluated according to the same rules for arithmetic operations outlined in chapter 3.

Now that the ground rules are in place, how can subscripted variables be put to use? One way is to store a list of numbers entered with INPUT or READ statements.

Let's use subscripted variables to do the averages a different way.

```
5 PRINT CHR$(147)
10 INPUT "HOW MANY NUMBERS:";X
20 FOR A = 1 TO X
30 PRINT "ENTER VALUE #";A;:INPUT B(A)
40 NEXT
50 SU = 0
60 FOR A = 1 TO X
70 SU = SU + B(A)
80 NEXT
90 PRINT:PRINT "AVERAGE =";SU/X

RUN

HOW MANY NUMBERS:? 5
ENTER VALUE # 1 ? 125
ENTER VALUE # 2 ? 167
ENTER VALUE # 3 ? 189
ENTER VALUE # 4 ? 167
ENTER VALUE # 5 ? 158

AVERAGE = 161.2
```

There might have been an easier way to accomplish what we did in this program, but it illustrates how subscripted variables work. Line 10 asks for how many numbers will be entered. This variable, X, acts as the counter for the loop within which values are entered and assigned to the subscripted variable, B.

Each time through the INPUT loop, A is increased by 1 and so the next value entered is assigned to the next element in the array A. For example, the first time through the loop A = 1, so the first value entered is assigned to B(1). The next time through, A = 2; the next value is assigned to B(2), and so on until all the values have been entered.

But now a big difference comes into play. Once all the values have been entered, they are stored in the array, ready to be put to work in a variety of ways. Before, you kept a running total each time through the INPUT or READ loop, but never could get back the individual pieces of data without re-reading the information.

In lines 50 through 80, another loop has been designed to add up the various elements of the array and then display the average. This separate part of the program shows that all of the values are stored and can be accessed as needed.

To prove that all of the individual values are actually stored separately in an array, type the following immediately after running the previous program:

```
FOR A = 1 TO 5 : ?B(A),:NEXT
125          167          189          167
158
```

and hit RETURN. The display will show your actual values as the contents of the array are PRINTed.

DIMENSION

If you tried to enter more than 10 numbers in the previous example, you got a DIMENSION ERROR. Arrays of up to eleven elements (subscripts 0 to 10 for a one-dimensional array) may be used where needed, just as simple variables can be used anywhere within a program. Arrays of more than eleven elements need to be "declared" in a dimension statement.

Add this line to the program:

```
5 DIM B(100)
```

This lets the computer know that you will have a maximum of 100 elements in the array.

This dimension statement may also be used with a variable, so the following line could replace line 5 (don't forget to eliminate line 5):

```
15 DIM B(X)
```

This would dimension the array with the exact number of values that will be entered.

Be careful, though. Once dimensioned, an array cannot be re-dimensioned in another part of the program. You can, however, have multiple arrays within the program and dimension them all on the same line, like this:

```
10 DIM C(20), D(50), E(40)
```

SIMULATED DICE ROLL WITH ARRAYS

As programs become more complex, using subscripted variables will cut down on the number of statements needed, and make the program simpler to write.

A single subscripted variable can be used, for example, to keep track of the number of times a particular face turns up:

```
1 REM DICE SIMULATION : PRINT CHR$(147)
10 INPUT "HOW MANY ROLLS:";X
20 FOR L = 1 TO X
30 R = INT(6*RND(1))+1
40 F(R) = F(R) + 1
50 NEXT L
60 PRINT "FACE", "NUMBER OF TIMES"
70 FOR C = 1 TO 6 : PRINT C, F(C) : NEXT
```

The array F, for FACE, will be used to keep track of how many times a particular face turns up. For example, every time a 2 is thrown, F(2) is increased by 1. By using the same element of the array to hold the actual number on the face that is thrown, we've eliminated the need for 5 other variables (one for each face) and numerous statements to check and see what number is thrown.

Line 10 asks for how many rolls you want to simulate.

Line 20 establishes the loop to perform the random roll and increment the proper element of the array by 1 each, for each toss.

After all of the required tosses are complete, line 60 PRINTs the heading and line 70 PRINTs the number of times each face shows up.

A sample run might look like this:

```
HOW MANY ROLLS:? 1000
FACE       NUMBER OF TIMES
 1         148
 2         176
 3         178
 4         166
 5         163
 6         169
```

Well, at least it wasn't loaded!

Just as a comparison, the following is one way of re-writing the same program, but without using subscripted variables. Don't bother to type it in, but do notice the additional statements necessary.

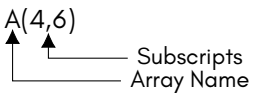
```
10 INPUT "HOW MANY ROLLS:";X
20 FOR L = 1 TO X
30 R = INT(6*RND(1))+1
40 IF R = 1 THEN F1 = F1 + 1 : NEXT
41 IF R = 2 THEN F2 = F2 + 1 : NEXT
42 IF R = 3 THEN F3 = F3 + 1 : NEXT
43 IF R = 4 THEN F4 = F4 + 1 : NEXT
44 IF R = 5 THEN F5 = F5 + 1 : NEXT
45 IF R = 6 THEN F6 = F6 + 1 : NEXT
60 PRINT "FACE", "NUMBER OF TIMES"
70 PRINT 1, F1
71 PRINT 2, F2
72 PRINT 3, F3
73 PRINT 4, F4
74 PRINT 5, F5
75 PRINT 6, F6
```

The program has doubled in size from 8 to 16 lines. In larger programs the space savings from using subscripted variables will be even more dramatic.

TWO-DIMENSIONAL ARRAYS

Earlier in this chapter you experimented with one-dimensional arrays. This type of array was visualized as a group of consecutive boxes within memory each holding an element of the array. What would you expect a two-dimensional array to look like?

First, a two-dimensional array would be written like this:



and could be represented as a two-dimensional grid within memory:

	0	1	2	3	4	5	6
0							
1							
2							
3							
4							

The subscripts could be thought of as representing the row and column within the table where the particular element of the array is stored.

A(3,4) = 255

Column
Row

	0	1	2	3	4	5	6
0							
1							
2							
3					255		
4							

If we assigned the value 255 to A(3,4), then 255 could be thought of as being placed in the 4th column of the 3rd row within the table.

Two-dimensional arrays behave according to the same rules that were established for one-dimensional arrays:

They must be dimensioned:	DIM A(20,20)
Assignment of data:	A(1,1) = 255
Assign values to other variables:	AB = A(1,1)
PRINT values:	PRINT A(1,1)

If two-dimensional arrays work like their smaller counterparts, what additional capabilities will the expanded arrays handle?

Try this: can you think of a way, using a two-dimensional array, to tabulate the results of a questionnaire for your cub that involves 4 questions and had up to 3 responses for each question? The problem could be represented like this:

CLUB QUESTIONNAIRE

Q1: ARE YOU IN FAVOUR OF RESOLUTION #1?

□ 1 — YES □ 2 — NO □ 3 — UNDECIDED

...and so on.

The array table for this problem could be represented like this:

	RESPONSES		
	YES	NO	UNDECIDED
QUESTION 1			
QUESTION 2			
QUESTION 3			
QUESTION 4			

The program to do the actual tabulation for the questionnaire might look like that shown on page 138.

This program makes use of many of the programming techniques that have been presented so far. Even if you don't have any need for the actual program right now, see if you can follow how the program works.

The heart of this program is a 4 by 3 two-dimensional array, A(4,3). The total responses for each possible answer to each question are held in the appropriate element of the array. For the sake of simplicity, we don't use the first rows and columns (A(0,0) to A(0,4)). Remember, though, that those elements are always present in any array you design.

In practice, if question 1 is answered YES, then A(1,1) is incremented by one: Row1 for question 1 and Column1 for a YES response. The rest of the questions and answers follow the same pattern. A NO response for question 3 would add one to element A(3,2), and so on.

```
20 PRINT CHR$(147)
30 FOR R = 1 TO 4
40 PRINT "QUESTION # :";R
50 PRINT " 1-YES 2-NO 3-UNDECIDED"
60 PRINT "WHAT WAS THE RESPONSE :";
61 GET C : IF C <1 OR C>3 THEN 61
65 PRINT C : PRINT
70 A(R,C) = A(R,C) + 1 : REM UPDATE ELEMENT
80 NEXT R
85 PRINT
90 PRINT "DO YOU WANT TO ENTER ANOTHER" :
PRINT "RESPONSE (Y/N)";
100 GET A$ : IF A$ = "" THEN 100
110 IF A$ = "Y" THEN 20
120 IF A$ <> "N" THEN 100
130 PRINT CHR$(147)";"THE TOTAL RESPONSES
WERE:":PRINT
140 PRINT SPC(18);"RESPONSE":PRINT
141 PRINT "QUESTION","YES","NO","UNDECIDED"
142 PRINT "--------","---","--","---------"
150 FOR R = 1 TO 4
160 PRINT R, A(R,1), A(R,2), A(R,3)
170 NEXT R

RUN

QUESTION # : 1
1-YES 2-NO 3-UNDECIDED
WHAT WAS THE RESPONSE : 1

QUESTION # : 2
1-YES 2-NO 3-UNDECIDED
WHAT WAS THE RESPONSE : 1

QUESTION # : 3
1-YES 2-NO 3-UNDECIDED
WHAT WAS THE RESPONSE : 1

QUESTION # : 4
1-YES 2-NO 3-UNDECIDED
WHAT WAS THE RESPONSE : 3

DO YOU WANT TO ENTER ANOTHER
RESPONSE (Y/N)

THE TOTAL RESPONSES WERE:

RESPONSE

QUESTION   YES       NO        UNDECIDED
--------   ---       --        ---------
1          1         0         0
2          1         0         0
3          1         0         0
4          0         0         1
```

CHAPTER 10

USING COMMODORE 64 PERIPHERALS

- Using Commodore 64 Peripherals
- Joysticks, gamepads, and mice
- Cartridges
- Disk drives
- Printers
- Datassette
- User port devices

USING COMMODORE 64 PERIPHERALS

The original Commodore 64 is a powerful all-in-one computer all on its own, but it really becomes a part of your life when you connect additional devices to it. Known generally as *peripherals*, these devices include joysticks, gamepads, mice, floppy disk drives, hard drives, Datassette drives, printers, and modems. Less common Commodore 64 peripherals even support home automation, science lab experiments, and control of robotics. Most of the peripherals from back in the day are no longer manufactured, but can still be acquired on the secondary market. Some types of Commodore 64 peripherals, especially game controllers and data storage devices, are still being made today.

The Commodore 64 Ultimate supports many of the same peripherals as the original Commodore 64. It includes many of the same connection ports: two 9-pin game ports, an IEC serial port for storage and printer interfaces, an expansion port for cartridges, and a Datassette port. With an adapter cable available at **`commodore.net`**, you can even add a *user port* for modems, additional printer options, and an RS-232 adapter.

The C64U comes pre-configured to emulate common peripherals (disk drives, printers, and modems) with internal logic, so you do not need to own such peripherals to enjoy your computer to its fullest. Some Commodore 64 peripherals require a change in the C64U configuration to disable the emulation in favor of an external device connected to a port.

JOYSTICKS, GAMEPADS, AND MICE

The C64U has two 9-pin game ports located on the right-hand side of the computer. The front-most port is "port 1," and the rear-most port is "port 2." Most Commodore 64 games expect a Commodore-style joystick or gamepad connected to one of these ports. The Commodore 1351 mouse, and compatible alternatives, also connect to the game port.

For various reasons technical and cultural, different games may prefer a joystick in one port or the other. To spare you from having to disconnect and reconnect your joystick to switch ports, the C64U can swap the joystick port assignments in a configuration menu. Pause the game by pressing upward on the Multi Function Switch, then navigate to "Joystick & Controllers," then "Joystick Input," then select "Swapped."

Several modern manufacturers make new joysticks, gamepads, mice, and mouse adapters that work with the C64U. Visit the Commodore website for information on how to purchase: **`commodore.net`**

CARTRIDGES

Cartridges are devices that connect to the expansion port in the back-right of the computer. Most cartridges contain program data, such as a game program, that runs the program when the computer is switched on with the cartridge connected. Some cartridges contain sophisticated electronics that add features to the computer.

NOTE: Always switch the C64U completely off before connecting or disconnecting a cartridge. This ensures that both the computer and the cartridge receive electrical power and signal only when the cartridge is seated properly, and that the computer executes the cartridge's program code in the way that the program expects.

The C64U will use a physical cartridge if one is connected. If no physical cartridge is present, it will use the cartridge ROM file if one is connected to the virtual cartridge port, or no cartridge otherwise.

DISK DRIVES

The IEC serial port on the back of the computer accommodates devices such as floppy disk drives and printer interfaces. Some IEC devices offer a passthru IEC port of their own, so you can connect multiple devices in a chain. Up to five IEC devices can be connected at a time to the C64U.

The computer refers to each device using a *unit number* known to the device. Each device must be configured to know its unit number, so it responds correctly when called by the computer. For example, with disk drives connected set to units 8, 9, and 10, the computer contacts drive unit 8 by announcing to all devices that it wishes to talk to unit 8, and only the drive set to unit 8 is expected to respond. If more than one connected device is configured to use the same unit number, the devices get confused and will not communicate properly.

The C64U provides two virtual drives, known as drive A and drive B. These drives behave as if connected to the IEC port with other drives, and simulate disk access for disk images. By default, drive A assumes it is unit 8, and drive B assumes it is unit 9.

If you wish an external drive to use unit numbers 8 or 9, you can change the unit number assigned to the virtual drives: from the C64U Menu, select "Disk Drive A Options" or "Disk Drive B Options," then adjust "Drive Bus ID." You can also disable and enable each virtual drive from this menu.

For more on using the C64U virtual drives with disk images, refer to chapter 2.

Commodore 64 disk drives are expected to use unit numbers in the range 8 – 31. Lower unit numbers are reserved for other purposes.

PRINTERS

Similar to disk drives, some printer interfaces connect to the Commodore 64 using the IEC port, and respond to messages addressed to a unit number. A Commodore 64 printer typically uses unit number 4 or 5.

The C64U provides a virtual printer that waits for a program to print a document, then saves the printed document in a modern file format in the filesystem. If an external IEC printer is connected, the document may be printed by both devices. You can disable the virtual printer in configuration: from the C64U Menu, select "Printers," then set "IEC printer" to "Disabled." This will cause printing to only engage the external IEC printer.

For more on using the C64U virtual printer, refer to chapter 13.

DATASSETTE

The C64U provides a Datassette port for connecting an original Commodore Datassette storage device. To use a Datassette, simply connect it to the C64U's Datassette port.

The C64U also emulates a Datassette drive when using tape images. This does not conflict with the use of an external Datassette drive: simply use the drive as normal. For more on using tape images, refer to chapter 2.

USER PORT DEVICES

The original Commodore 64 has another port for connecting devices, known as the *user port*. This port is often used with telecommunication devices such as modems, or for connecting to other computers or devices. The C64U locates its USB, Ethernet, and HDMI connectors where the user port would be on an original Commodore 64.

The C64U *does* have a way to connect to user port devices using an adapter, sold separately. The adapter connects to the mainboard inside the C64U case, and has a ribbon cable that extends to the outside of the case for use with devices. For information on how to obtain this adapter, see the Commodore website: **`commodore.net`**

The C64U provides built-in emulation of a modem device for the purposes of connecting to other computers over the Internet, where both computers are pretending to be connected using modems over a telephone line. For more information on the C64U's virtual modem, refer to chapter 12.

CHAPTER 11

C64U NETWORKING AND WI-FI

- Getting Online
- Searching the CommoServe File Index
- FTP File Service
- Telnet Remote Menu
- Other Network Features

GETTING ONLINE

The Commodore 64 Ultimate can connect to your local network via an Ethernet cable or a Wi-Fi connection. This enables powerful features, including the ability to download and run Commodore 64 software from the Internet.

Ethernet

You can connect the C64U to your local network router with an Ethernet cable.

Most local network routers support the DHCP standard for assigning IP addresses to connected devices. To connect the C64U to your local network with DHCP, simply connect an Ethernet cable from the port on the back-left of the computer to your router.

To confirm that this worked:

1. Open the C64U Menu: press the Multi Function Switch upward. The menu appears.
2. Use the W and S keys to move the selection to "Wired Network Setup." Press the RETURN key.
3. Confirm that "Use DHCP" is "Enabled."
4. Confirm that "Active IP address" is a DHCP-assigned IP address (and not `0.0.0.0`). If you connected an ethernet cable or enabled DHCP with this menu displayed, exit and re-enter the menu to check for an updated IP address.

If your local network requires that you assign a static IP address:

1. In the "Wired Network Setup" screen, select "Use DHCP" then press RETURN.
2. Move the selection in the pop-up menu to "Disabled," then press RETURN.
3. Move the selection to "Static IP," press RETURN, then enter the static IP address. Repeat this for the netmask, gateway, and DNS address for your local network.
4. Exit the menu, and confirm saving the settings when prompted.

Wi-Fi

The C64U supports connecting to Wi-Fi networks. To connect to your wireless access point:

1. Open the C64U Menu: press the Multi Function Switch upward. The menu appears.
2. Use the W and S keys to move the selection to "Wi-Fi Network Setup." Press the RETURN key.
3. Select "Select AP from list." The C64U scans for local wireless access points, then displays a list.

4. Select your wireless access point, then select "Connect." When prompted, enter your wireless access point password, then press RETURN.

5. Press RUN/STOP to return to the Wi-Fi Network Setup menu. Confirm the connection status at the bottom of the screen: "Status" says "Link Up," and "Connected to" indicates your access point.

If your wireless access point is a private network, it will not appear in the list. Instead, select "Enter AP manually," then enter the name (SSID) of your wireless access point, followed by the password. You will also need to select the Authentication method. Most modern wireless access points support "WPA2 PSK."

SEARCHING THE COMMOSERVE FILE INDEX

Commodore enthusiasts have been archiving and preserving the long history of Commodore 64 software, transferring data off of aging magnetic media, and making the software available for download from the Internet in the form of disk images, tape images, and cartridge ROMs. As discussed in chapter 2, you can download such software to your PC, then transfer it to a USB storage device for use with your Commodore 64 Ultimate.

CommoServe is an Internet service that provides a continuously updated index of archived Commodore 64 software. You can use your Commodore 64 Ultimate to search this database, and download and run games, de-

mos, and other programs directly to the C64U, all without the need of a PC.

To perform a search of the CommoServe index:

1. Open the C64U Menu: press the Multi Function Switch upward. The menu appears.
2. Select "CommoServe File Search", press RETURN. The CommoServe File Search form displays.
3. The "Name" field is selected. Press RETURN, then type the name of a program to find. For example: **jumpman**
4. Use the W and S keys to move the field selection below the bottom of the form to select the "Submit" button. Press the RETURN key. The C64U connects to CommoServe over the Internet to perform the search, and the results are displayed in a list.
5. Select a matching title (for example, "Jumpman"), then press RETURN. Select an image file to download and run it.

You can optionally select other fields to narrow the search. For example, you can use the "Type" field to see only results in the form of D64 disk images.

There is not a way to browse the index's contents in a single list, but you can perform a search by category and rating to find highly rated games and demos. Look for websites that list popular Commodore 64 games for examples of things to try.

The index is large, and contains multiple copies of some titles. It sometimes takes some trial and error to find the right version of a given game or demo.

FTP FILE SERVICE

You can use the network connection to transfer files between your PC and your Commodore 64 Ultimate. This works with an Ethernet connection or a Wi-Fi connection. Your PC must be on the same local network as the C64U.

This requires a file transfer program for your PC that supports the File Transfer Protocol (FTP). This feature does not support encrypted connections (such as SFTP).

FTP file transfer is disabled by default. To enable it:

1. Open the C64U Menu.
2. Select "Network Services & Timezone."
3. Select "FTP File Service," then select "Enable."
4. Exit the menu, and confirm saving the settings when prompted.

To connect an FTP client program to the C64U:

1. On the C64U, open the "Wired Network Setup" or "Wi-Fi Network Setup," depending on how the computer is connected.
2. Note the IP address of the active network connection, such as: "192.168.0.64"
3. On your PC, use the FTP file transfer program to open a connection to this IP address.

The file transfer client can access every storage device connected to the C64U.

TELNET REMOTE MENU

You can access the C64U Menu remotely from your PC over your local network. As with file transfers, this works with an Ethernet connection or a Wi-Fi connection, and your PC must be on the same local network as the C64U.

NOTE: Using this feature requires familiarity with a command line terminal and a Telnet client. Most modern operating systems require that a Telnet

client be installed separately. This feature does not support encrypted connections (such as SSH).

Telnet Remote Menu is disabled by default. To enable it:

1. Open the C64U Menu.
2. Select "Network Services & Timezone."
3. Select "Telnet Remote Menu Service," then select "Enable."
4. Exit the menu, and confirm saving the settings when prompted.

To connect to the Telnet Remote Menu from your PC:

1. On the C64U, open the "Wired Network Setup" or "Wi-Fi Network Setup," depending on how the computer is connected.
2. Note the IP address of the active network connection, such as: "192.168.0.64"
3. On your PC, use your Telnet client to open a connection to this IP address. If you are using a command line **`telnet`** client in a terminal program, enter the command with the IP address as an argument: **`telnet 192.168.0.64`**

The Telnet client connects to the C64U, and displays a version of the Disk File Browser menu. You can use this to access any feature available in the Disk File Browser, including mounting disks and playing SID music files. Use your PC's cursor keys and function keys to navigate. (Some PC keyboards require holding a **`fn`** key to press F1 through F8.)

Unlike the menu system on the C64U, the Telnet Remote Menu will not exit. The "Return to Main Menu" action does nothing: the C64U Menu is not accessible. You can access advanced settings by pressing F2.

You can reset the C64U remotely using the C64 Machine menu from the Tool menu: press F1, select "C64 Machine," then select one of the reset options. Note that "Power OFF" and "Power Cycle" will terminate the Telnet connection.

OTHER NETWORK FEATURES

Your Commodore 64 Ultimate can connect to computer bulletin board systems (BBSes) using the Telnet protocol over the Internet. This replicates the experience of connecting to BBSes over telephone lines with a modem, and works with most Commodore 64 BBS client software. With appropriate network configuration, the C64U modem emulation can accept incoming connections as well, for hosting a Telnet-based BBS. See chapter 12 for a complete introduction to modem emulation and BBSes.

You can use software on your PC to control your Commodore 64 Ultimate remotely over the network. The Web Remote Control service, available in the "Network Services & Timezone" menu, features an HTTP-based API for launching programs, playing music files, manipulating disk images, updat-

ing configuration, and more. The C64U is also capable of sending data streams of video, audio, and CPU traces to a local broadcast address. You can activate these streams from the Tool menu (press F1 from the C64U Menu). Reference information for these features is out of scope for this Guide. See the website for information on writing PC software that can access these features.

CHAPTER 12

C64U MODEM EMULATION

- C64U Modem Emulation
- Configuring Modem Emulation
- Modem Commands
- Incoming Connections

C64U MODEM EMULATION

The original Commodore 64 connected to other computers over telephone lines using a device called a *modem*, typically connected to the User Port. Commodore 64 enthusiasts would use modems to connect to hobbyist-run bulletin board systems (BBSes) running on their own Commodore 64s set up with modems, or to use commercial networking services or dial into corporate systems. If you have the C64U User Port adapter, you could connect such a device to your computer today, though there are few BBSes and services available via telephone line today. (There are a few!)

Today, it is more common for hobbyists to set up Commodore BBSes connected to the Internet, available via a networking protocol known as *Telnet*. The Commodore 64 Ultimate has built-in support for emulating a modem that can connect to BBSes and similar services over the Internet via Telnet. This works over Ethernet or Wi-Fi connections. See chapter 11 for information on setting up your Internet connection.

With the C64U modem emulation, you can use any Commodore 64 BBS client program, such as UltimateTerm, or Commodore Color Graphics Manipulation System (CCGMS). The C64U emulates the MOS 6551 ACIA chip, originally found in the SwiftLink cartridge and other RS-232 cartridges.

NOTE: The Telnet protocol does not encrypt data, as many modern Internet protocols do. Anyone connected to your local network and any intermediate network may be able to see your communication with Telnet BBSes, including your username and password. Always use a unique password when creating an account at a Telnet BBS, and never send sensitive information.

CONFIGURING MODEM EMULATION

The modem emulation is disabled by default. To enable it, you tell the C64U to connect the ACIA emulation to a memory address and interrupt interface. To set this up for use with CCGMS emulating a SwiftLink modem:

1. Open the C64U Menu. Select "Modems."
2. Select "ACIA (6551) Mapping," then set it to "DE00/NMI."
3. Ensure "Hardware Mode" is set to "SwiftLink."
4. Exit the menu, the save settings to flash memory when prompted.

NOTE: The address DE00 is a memory address where the ACIA will connect. It is possible to configure other C64U features that may conflict with this setting, such as setting up SID sound chips, or utility cartridges such as Retro Replay.

You can now run a program such as CCGMS. Using CCGMS is beyond the scope of this Guide. The following are example CCGMS settings:

- Baud Rate: 19200
- Duplex: Full
- Modem Type: Swift / Turbo DE
- Protocol: Punter

MODEM COMMANDS

Many vintage modems supported being controlled by commands, known as the *Hayes AT command set*. The operator would initiate a phone call by typing **ATDT** followed by the phone number, then RETURN.

The modem emulation supports a subset of the Hayes commands, with small differences for connecting to locations on the Internet instead of telephone numbers. To connect to a Telnet BBS, type **ATDT** followed by the domain name, a colon (**:**), and a port number.

ATDTAFTERLIFE.DYNU.COM:6400

The complete set of supported commands are as follows.

Command	Description
ATI	Identify. This command prints the modem identification text message.
ATZ	Reset. This command resets the modem. Any existing connection will be dropped.
ATH	Hangup. This command terminates the current connection.
ATD	Dial. With this command an outgoing connection is initiated. The **D** should be followed by another character, usually **T** or **P** for tone and pulse dialing. However, the Commodore 64 Ultimate ignores this character. The domain name follows. The port number can be specified after a colon. This is optional; when the port number is not given, the Commodore 64 Ultimate will attempt to connect to port 80. An example of such command is: **ATDTAFTERLIFE.DYNU.COM:6400**

Command	Description
ATA	Answer. This command picks up the incoming call. This is a required command when the option "Do RING sequence" is set to "Enabled." If this command is not given in time, the incoming call times out after a number of rings.
ATO	Online. Use this command to go back to an active connection, if it was interrupted by the **+++** sequence.
ATV	Verbose mode. Recognized but ignored. Usually, such a command appears in the initialization string of a terminal program, such as StrikeTerm. It is followed by a digit.
ATS	Register Select. With this command the so-called **S**-registers can be read and set. Not all registers are supported, but some useful registers are **S0** (auto answer), **S1** (ring counter), **S2** (escape char) and **S12** (escape time). See Hayes modem specification for more details.
+++	Escape sequence. The actual character can be set with register **S2**, with defaults to **+**. When three of these characters are sent to the modem, and at least **S12** jiffies expire (by default 50, thus one second), the modem switches to command mode, but the existing connection remains active. A command such as ATH can then be given.

INCOMING CONNECTIONS

The C64U modem emulation supports accepting incoming connections over the Internet. It listens on a numbered TCP port (such as 3000), which you can set in the modem configuration. This enables you to run a simple server on your C64U, or a BBS of your own!

Your Internet connection has an IP address accessible to your local network. You can see this address in the Disk File Browser, where you enabled the connection. You can use a computer on your local network (such as your PC, or another C64U) to connect to this IP address at the configured port.

Most local network routers are set up with firewall rules to disallow incoming connections from the wider Internet. (This is a good thing.) To allow connections to the C64U from the Internet, you will need to configure your router to assign the C64U a static IP address, and enable external connections to that IP address and the configured port. Setting this up is outside the scope of this Guide.

When an external node on the network attempts to connect to the C64U, this is recognized as an incoming connection. Depending on the current state of the modem, the following will happen:

State	Behavior
Offline	When **`DTR=0`**, it is assumed that the modem software is not running. This happens when the ACIA is not configured and thus not enabled. In this case, the connecting party will receive a message, which is defined by the file specified in the configuration (default: **`/Usb0/offline.txt`**). If this file does not exist, the C64U replies with the default message, "Modem Software is currently not running..."
Busy	When the modem is currently already in a call, thus the modem has an active connection, the connecting party will receive a message, which is defined by the file specified in the configuration (default: **`/Usb0/busy.txt`**). If this file does not exist, the C64U replies with the default message, "The modem you are connecting to is currently busy."
Ready	The modem is configured and the software is ready to accept a call. In this case, the connecting party will receive a message, which is defined by the file specified in the configuration (default: **`/Usb0/connect.txt`**). If this file does not exist, the C64U replies with the default message "Welcome to the Modem Emulation Layer of the Commodore 64 Ultimate!" Following this message the RING sequence will begin (if enabled in the configuration). This means that the terminal program will receive **`RING`** messages, which it needs to answer with **`ATA`** to answer.

CHAPTER 13

C64U PRINTER EMULATION

- C64U Printer Emulation
- Enabling the Virtual Printer
- Testing the Printer
- Configuring the Printer
- Printer Capabilities

C64U PRINTER EMULATION

The original Commodore 64 connected to printers using the IEC serial port or user port, sometimes via printer interface devices. You can connect such printers to your Commodore 64 Ultimate in the same way. If you do not have a compatible printer, the C64U can emulate a vintage Commodore MPS-1230 printer.

With the virtual printer, the prints that you make using Commodore 64 printing software or BASIC commands appear as PNG image files in the filesystem, such as on a USB storage device.

You can also configure it to bypass the printer emulation and simply send the raw data to a file in the filesystem. This is useful for redirecting the screen terminal output with the CMD command, to save the terminal output to a text file.

Similar to disk drives, printers that connect to the IEC serial port use unit numbers. A printer can be assigned unit number 4 or 5.

The MPS-1230 printer is a mid-range black ink ribbon 9 needle matrix printer, manufactured in the late 1980's. It is compatible with nearly all the usual programs that allow editing for the Commodore 64 and 128. It can interpret four printer instruction sets:

- Commodore MPS-801
- Epson FX-80
- IBM Graphics Printer
- IBM Proprinter

ENABLING THE VIRTUAL PRINTER

The virtual printer is disabled by default. To enable it:

1. Open the C64U Menu. Select "Printers."
2. Select "IEC printer," then set it to "Enabled."
3. Select "Output file," then set it to a file path that exists on your system. The default value **`/Usb0/printer`** only works if you have a USB storage device connected to the innermost USB port. If you're using the outermost USB port, change this setting to **`/Usb1/printer`** (or a filename of your choice).

4. Exit the menu, the save settings to flash memory when prompted.

TESTING THE PRINTER

You can test the virtual printer by entering and running the following program:

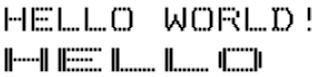
```
10 OPEN1,4
20 PRINT#1,"HELLO WORLD!"
30 PRINT#1,CHR$(14)"HELLO"
40 CLOSE1
```

When you RUN the program, it immediately returns to the **READY** prompt.

Important: At this point, the image file has not yet been saved to storage, because the printer hasn't finished printing a page. Flush the page to save the image:

1. Open the C64U Menu.
2. Open the Tool menu: press F1.
3. Select "Printer."
4. Select "Flush/Eject."

You can now use the Disk File Browser to locate the image file (such as **printer-001.png**). You cannot view this file directly on the C64U. To view it, transfer your USB storage device to your PC.



You can copy, rename, and delete the image file just like any other filesystem file. (See chapter 2.)

Here's another test you can perform. With the BASIC program still in memory, enter these commands at the **READY** prompt:

```
OPEN 1,4
CMD 1
LIST
PRINT#1
CLOSE 1
```

Flush the page to create the image file, as before. The printed file is the program listing output by the LIST command.

CONFIGURING THE PRINTER

The following configuration options are available in the "Printers" menu.

Bus ID: 4 or 5 (default is 4)
This will assign device ID 4 or 5 to the printer.

Output file: (default is /Usb0/printer)
You can select file base name that the virtual printer will use to create the PNG files. If you choose to generate PNG files they will be named **`printer-001.png`**, **`printer-002.png`**, and so on. If you chose the bypass the emulation and write RAW binary data to disk the file will be named printer with no extension. When using ASCII filter output, extension **`.txt`** will be appended to file name.

Output type: RAW, ASCII, PNG B&W, PNG COLOR (default is PNG B&W)
PNG files are images created by the printer emulator each time a page is ejected from the printer. A number and filename extension is added to the filename to ensure that it doesn't overwrite previous files when printing multiple pages. RAW is the data directly sent by the Commodore 64/128 to the IEC port and recorded as binary to a file. ASCII will keep and convert printable characters to ISO8859-1 standard. This output only makes sense if you are printing text as you will only get garbage with bitmap. In both RAW and ASCII output mode, if the file already exists, the new data will be appended to it.

Ink density: Low, Medium, or High (default is Medium)
The density (image contrast) of the print. For PNG images, this is implemented as spacing between printed dots. See table below for examples.

Page top margin: (default is 5)
The number of text lines to use for a top margin of the page.

Page height: (default is 60)
The number of text lines to use for the height of the page.

Emulation: Commodore MPS, Epson FX-80, IBM Graphics Printer, IBM Proprinter (default is Commodore MPS)
You can select which instruction set the emulator will recognize. Changing from one emulation to another will reset the printer attributes but the printer head stays at the same place and the page is not ejected.

Commodore charset: USA/UK, Denmark, France/Italy, Germany, Spain, Sweden, Switzerland (default is USA/UK)
Select which charset to use when using Commodore MPS emulation. US-A/UK has the expected PETSCII graphics characters.

Epson charset: Basic, USA, France, Germany, England, Denmark I, Sweden, Italy, Spain, Japan, Norway, Denmark II (default is Basic)
Select which charset to use when using Epson FX-80 emulation.

Printer IBM table 2: International 1, International 2, Israel, Greece, Portugal, Spain (default is International 1)
Select which charset to use for Table2 when using IBM Graphics Printer or IBM Proprinter emulation. IBM printers can use 2 charsets: Table 1 and Table2. Table 1 cannot be modified and is the default charset. Table 2 is the one you chose with this parameter.

Elementary Dot	Low	■
	Medium	
	High	
Draft text	Low	
	Medium	1541 ULTIMATE II
	High	1541 ULTIMATE II
NLQ text	Low	
	Medium	1541 ULTIMATE II
	High	1541 ULTIMATE II
Draft graphic chars	Low	
	Medium	♠ ♥ ♦ ♣
	High	♠ ♥ ♦ ♣
NLQ graphic chars	Low	
	Medium	♠ ♥ ♦ ♣
	High	♠ ♥ ♦ ♣

PRINTER CAPABILITIES

The table below summarizes the printer capabilities depending on which printer emulation is active:

	MPS	Epson FX-80	IBM Graphics	IBM Proprinter
Draft	•	•	•	•
Double strike	•	•	•	•
Bold	•	•	•	•
Italic (draft only)	•	•	•	
NLQ	•	•	•	•
Underline	•	•	•	•
Double width	•	•	•	•
Superscript	•	•	•	•
Subscript	•	•	•	•
Reverse	•			
Overline				•
Backspace		•	•	•
Reverse page feed		•		
CR=CR+LF	•			*optional*
LF=CR+LF	•	•		
7 dot BIM	•			
8 dot BIM		•	•	•
9 dot BIM		•		
HT Program		•	•	•
VT Program		•		•
60 dpi BIM	• *(dbl width)*	•	•	•
75 dpi BIM		•		
80 dpi BIM		•		
90 dpi BIM		•		
120 dpi BIM		•	•	•
240 dpi BIM		•	•	•
Pica (10cpi)	•	•	•	•
Elite (12cpi)	•	•	•	•
Micro (15cpi)	•			
Condensed (17.1cpi)	•	•	•	•
Pica Comp (20cpi)	•			
Elite Comp (24 cpi)	•			
Micro Comp (30 cpi)	•			

APPENDICES

APPENDIX A

COMMODORE 64 BASIC

This Guide has given you an introduction to the BASIC language — enough for you to get a feel for computer programming and some of the vocabulary involved. This appendix gives a complete list of the rules (SYNTAX) of Commodore 64 BASIC, along with concise descriptions. Please experiment with these commands. Remember, you can't do any permanent damage to the computer by just typing in programs, and the best way to learn computing is by doing.

This appendix is divided into sections according to the different types of operations in BASIC. These include:

1. Variables and Operators: describes the different type of variables, legal variable names, and arithmetic and logical operators.
2. Commands: describes the commands used to work with programs, edit, store, and erase them.
3. Statements: describes the BASIC program statements used in numbered lines of programs.
4. Functions: describes the string, numeric, and print functions.

VARIABLES

The Commodore 64 uses three types of variables in BASIC. These are real numeric, integer numeric, and string (alphanumeric) variables.

Variable names may consist of a single letter, a letter followed by a number, or two letters.

An integer variable is specified by using the percent (%) sign after the variable name. String variables have the dollar sign ($) after their name.

EXAMPLES

Real Variable Names: **A**, **A5**, **BZ**
Integer Variable Names: **A%**, **A5%**, **BZ%**
String Variable Names: **A$**, **A5$**, **BZ$**

Arrays are lists of variables with the same name, using extra numbers to specify the element of the array. Arrays are defined using the DIM statement, and may contain floating point, integer, or string variables. The array variable name is followed by a set of parentheses **( )** enclosing the number of variables in the list.

A(7), **BZ%(11)**, **A$(50)**, **PT(20,20)**

NOTE: there are three variable names which are reserved for use by the Commodore 64, and may not be defined by you. These variables are: ST, TI, and TI$. ST is a status variable which relates to input/output operations. The value of ST will change if there is a problem loading a program from disk or tape.

TI and TI$ are variables which relate to the real-time clock built into the Commodore 64. The variable TI is updated every 1/60th of a second. It starts at 0 when the computer is turned on, and is reset only by changing the value of TI$.

TI$ is a string which is constantly updated by the system. The first two characters contain the number of hours, the 3rd and 4th characters the number of minutes, and the 5th and 6th characters are the number of seconds. This variable can be given any numeric value, and will be updated from that point.

TI$ = "101530" sets the clock to 10:15 and 30 seconds AM.

This clock is erased when the computer is turned off, and starts at zero when the system is turned back on.

OPERATORS

The arithmetic operators include the following signs:

+	Addition
-	Subtraction
*****	Multiplication
/	Division
↑	Raising to a power (exponentiation)

On a line containing more than one operator, there is a set order in which operations always occur. If several operations are used together on the same line, the computer assigns priorities as follows: first, exponentiation; next, multiplication and division, and last, addition and subtraction.

You can change the order of operations by enclosing within parentheses the calculation to be performed first. Operations enclosed in parentheses will take place before other operations.

There are also operations for equalities and inequalities:

=	Equal To
<	Less Than
>	Greater Than
<=	Less Than or Equal To
>=	Greater Than or Equal To
<>	Not Equal To

Finally, there are three logical operators:

AND
OR
NOT

These are used most often to join multiple formulas in IF...THEN statements. For example:

IF A = B AND C = D THEN 100 (Requires both parts to be true)
IF A = B OR C = D THEN 100 (Allows either part to be true)

COMMANDS

CONT (Continue)

This command is used to restart the execution of a program which has been stopped by either using the STOP key, a STOP statement, or an END statement within the program. The program will restart at the exact place from where it left off.

CONT will not work if you have changed or added lines to the program (or even just moved the cursor), or if the program halted due to an error, or if you caused an error before trying to restart the program. In these cases you will get a CAN'T CONTINUE ERROR.

LIST

The LIST command allows you to look at lines of a BASIC program in memory. You can ask for the entire program to be displayed, or only certain line numbers.

`LIST`	Shows entire program
`LIST 10-`	Shows only from line 10 until end
`LIST 10`	Shows only line 10
`LIST -10`	Shows lines from beginning until 10
`LIST 10-20`	Shows line from 10 to 20, inclusive

LOAD

This command is used to transfer a program from tape or disk into memory so the program can be used. If you just type LOAD and hit RETURN, the first program found on the cassette unit will be placed in memory. The command may be followed by a program name enclosed within quotes. The name may then be followed by a comma and a number or numeric variable, which acts as a device number to indicate where the program is coming from.

If no device number is given, the Commodore 64 assumes device #1, which is the cassette unit. The other device commonly used with the LOAD command is the disk drive, which is device #8.

`LOAD`	Reads in the next program on tape
`LOAD "HELLO"`	Searches tape for program called HELLO, and loads program, if found
`LOAD A$`	Looks for program whose name is in the variable A$
`LOAD "HELLO",8`	Looks for program called HELLO on the disk drive
`LOAD "*",8`	Looks for first program on disk
`LOAD "$",8`	Loads the disk directory. Display with LIST.

NEW

This command erases the entire program in memory, and also clears out any variables that may have been used. Unless the program was SAVEd, it is lost. **BE CAREFUL WHEN YOU USE THIS COMMAND.**

The NEW command can also be used as a BASIC program statement. When the program reaches this line, the program is erased. This is useful if you want to leave everything neat when the program is done.

RUN

This command causes execution of a program, once the program is loaded into memory. If there is no line number following RUN, the computer will start with the lowest line number. If a line number is designated, the program will start executing from the specified line.

`RUN`	Starts program at lowest line number.
`RUN 100`	Starts execution at line 100.
`RUN X`	UNDEFINED STATEMENT ERROR. You must always specify an actual line number, not a variable representation.

SAVE

This command will store the program currently in memory on cassette or disk. If you just type SAVE and RETURN, the program will be SAVEd on cassette. The computer has no way of knowing if there is a program already on that tape, so be careful with your tapes or you may erase a valuable program.

If you type SAVE followed by a name in quotes or a string variable, the computer will give the program that name, so it can be more easily located and retrieved in the future. The name may also be followed by a device number.

After the device number, there can be a comma and a second number, either 0 or 1. If the second number is 1, the Commodore 64 will put an END-OF-TAPE marker after your program. This signals the computer not to look any further on the tape if you were to give an additional LOAD command. If you try to LOAD a program and the computer finds one of these markers, you will get a FILE NOT FOUND ERROR.

`SAVE`	Stores program to tape without name
`SAVE "HELLO"`	Stores on tape with name HELLO
`SAVE A$`	Stores on tape with name in A$
`SAVE "HELLO",8`	Stores on disk with name HELLO
`SAVE "HELLO",I,1`	Stores on tape with name HELLO and follows program with END-OF-TAPE marker

VERIFY

This command causes the computer to check the program on disk or tape against the one in memory. This is proof that the program is actually SAVEd, in case the tape or disk is bad, or something went wrong during the SAVE. VERIFY without anything after the command causes the Commodore 64 to check the next program on tape, regardless of name, against the program in memory.

VERIFY followed by a program name, or a string variable, will search for that program and then check. Device numbers can also be included with the VERIFY command.

`VERIFY`	Checks the next program on tape.
`VERIFY "HELLO"`	Searches for HELLO, checks against memory.
`VERIFY "HELLO",8`	Searches for HELLO on disk, then checks.

STATEMENTS

CLOSE

This command completes and closes any files used by OPEN statements. The number following CLOSE is the file number to be closed.

`CLOSE 2`	Only file #2 is closed

CLR

This command will erase any variables in memory, but leaves the program itself intact. This command is automatically executed when a RUN command is given.

CMD

CMD sends the output which normally would go to the screen (i.e. PRINT statements, LISTs, but not POKEs onto the screen) to another device instead. This could be a printer, or a data file on tape or disk. This device or file must be OPENed first. The CMD command must be followed by a number or numeric variable referring to the file.

`OPEN 1,4`	OPENS device #4, which is the printer.
`CMD 1`	All normal output now goes to printer.
`LIST`	The program listing now goes to the printer, not the screen.

To send output back to the screen, CLOSE the file with CLOSE 1.

DATA

This statement is followed by a list of items to be used by READ statements. Items may be numeric values or text strings, and items are separated by commas. String items need not be inside quote marks unless they contain space, colon, or comma. If two commas have nothing between them, the value will be READ as a zero for a number, or an empty string.

```
DATA 12, 14.5, "HELLO, MOM", 3.14, PART1
```

DEF FN

This command allows you to define a complex calculation as a function with a short name. In the case of a long formula that is used many times within the program, this can save time and space.

The function name will be FN and any legal variable name (1 or 2 characters long). First you must define the function using the statement DEF followed by the function name. Following the name is a set of parentheses enclosing a numeric variable. Then follows the actual formula that you want to define, with the variable in the proper spot. You can then "call" the formula, substituting any number for the variable.

```
10 DEF FNA (X) = 12*(34.75 - X/.3)
20 PRINT FNA(7) T
```

7 is inserted where X is in the formula

For this example, the result would be 137.

DIM

When you use more than 11 elements of an array, you must execute a DIM statement for the array. Keep in mind that the whole array takes up room in memory, so don't create an array much larger than you'll need. To figure the number of variables created with DIM, multiply the total number of elements in each dimension of the array.

```
10 DIM A$(40), B7(15), CC%(4,4,4)
```

41 ELEMENTS

16 ELEMENTS

125 ELEMENTS

You can dimension more than one array in a DIM statement. However, be careful not to dimension an array more than once.

END

When a program encounters an END statement, the program halts, as if it ran out of lines. You may use CONT to restart the program.

FOR...TO...STEP

This statement works with the NEXT statement to repeat a section of the program a set number of times. The format is:

FOR <var name>=<start of count> **TO** <end of count> **STEP** <count by>

The loop variable will be added to or subtracted from during the program. Without any STEP specified, STEP is assumed to be 1. The start count and end count are the limits to the value of the loop variable.

```
10 FOR L = 1 TO 10 STEP .1
20 PRINT L
30 NEXT L
```

The end of the loop value may be followed by the word STEP and another number or variable. In this case, the value following STEP is added each time instead of 1. This allows you to count backwards, or by fractions.

GET

The GET statement allows you to get data from the keyboard, one character at a time. When GET is executed, the character that is typed is assigned to the variable. If no character is typed, then a null (empty) character is assigned.

GET is followed by a variable name, usually a string variable. If a numeric variable was used and a nonnumeric key depressed, the program would halt with an error message. The GET statement may be placed into a loop, checking for any empty result. This loop will continue until a key is hit.

```
10 GET A$ : IF A$ ="" THEN 10
```

GET#

The GET# statement is used with a previously OPENed device or file, to input one character at a time from that device or file.

```
GET #1,A$
```

This would input one character from a data file.

GOSUB

This statement is similar to GOTO, except the computer remembers which program line it lost executed before the GOSUB. When a line with a RETURN statement is encountered, the program jumps back to the statement immediately following the GOSUB. This is useful if there is a routine in your program that occurs in several parts of the program. Instead of typing the routine over and over, execute GOSUBs each time the routine is needed.

```
20 GOSUB 800
```

GOTO OR GO TO

When a statement with the GOTO command is reached, the next line to be executed will be the one with the line number following the word GOTO.

IF...THEN

IF...THEN lets the computer analyze a situation and take two possible courses of action, depending on the outcome. If the expression is true, the statement following THEN is executed. This may be any BASIC statement.

If the expression is false, the program goes directly to the next line. The expression being evaluated may be a variable or formula, in which case it is considered true if nonzero, and false if zero. In most cases, there is an expression involving relational operators (=, <, >, <=, >=, <>, AND, OR, NOT).

```
10 IF X > 10 THEN END
```

INPUT

The INPUT statement allows the program to get data from the user, assigning that data to a variable. The program will stop, print a question mark (?) on the screen, and wait for the user to type in the answer and hit RETURN.

INPUT is followed by a variable name, or a list of variable names, separated by commas. A message may be placed within quote marks, before the list of variable names to be INPUT. If more than one variable is to be INPUT, they must be separated by commas when typed.

```
10 INPUT "PLEASE ENTER YOUR FIRST NAME ";A$
20 PRINT "ENTER YOUR CODE NUMBER"; : INPUT B
```

INPUT#

INPUT# is similar to INPUT, but takes data from a previously OPENed file or device.

```
10 INPUT#1, A
```

LET

LET is hardly ever used in programs, since it is optional, but the statement is the heart of all BASIC programs. The variable name which is to be assigned the result of a calculation is on the left side of the equal sign, and the formula on the right.

```
10 LET A = 5
20 LET D$ = "HELLO"
```

NEXT

NEXT is always used in conjunction with the FOR statement. When the program reaches a NEXT statement, it checks the FOR statement to see if the limit of the loop has been reached. If the loop is not finished, the loop variable is increased by the specified STEP value. If the loop is finished, execution proceeds with the statement following NEXT.

NEXT may be followed by a variable name, or list of variable names, separated by commas. If there are no names listed, the last loop started is the one being completed. If variables are given, they are completed in order from left to right.

```
10 FOR X = 1 TO 100: NEXT
```

ON

This command turns the GOTO and GOSUB commands into special versions of the IF statement. ON is followed by a formula, which is evaluated. If the result of the calculation is one, the first line on the list is executed; if the result is 2, the second line is executed, and so on. If the result is 0, negative, or larger than the list of numbers, the next line executed will be the statement following the ON statement.

```
10 INPUT X
20 ON X GOTO 10,20,30,40,50
```

OPEN

The OPEN statement allows the Commodore 64 to access devices such as the cassette recorder and disk for data, a printer, or even the screen. OPEN is followed by a number (0-255), to which all following statements will refer. There is usually a second number after the first, which is the device number.

The device numbers are:

0 Screen
1 Cassette
4 Printer
8 Disk

Following the device number may be a third number, separated again by a comma, which is the secondary address. In the case of the cassette, this is 0 for read, 1 for write, and 2 for write with end-of-tape marker.

In the case of the disk, the number refers to the buffer, or channel, number. In the printer, the secondary address controls features like expanded printing. See the Commodore 64 Programmer's Reference Guide for more details.

`10 OPEN 1,0`	OPENs the SCREEN as a device.
`20 OPEN 2,1,0,"D"`	OPENs the cassette for reading, file to be searched for is D.
`30 OPEN 3,4`	OPENs the printer.
`40 OPEN 4,8,15`	OPENs the data channel on the disk.

Also see: CLOSE, CMD, GET#, INPUT#, and PRINT#, system variable ST, and Appendix **??**.

POKE

POKE is always followed by two numbers, or formulas. The first location is a memory location; the second number is a decimal value from 0 to 255, which will be placed in the memory location, replacing any previously stored value.

```
10 POKE 53281,0
20 S=4096 * 13
30 POKE S + 29,8
```

PRINT

The PRINT statement is the first one most people learn to use, but there are a number of variations to be aware of. PRINT can be followed by:

Text String with quotes
Variable names
Functions
Punctuation marks

Punctuation marks are used to help format the data on the screen. The comma divides the screen into four columns, while the semicolon suppresses all spacing. Either mark can be the last symbol on a line. This results in the next thing PRINTed acting as if it were a continuation of the some PRINT statement.

```
10 PRINT "HELLO"
20 PRINT "HELLO",A$
30 PRINT A+B
40 PRINT J;
60 PRINT A,B,C,D
```

Also see: POS, SPC and TAB functions.

PRINT#

There are a few differences between this statement and PRINT. PRINT# is followed by a number, which refers to the device or data file previously OPENed. This number is followed by a comma and a list to be printed. The comma and semicolon have the same effect as they do in PRINT. Please note that some devices may not work with TAB and SPC.

```
100 PRINT#1,"DATA VALUES"; A%, B1, C$
```

READ

READ is used to assign information from DATA statements to variables, so the information may be put to use. Care must be taken to avoid READing strings where READ is expecting a number, which will give a TYPE MISMATCH ERROR.

REM (Remark)

REMark is a note to whomever is reading a LIST of the program. It may explain a section of the program, or give additional instructions. REM statements in no way affect the operation of the program, except to add to its length. REM may be followed by any text.

RESTORE

When executed in a program, the pointer to which an item in a DATA statement will be READ next is reset to the first item in the list. This gives you the ability to re-READ the information. RESTORE stands by itself on a line.

RETURN

This statement is always used in conjunction with GOSUB. When the program encounters a RETURN, it will go to the statement immediately following the GOSUB command. If no GOSUB was previously issued, a RETURN WITHOUT GOSUB ERROR will occur.

STOP

This statement will halt program execution. The message, BREAK IN xxx will be displayed, where xxx is the line number containing STOP. The program may be restarted by using the CONT command. STOP is normally used in debugging a program.

SYS

SYS is followed by a decimal number or numeric value in the range 0-65535. The program will then begin executing the machine language program starting at that memory location. This is similar to the USR function, but does not allow parameter passing.

WAIT

WAIT is used to halt the program until the contents of a memory location changes in a specific way. WAIT is followed by a memory location (X) and up to two variables. The format is:

```
WAIT X,Y,Z
```

The contents of the memory location are first exclusive-ORed with the third number, if present, and then logically ANDed with the second number. If the result is zero, the program goes back to that memory location and checks again. When the result is nonzero, the program continues with the next statement.

NUMERIC FUNCTIONS

ABS(X) (absolute value)

ABS returns the absolute value of the number, without its sign (+ or -). The answer is always positive.

ATN(X) (arctangent)

Returns the angle, measured in radians, whose tangent is X.

COS(X) (cosine)

Returns the value of the cosine of X, where X is an angle measured in radians.

EXP(X)

Returns the value of the mathematical constant e (2.71828183) raised to the power of X.

FNxx(X)

Returns the value of the user-defined function xx created in a DEF FNxx(X) statement.

INT(X)

Returns the truncated value of X, that is, with all the decimal places to the right of the decimal point removed. The result will always be less than, or equal to, X. Thus, any negative numbers with decimal places will become the integer less than their current value.

LOG(X) (logarithm)

Will return the natural log of X. The natural log to the base e (see EXP(X)). To convert to log base 10, simply divide by LOG(10).

PEEK(X)

Used to find out contents of memory location X, in the range 0-65535, giving a result from 0-255. PEEK is often used in conjunction with the POKE statement.

RND(X) (random number)

RND(X) returns a random number in the range 0-1. The first random number should be generated by the formula RND(-TI) to start things off differently every time. After this, X should be a 1 or any positive number. If X is zero, the result will be the same random number as the last one.

A negative value for X will reseed the generator. The use of the same negative number for X will result in the same sequence of "random" numbers.

The formula for generating a number between X and Y is:

```
N = RND(1)*(Y-X)+X
```

where:

Y is the upper limit
X is the lower range of numbers desired.

SGN(X) (sign)

This function returns the sign (positive, negative, or zero) of X. The result will be + 1 if positive, 0 if zero, and -l if negative.

SIN(X) (sine)

SIN(X) is the trigonometric sine function. The result will be the sine of X, where X is an angle in radians.

SQR(X) (square root)

This function will return the square root of X, where X is a positive number or 0. If X is negative, an ILLEGAL QUANTITY ERROR results.

TAN(X) (tangent)

The result will be the tangent of X, where X is an angle in radians.

USR(X)

When this function is used, the program jumps to a machine language program whose starting point is contained in memory locations. The parameter X is passed to the machine language program, which will return another value back to the BASIC program. Refer to the Commodore 64 Programmer's Reference Guide for more details on this function and machine language programming.

STRING FUNCTIONS

ASC(X$)

This function will return the ASCII code of the first character of X$.

CHR$(X)

This is the opposite of ASC, and returns a string character whose ASCII code is X.

LEFT$(X$,X)

Returns a string containing the leftmost X characters of $X.

LEN(X$)

Returned will be the number of characters (including spaces and other symbols) in the string X$.

MID$(X$,S,X)

This will return a string containing X characters starting from the Sth character in X$.

RIGHT$(X$,X)

Returns the rightmost X characters in X$.

STR$(X)

This will return a string which is identical to the PRINTed version of X.

VAL(X$)

This function converts X$ into a number, and is essentially the inverse operation from STR$. The string is examined from the leftmost character to the right, for as many characters as are in recognizable number format.

```
10 X = VAL("123.456")        X = 123.456
10 X = VAL("12A13B")         X = 12
10 X = VAL("RIU017")         X = 0
10 X = VAL("-1.23.45.67")    X = -1.23
```

OTHER FUNCTIONS

FRE(X)

This function returns the number of unused bytes available in memory, regardless of the value of X. Note that FRE(X) will read out in negative numbers if the number of unused bytes is over 32K.

POS(X)

This function returns the number of the column (0-39) at which the next PRINT statement will begin on the screen. X may have any value and is not used.

SPC(X)

This is used in a PRINT statement to skip X spaces forward.

TAB(X)

TAB is also used in a PRINT statement; the next item to be PRINTed will be in column X.

APPENDIX B

ABBREVIATIONS FOR BASIC KEYWORDS

As a time-saver when typing in programs and commands, Commodore 64 BASIC allows the user to abbreviate most keywords. The abbreviation for PRINT is a question mark. The abbreviations for other words are made by typing the first one or two letters of the word, followed by the SHIFTed next letter of the word. If the abbreviations are used in a program line, the keyword will LIST in the full form.

Command	Abbreviation	Looks like this on screen	Command	Abbreviation	Looks like this on screen
ABS	A SHIFT B	A▌	GOTO	G SHIFT O	G▛
AND	A SHIFT N	A◢	IF	NONE	IF
ASC	A SHIFT S	A♥	INPUT	NONE	INPUT
ATN	A SHIFT T	A▌	INPUT#	I SHIFT N	G◢
CHR$	C SHIFT H	A▌	INT	NONE	INT
CLOSE	CL SHIFT O	CL▛	LEFT$	LE SHIFT F	LE▬
CLR	C SHIFT L	C▙	LEN	NONE	LEN
CMD	C SHIFT M	C◥	LET	L SHIFT E	L▀
CONT	C SHIFT O	C▛	LIST	L SHIFT I	L▚
COS	NONE	COS	LOAD	L SHIFT O	L▛
DATA	D SHIFT A	D♠	LOG	NONE	LOG
DEF	D SHIFT E	D▀	MID$	M SHIFT I	M▚

Command	Abbreviation	Looks like this on screen	Command	Abbreviation	Looks like this on screen
DIM	D SHIFT I	D	NEW	NONE	NEW
END	E SHIFT N	E	NEXT	N SHIFT E	N
EXP	E SHIFT X	E	NOT	N SHIFT O	N
FN	NONE	FN	ON	NONE	ON
FOR	F SHIFT O	F	OPEN	O SHIFT P	O
FRE	F SHIFT R	F	OR	NONE	OR
GET	G SHIFT E	G	PEEK	P SHIFT E	P
GET#	NONE	GET#	POKE	P SHIFT O	P
GOSUB	GO SHIFT S	GO	POS	NONE	POS
PRINT	?	?	STATUS	ST	ST
PRINT#	P SHIFT R	P	STEP	ST SHIFT E	ST
READ	R SHIFT E	R	STOP	S SHIFT T	S
REM	NONE	REM	STR$	ST SHIFT R	ST
RESTORE	RE SHIFT S	RE	SYS	S SHIFT Y	S
RETURN	RE SHIFT T	RE	TAB	T SHIFT A	T
RIGHT$	R SHIFT I	R	TAN	NONE	TAN
RND	R SHIFT N	R	THEN	T SHIFT H	T
RUN	R SHIFT U	A	TIME	TI	TI
SAVE	S SHIFT A	S	TIME$	TI$	TI$
SGN	S SHIFT G	S	USR	U SHIFT S	U
SIN	S SHIFT I	S	VAL	V SHIFT A	V
SPC	S SHIFT P	S	VERIFY	V SHIFT E	V
SQR	S SHIFT Q	S	WAIT	W SHIFT A	W

APPENDIX C

SCREEN DISPLAY CODES

The following chart lists all of the characters built into the Commodore 64 character sets. It shows which numbers should be POKEd into screen memory (locations 1024 - 2023) to get a desired character. Also shown is which character corresponds to a number PEEKed from the screen.

Two character sets are available, but only one set at a time. This means that you cannot have characters from one set on the screen at the same time you have characters from the other set displayed. The sets are switched by holding down the SHIFT and C= keys simultaneously.

From BASIC, POKE 53272,21 will switch to upper case mode and POKE 53272,23 switches to lower case.

Any number on the chart may also be displayed in REVERSE. The reverse character code may be obtained by adding 128 to the values shown.

If you want to display a solid circle at location 1504, POKE the code for the circle (81) into location 1504: POKE 1504,81.

There is a corresponding memory location to control the color of each character displayed on the screen (locations 55296-56295). To change the color of the circle to yellow (color code 7) you would POKE the corresponding memory location (55776) with the character color: POKE 55776,7.

Refer to Appendix E for the complete screen and color memory maps, along with color codes.

SCREEN CODES

SET 1	SET 2	POKE	SET 1	SET 2	POKE	SET 1	SET 2	POKE
@		0	!		33		B	66
A	a	1	"		34		C	67
B	b	2	#		35		D	68
C	c	3	$		36		E	69
D	d	4	%		37		F	70
E	e	5	&		38		G	71
F	f	6	'		39		H	72
G	g	7	(		40		I	73
H	h	8	)		41		J	74
I	i	9	*		42		K	75
J	j	10	+		43		L	76
K	k	11	,		44		M	77
L	l	12	-		45		N	78
M	m	13	.		46		O	79
N	n	14	/		47		P	80
O	o	15	0		48		Q	81
P	p	16	1		49		R	82
Q	q	17	2		50		S	83
R	r	18	3		51		T	84
S	s	19	4		52		U	85
T	t	20	5		53		V	86
U	u	21	6		54		W	87
V	v	22	7		55		X	88
W	w	23	8		56		Y	89
X	x	24	9		57		Z	90
Y	y	25	:		58			91
Z	z	26	;		59			92
[		27	<		60			93
£		28	=		61			94
]		29	>		62			95
↑		30	?		63	SPACE		96
←		31			64			97
SPACE		32		A	65			98

SET 1	SET 2	POKE	SET 1	SET 2	POKE	SET 1	SET 2	POKE
		99			109			119
		100			110			120
		101			111			121
		102			112			122
		103			113			123
		104			114			124
		105			115			125
		106			116			126
		107			117			127
		108			118			

Codes from 128 – 255 are reversed images of codes 0 – 127.

APPENDIX D

ASCII AND CHR$ CODES

This appendix shows you what characters will appear if you PRINT CHR$(X), for all possible values of X. It will also show the values obtained by typing PRINT ASC("x"), where x is any character you can type. This is useful in evaluating the character received in a GET statement, converting upper/lower case, and printing character based commands (like switch to upper/lower case) that could not be enclosed in quotes.

PRINT	CHR$	PRINT	CHR$	PRINT	CHR$	PRINT	CHR$
	0		22	,	44	B	66
	1		23	-	45	C	67
	2		24	.	46	D	68
	3		25	/	47	E	69
	4		26	0	48	F	70
WHT	5		27	1	49	G	71
	6	RED	28	2	50	h	72
	7	CRSR→	29	3	51	I	73
DISABLES SHIFT C=	8	GRN	30	4	52	J	74
ENABLES SHIFT C=	9	BLU	31	5	53	K	75
	10	SPACE	32	6	54	L	76
	11	!	33	7	55	M	77
	12	"	34	8	56	N	78
RETURN	13	#	35	9	57	O	79
SWITCH TO LOWER CASE	14	$	36	:	58	P	80
	15	%	37	;	59	Q	81
	16	&	38	<	60	R	82
CRSR↓	17	'	39	=	61	S	83
RVS ON	18	(	40	>	62	T	84
CLR HOME	19	)	41	?	63	U	85
INST DEL	20	*	42	@	64	V	86
	21	+	43	A	65	W	87

PRINT	CHR$	PRINT	CHR$	PRINT	CHR$	PRINT	CHR$
X	88		114	f8	140		166
Y	89		115	SHIFT RETURN	141		167
Z	90		116	SWITCH TO UPPER CASE	142		168
[	91		117		143		169
£	92		118	BLK	144		170
]	93		119	CRSR↑	145		171
↑	94		120	RVS OFF	146		172
←	95		121	CLR HOME	147		173
	96		122	INST DEL	148		174
	97		123	Brown	149		175
	98		124	Lt Red	150		176
	99		125	Gray 1	151		177
	100		126	Gray 2	152		178
	101		127	Lt Green	153		179
	102		128	Lt Blue	154		180
	103	Orange	129	Gray 3	155		181
	104		130	PUR	156		182
	105		131	←CRSR	157		183
	106		132	YEL	158		184
	107	f1	133	CYN	159		185
	108	f3	134	SPACE	160		186
	109	f5	135		161		187
	110	f7	136		162		188
	111	f2	137		163		189
	112	f4	138		164		190
	113	f6	139		165		191

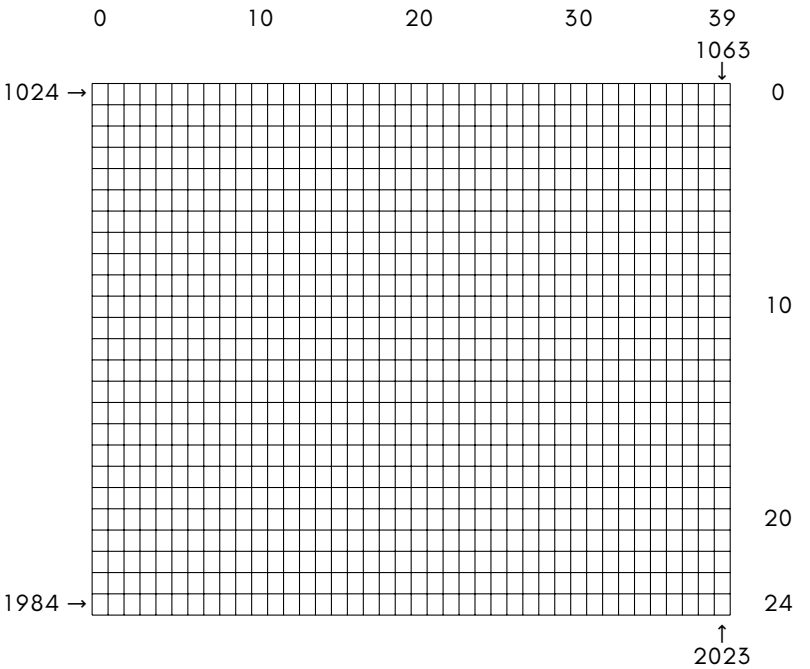
CODES 192 – 223 SAME AS 96 – 127
CODES 224 – 254 SAME AS 160 – 190
CODE 255 SAME AS 126

APPENDIX E

SCREEN AND COLOR MEMORY MAPS

The following charts list which memory locations control placing characters on the screen, and the locations used to change individual character colors, as well as showing character color codes.

SCREEN MEMORY MAP

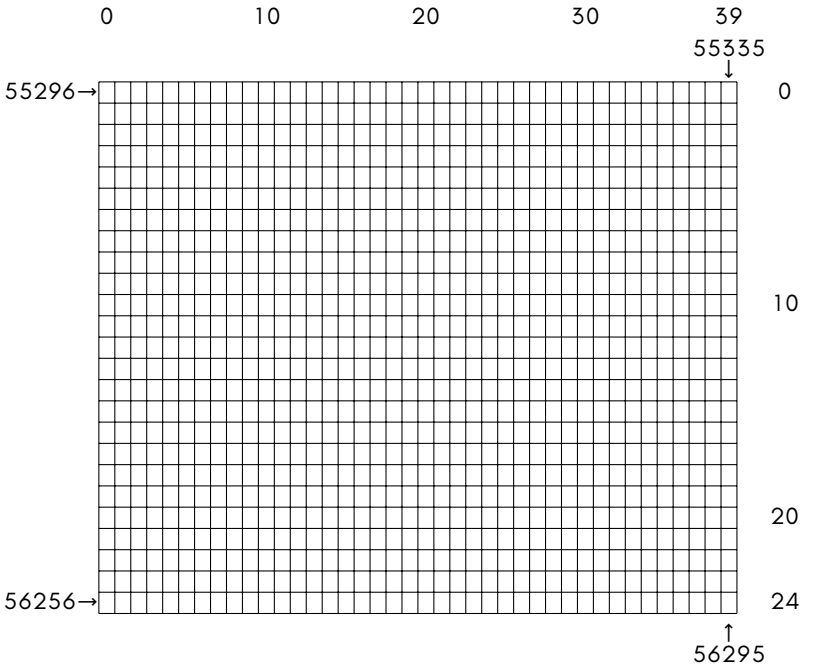


The actual values to POKE into a color memory location to change a character's color are:

0	BLACK	8	ORANGE
1	WHITE	9	BROWN
2	RED	10	Light RED
3	CYAN	11	GRAY 1
4	PURPLE	12	GRAY 2
5	GREEN	13	Light GREEN
6	BLUE	14	Light BLUE
7	YELLOW	15	GRAY 3

For example, to change the color of a character located at the upper left-hand corner of the screen to red, type: POKE 55296,2.

COLOR MEMORY MAP



APPENDIX F

DERIVING MATHEMATICAL FUNCTIONS

Functions that are not intrinsic to Commodore 64 BASIC may be calculated as follows:

FUNCTION	BASIC EQUIVALENT
Secant	`SEC(X)=1/COS(X)`
Cosecant	`CSC(X)=1/SIN(X)`
Cotangent	`COT(X)=1/TAN(X)`
Inverse Sine	`ASIN(X)=ATN(X/SQR(-X*X+1))`
Inverse Cosine	`ACOS(X)=-ATN(X/SQR(-X*X+1))+π/2`
Inverse Secant	`ASEC(X)=ATN(SQR(X*X-1))+(SGN(X)-1)*π/2`
Inverse Cosecant	`ASEC(X)=ATN(1/SQR(X*X-1))+(SGN(X)-1)*π/2`
Inverse Cotangent	`AOT(X)=ATN(-X)+π/2`
Hyperbolic Sine	`SINH(X)=(EXP(X)-EXP(-X))/2`
Hyperbolic Cosine	`COSH(X)=(EXP(X)+EXP(-X))/2`
Hyperbolic Tangent	`TANH(X)=(EXP(X)-EXP(-X))/(EXP(X)+EXP(-X))`
Hyperbolic Secant	`SECH(X)=2/(EXP(X)+EXP(-X))`
Hyperbolic Cosecant	`CSCH(X)=2/(EXP(X)-EXP(-X))`
Hyperbolic Cotangent	`COTH(X)=EXP(-X)/(EXP(X)-EXP(-X))*2+1`
Inverse Hyperbolic Sine	`ASINH(X)=LOG(X+SQR(X*X+1))`
Inverse Hyperbolic Cosine	`ACOSH(X)=LOG(X+SQR(X*X-1))`
Inverse Hyperbolic Tanget	`ATANH(X)=LOG((1+X)/(1-X))/2`
Inverse Hyperbolic Secant	`ASECH(X)=LOG((1+SQR(1-X*X))/X)`
Inverse Hyperbolic Cosecnat	`ACSCH(X)=LOG((SGN(X)+SQR(X*X+1))/X)`
Inverse Hyperbolic Cotangent	`ACOTH(X)=LOG((SQR(X*X-1))/(X-1))`

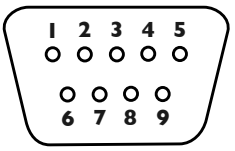
APPENDIX G

CONNECTIONS AND PINOUTS

This appendix is designed to show you what connections may be made to the original Commodore 64 ports, as well as notable items on the mainboard.

Pin numbering for ports is pictured from the point of view of looking at the port from the outside of the computer.

Game I/O



Control Port 1

Pin	Type	Note
1	JOYA0	
2	JOYA1	
3	JOYA2	
4	JOYA3	
5	POT AY	
6	BUTTON A/LP	
7	+5V	MAX 50mA
8	GND	
9	POT AX	

Control Port 2

Pin	Type	Note
1	JOYB0	
2	JOYB1	
3	JOYB2	
4	JOYB3	
5	POT BY	
6	BUTTON B/LP	
7	+5V	MAX 50mA
8	GND	
9	POT BX	

Cartridge Slot

Pin	Type
1	GND
2	+5V
3	+5V
4	$\overline{IRQ}$
5	R/$\overline{W}$
6	Dot Clock
7	I/O 1
8	$\overline{GAME}$
9	$\overline{EXROM}$
10	I/O 2
11	$\overline{ROML}$

Pin	Type
12	BA
13	$\overline{DMA}$
14	D7
15	D6
16	D5
17	D4
18	D3
19	D2
20	D1
21	D0
22	GND

Pin	Type
A	GND
B	$\overline{ROMH}$
C	$\overline{RESET}$
D	$\overline{NMI}$
E	S 02
F	A15
H	A14
J	A13
K	A12
L	A11
M	A10

Pin	Type
N	A9
P	A8
R	A7
S	A6
T	A5
U	A4
V	A3
W	A2
X	A1
Y	A0
Z	GND

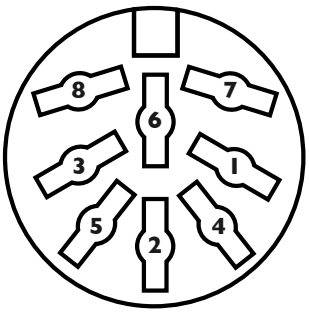
Commodore Audio/Video

This describes the 8-pin Commodore Audio/Video connector, used by most Commodore 64s, all Commodore 128s, and the C64U. (The VIC-20 and early Commodore 64s use a 5-pin Audio/Video connector.)

The connector is a full-size 8-pin 262° DIN. Note that this is different from the 270° DIN connector found on MIDI cables. Be sure to use an A/V cable designed for use with Commodore computers.

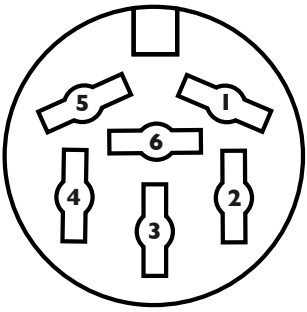
The Commodore 64 Ultimate treats pins 3 and 5 as stereo audio output, left and right channels respectively. The original Commodore 64 offered only monaural audio output on pin 3 and nominally described pin 5 as an audio input. The C64U does not support audio input over this port. Audio output uses "line out" levels.

The Commodore 64 Ultimate supports an alternate mode for this port, known as "RGB" mode. You can select this mode in Advanced Settings, U64 Specific Settings, Analog Video Mode. RGB mode supports analog video adapters that need separate red, green, and blue signals, such as a SCART adapter. Be sure to use "CVBS + S-Video" mode (the default) when using a composite or S-Video cable.



Pin	CVBS + S-Video mode	RGB mode
1	Luminance (Y)	Green
2	Ground	Ground
3	Audio out left	Audio out left
4	Composite video (Y+C)	Red
5	Audio out right	Audio out right
6	Chrominance (C)	Blue
7	Not connected	Csync
8	Not connected	Fast switching

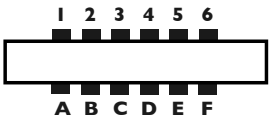
IEC Serial Port



Pin	Type
1	SERIAL $\overline{\text{SRQIN}}$
2	GND
3	SERIAL ATN IN/OUT
4	SERIAL CLK IN/OUT
5	SERIAL DATA IN/OUT
6	$\overline{\text{RESET}}$

Cassette

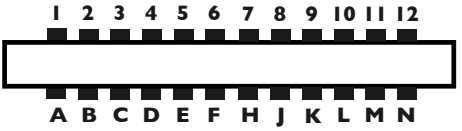
The Datassette connector has a key notch between pins B-2 and C-3, to orient the Datassette plug.



Pin	Type
A-1	GND
B-2	+5V
C-3	Cassette Motor
D-4	Cassette Read
E-5	Cassette Write
F-6	Cassette Sense

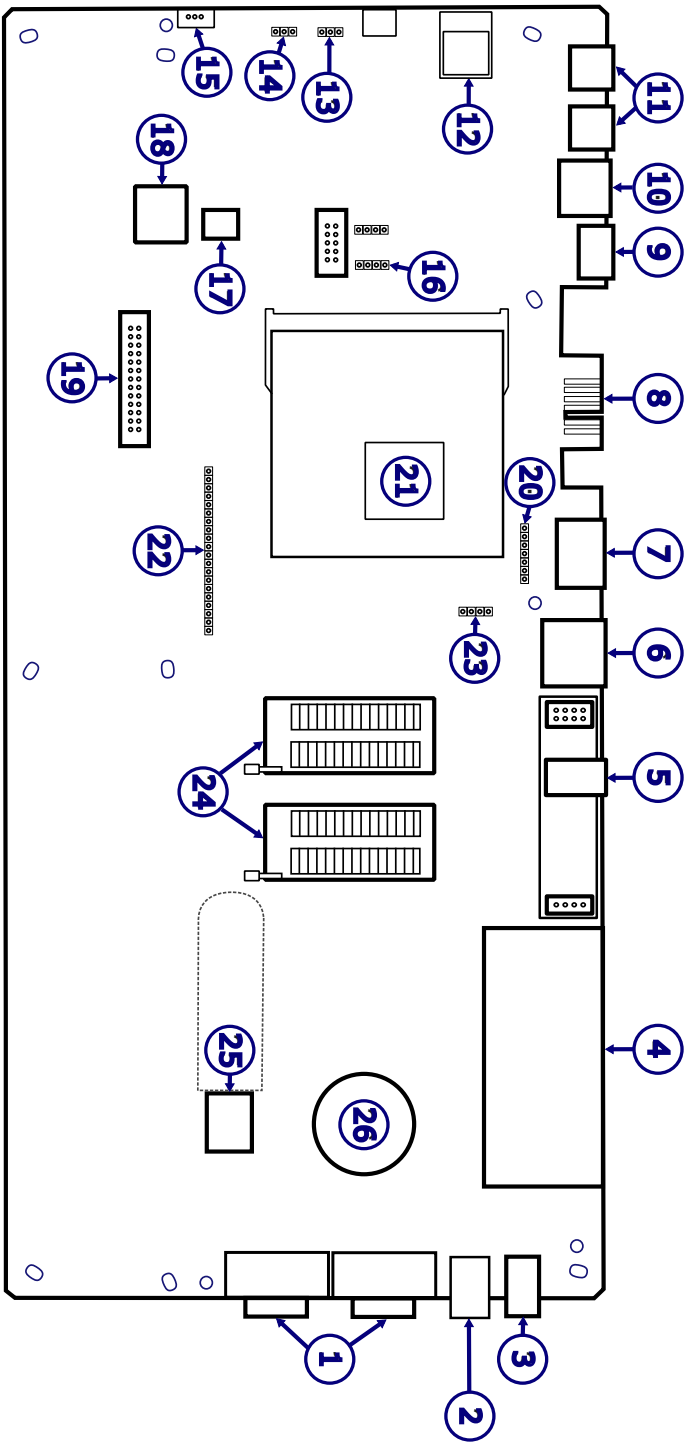
User Port

This port is provided by the C64U User Port adapter, available from the Commodore International website: **commodore.net**



Pin	Type	Note
1	GND	
2	+5V	MAX 100mA
3	$\overline{\text{RESET}}$	
4	CNTI	
5	SP1	
6	CNT2	
7	SP2	
8	$\overline{\text{PC2}}$	
9	SER ATN IN	
10	9V AC	MAX 100mA
11	9V AC	MAC 100mA
12	GND	
A	GND	
B	$\overline{\text{FLAG2}}$	
C	PB0	
D	PB1	
E	PB2	
F	PB3	
H	PB4	
J	PB5	
K	PB6	
L	PB7	
M	PA2	
N	GND	

The C64U Mainboard



Mainboard connections and components:

1. Control (Game) ports
2. Multi Function Switch
3. Power socket
4. Cartridge slot
5. 3.5mm audio line output / optical S/PDIF
6. Commodore 64 video output
7. IEC serial port
8. Cassette interface
9. HDMI® video output
10. Ethernet
11. USB storage
12. Wi-Fi module
13. Keyboard lighting output (equipped models only)
14. Case lighting output (equipped models only)
15. Case lighting strip (equipped models only)
16. Utility buttons
17. C64U keyboard connector
18. SD card slot
19. User port connector
20. IEC header
21. FPGA unit
22. Commodore 64 keyboard connector
23. Multi-color power LED
24. SID chip sockets
25. USB storage (USB-A)
26. Internal speaker

Connection notes:

- **3: Power socket.** The power connection expects a 12 volt DC supply capable of 2.5 amps (30 watts) for models with LED case lighting, or 1.25 amps (15 watts) for models without LED case lighting. The supply must be center-positive.
- **16: Utility buttons.** Connections for dedicated "reset," "menu," and "freeze" buttons.
- **17: C64U keyboard connector.** Only connect the C64U keyboard to this connector. Though this uses a USB type C connector, it is not a general purpose USB port.
- **18: SD card slot.** Insert a microSD card to serve as internal storage accessible from the Disk File Browser, similar to USB storage.
- **19: User port connector.** See the website for information on how to purchase an adapter that provides a Commodore 64-style user port. The adapter connects here.
- **22: Commodore 64 keyboard connector.** Orient the black wire to the leftmost pin, as seen from the front of the computer.

- **23: Multi-color power LED.** The four pins support a two-pin power LED (power only), a three-pin two-color LED (power and disk activity), or a four-pin RGB LED. Connections always use the rearmost pins, as indicated.
- **24: SID chip sockets.** You can install vintage SID chips or modern equivalents to supplement the FPGA UltiSIDs. Lift the ZIF socket lock, then insert the SID chip with the notch toward the back of the computer. Secure the chip by setting the socket lock in the down position, parallel to the mainboard.
- **25: USB storage.** Connect a USB storage device to the upper USB-A port to serve as additional internal storage accessible from the Disk File Browser, similar to the external USB storage ports. Only the upper port is active.

Ports not labeled above are for factory use only. Connecting anything to the unlabeled ports may damage the computer.

APPENDIX H

PROGRAMS TO TRY

We've included a number of useful programs for you to try with your Commodore 64. These programs will prove both entertaining and useful.

JOTTO

```
100 PRINTCHR$(17):PRINT"JOTTO JIM BUTTERFIELD"
120 PRINTCHR$(17):INPUT"WANT INSTRUCTIONS";Z$:IFASC(Z$)=78 GOTO250
130 PRINTCHR$(17):PRINT"TRY TO GUESS THE MYSTERY 5-LETTER WORD"
140 PRINTCHR$(17):PRINT"YOU MUST GUESS ONLY LEGAL 5-LETTER"
150 PRINT"WORDS, TOO..."
160 PRINT"YOU WILL BE TOLD THE NUMBER OF MATCHES"
170 PRINT"(OR 'JOTS') OF YOUR GUESS."
180 PRINTCHR$(17):PRINT"HINT: THE TRICK IS TO VARY SLIGHTLY"
190 PRINT" FROM ONE GUESS TO THE NEXT; SO THAT"
200 PRINT" IF YOU GUESS 'BATCH' AND GET 2 JOTS"
210 PRINT" YOU MIGHT TRY 'BOTCH' OR 'CHART'"
220 PRINT" FOR THE NEXT GUESS..."
250 DATA BXBSF,IPCCZ,DBDIF,ESFBE,PGGBM
260 DATA HPSHF,IBUDI,DJWJM,KPMMZ,LBZBL
270 DATA SBKBI,MFWFM,NJNJD,BOOFY,GJGFS
280 DATA RVFTU,SJWFS,GSFTT,PUUFS,FWFOU
290 DATA XFBWF,FYUPM,NVTIZ,AFCSB,GJAAZ
300 DATA UIJDL,ESVOL,GMPPE,UJHFS,GBLFS
310 DATA CPPUI,MZJOH,TRVBU,HBVAF,PXJOH
320 DATA UISFF,TJHIU,BYMFT,HSVNQ,BSFOB
330 DATA RVBSU,DSFFQ,CFMDI,GSFTT,TGBSL
```

```
340 DATA SBEBS,SVSBM,TNFMM,GSPXO,ESJGU
400 N=50
410 DIMN$(N),Z(5),Y(5)
420 FORJ=1TON:READN$(J):NEXTJ
430 T=TI
440 T=T/1000:IFT>=1THENGOTO440
450 Z=RND(-T)
500 G=0:N$=N$(RND(1)*N+1)
510 PRINTCHR$(17):PRINT"I HAVE A FIVE LETTER WORD:":IFR>0GOTO 560
520 PRINT"GUESS (WITH LEGAL WORDS)"
530 PRINT"AND I'LL TELL YOU HOW MANY"
540 PRINT"'JOTS', OR MATCHING LETTERS,"
550 PRINT"YOU HAVE..."
560 G=G+1:INPUT"YOUR WORD";Z$
570 IFLEN(Z$)<>5THENPRINT"YOU MUST GUESS A 5-LETTER WORD!":GOTO 560
580 V=0:H=0:M=0
590 FORJ=1TO5
600 Z=ASC(MID$(Z$,J,1)):Y=ASC(MID$(N$,J,1))-1:IFY=64THENY=90
610 IFZ<65ORZ>90THENPRINT"THAT'S NOT A WORD!":GOTO560
620 IFZ=65ORZ=69ORZ=73ORZ=79ORZ=85ORZ=89THENV=V+1
630 IFZ=YTHENM=M+1
640 Z(J)=Z:Y(J)=Y:NEXTJ
650 IFM=5GOTO800
660 IFV=0ORV=5THENPRINT"COME ON-WHAT KIND OF A WORD IS THAT?":
GOTO560
670 FORJ=1TO5:Y=Y(J)
680 FORK=1TO5:IFY=Z(K)THENH=H+1:Z(K)=0:GOTO700
690 NEXTK
700 NEXTJ
710 PRINTCHR$(145):PRINT">>>";H;"JOTS"
720 IFG<30GOTO560
730 PRINT"I'D BETTER TELL YOU. WORD WAS'"
740 FORJ=1TO5:PRINTCHR$(Y(J));:NEXTJ
750 PRINT"'":GOTO810
800 PRINT"YOU GOT IT IN ONLY";G;"GUESSES."
810 PRINTCHR$(17):INPUT"ANOTHER WORD";Z$
820 R=1:IFASC(Z$)<>78GOTO500
```

SEQUENCE

```
1 REM *** SEQUENCE
2 REM
3 REM *** FROM PET USER GROUP
4 REM *** SOFTWARE EXCHANGE
5 REM *** PO BOX 371
6 REM *** MONTGOMERYVILLE, PA 18936
7 REM ***
50 DIMA$(26)
100 Z$="ABCDEFGHIJKLMNOPQRSTUVWXYZ"
110 Z1$="12345678901234567890123456"
200 PRINT"▚▚▚ENTER LENGTH OF STRING TO BE SEQUENCED▚"
220 INPUT"MAXIMUM LENGTH IS 26 ";S%
230 IF S%<1 OR S%>26 THEN 200
240 S=S%
300 FOR I=1 TO S
310 A$(I)=MID$(Z$,I,1)
320 NEXT I
400 REM RANDOMIZE STRING
420 FOR I=1 TO S
430 K=INT(RND(1)*S+1)
440 T$=A$(I)
450 A$(I)=A$(K)
460 A$(K)=T$
470 NEXT I
480 GOSUB 950
595 T=0
600 REM RVERSE SUBSTRING
605 T=T+1
610 INPUT "HOW MANY TO REVERSE ";R%
620 IF R%=0 GOTO 900
630 IF R%>0 AND R%<=S GOTO 650
640 PRINT "MUST BE BETWEEN 1 AND ";S: GOTO 610
650 R=INT(R%/2)
660 FOR I=1 TO R
670 T$=A$(I)
680 A$(I)=A$(R%-I+1)
690 A$(R%-I+1)=T$
700 NEXT I
```

```
750 GOSUB 950
800 C=1: FOR I=2 TO S
810 IF A$(I)>A$(I+1) GOTO 830
820 C=0
830 NEXT I
840 IF C=0 GOTO 600
850 PRINT "▯YOU DID IT IN ";T;" TRIES"
900 REM CHECK FOR ANOTHER GAME
910 INPUT "▯WANT TO PLAY AGAIN ";Y$
920 IF LEFT$(Y$,1)="Y" OR Y$="OK" OR Y$="1" GOTO 200
930 END
950 PRINT
960 PRINT LEFT$(Z1$,S)
970 FOR I=1 TO S: PRINT A$(I);: NEXT I
980 PRINT "▯"
990 RETURN
```

This program courtesy of Gene Deals

PIANO KEYBOARD

```
5 REM PIANO KEYBOARD
10 POKE 53281,0:POKE 53280,0
100 PRINT"▚ ▛ ▟ ▟ ▌ ▟ ▟ ▟ ▌ ▟ ▟ ▌ ▟ ▟ ▌ "
110 PRINT" ▛ ▟ ▟ ▌ ▟ ▟ ▟ ▌ ▟ ▟ ▌ ▟ ▟ ▌ "
120 PRINT" ▛ ▟ ▟ ▌ ▟ ▟ ▟ ▌ ▟ ▟ ▌ ▟ ▟ ▌ "
130 PRINT" ▛ ▌ ▌ ▌ ▌ ▌ ▌ ▌ ▌ ▌ ▌ ▌ ▌ "
140 PRINT" ▛Q▌W▌E▌R▌T▌Y▌U▌I▌O▌P▌@▌*▌↑"
150 PRINT"▯'SPACE' FOR SOLO OR POLYPHONIC"
160 PRINT"▯'F1,F3,F5,F7' OCTAVE SELECTION"
170 PRINT"▯'F2,F4,F6,F8' WAVEFORM"
175 PRINT"▯ PRESS X TO PLAY A TUNE▯"
180 PRINT"HANG ON, SETTING UP FREQUENCY TABLE..."
190 S=13*4096+1024:DIMF(26):DIMK(255)
200 FORI=0TO28:POKES+I,0:NEXT
210 FI=7040:FORI=1TO26:F(27-I)=FI*5.8+30:FI=FI/2^(1/12):NEXT
220 K$="Q2W3ER5T6Y7UI9O0P@-*£^"
230 FORI=1TOLEN(K$)
235 K(ASC(MID$(K$,I)))=I:NEXT
240 PRINT"▢                                        "
```

```
250 AT=0:DE=0:SU=15:RE=10:SR=SU*16+RE:AD=AT*16+DE:
WV=16:W=0:M=1:OC=4:HB=256:Z=0
260 FORI=0TO2:T=I*7:POKES+5+T,AD:POKES+6+T,SR
270 POKES+2+T,15:POKES+3+T,15:NEXT
280 POKES+24,15
300 GETA$:IFA$=""THEN300
310 FR=K(ASC(A$)):IFFR=ZTHEN500
315 FR=F(FR)/M:T=V*7:CR=S+T+4
320 POKES+5+T,Z:POKES+6+T,Z
330 POKECR,8:POKECR,Z
340 POKES+T,FR-HB*INT(FR/HB)
350 POKES+1+T,FR/HB
360 POKES+5+T,AD:POKES+6+T,SR
370 POKECR,WV+1:FORI=1TO50*AT:NEXT
375 POKECR,WV
380 IFP=1THENV=V+1:IFV=3THENV=0
400 GOTO300
500 IFA$="▀"THENM=1:OC=4:GOTO300
510 IFA$="▬"THENM=2:OC=3:GOTO300
520 IFA$="▌"THENM=4:OC=2:GOTO300
530 IFA$="▐"THENM=8:OC=1:GOTO300
540 IFA$="▛"THENW=0:WV=16:GOTO300
550 IFA$="▜"THENW=1:WV=32:GOTO300
560 IFA$="▟"THENW=2:WV=64:GOTO300
570 IFA$="■"THENW=3:WV=128:GOTO300
580 IFA$=" "THENP=1-P:GOTO300
585 IFA$="X"THEN10000
590 IFA$="▚"THEN200
600 GOTO 300
800 PRINT"HIT A KEY"
810 GETA$:IFA$=""THEN810:WAIT FOR A KEY
820 PRINTA$:RETURN
9000 DATA 40,17,15,17,13,17,12,17,10,
17,8,17,6,17,15,13,15,15,13,15,12
9005 DATA 15,10,15,8,15,6,15,5,15,13,
12,13,13,12,13,10,13,8,13,6,13,5,13,4,13
9006 DATA 12,10,12,12
9010 DATA 10,12,9,12,7,12,5,12,3,12,1,12
9020 DATA 10,8,10,0
9600 DATA 40,12,8,10,12,15,13,13,17,15,15,20
9610 DATA 19,20,15,12,8,10,12,13,15,17,15,13,12,10,12,8,7,8,10,3
```

```
9620 DATA 7,10,13,12,10
9630 DATA 12,8,10,12,15,13,13,17,15,15,20
9640 DATA 19,20,15,12,8,10,12
9650 DATA 5,15,13,12,10,8,3,8,7,8,12,15,20,15,12,8
9660 DATA 12,15,18,15,12,8,12,15,17,13,10
9670 DATA 7,10,13,15,12,8,5,8,12,13,10,7,3,7,10,13,12,10
9680 DATA 8,12,15,20,0
9999 DATA -1,-1
10000 READTE
10005 READA:IFA=ZTHEN300
10015 FR=F(A)/M:T=V*7:CR=S+T+4
10020 POKES+5+T,Z:POKES+6+T,Z
10030 POKECR,8:POKECR,Z
10040 POKES+T,FR-HB*INT(FR/HB)
10050 POKES+1+T,FR/HB
10060 POKES+5+T,AD:POKES+6+T,SR
10070 POKECR,WV+1:FORI=1TO50*AT:NEXT
10075 POKECR,WV
10080 IFP=1THENV=V+1:IFV=3THENV=0
10090 FORI=1TOTE:NEXT
10100 GOTO10005
```

NOTES:

Line 100 uses (SHIFT CLR/HOME) (CTRL 9, CTRL]), (SHIFT B)
Line 150 uses (CRSR DOWN)
Line 240 uses (CRSR UP)
Line 500 uses (f1)
Line 510 uses (f3)
Line 520 uses (f5)
Line 530 uses (f7)
LIne 540 uses (f2)
Line 550 uses (f4)
Line 560 uses (f6)
Line 570 uses (f8)
Line 590 uses (SHIFT CLR/HOME)

APPENDIX I

ERROR MESSAGES

This appendix contains a complete list of the error messages generated by the Commodore 64, with a description of causes.

BAD DATA	String data was received from an open file, but the program was expecting numeric data.
BAD SUBSCRIPT	The program was trying to reference an element of an array whose number is outside of the range specified in the DIM statement.
BREAK	Program execution was stopped because you hit the RUN/STOP key.
CAN'T CONTINUE	The CONT command will not work, either because the program was never RUN, there has been an error, or a line has been edited.
DEVICE NOT PRESENT	The required I/O device was not available for an OPEN, CLOSE, CMD, PRINT#, INPUT#, or GET#.
DIVISION BY ZERO	Division by zero is a mathematical oddity and not allowed.
EXTRA IGNORED	Too many items of data were typed in response to an INPUT statement. Only the first few items were accepted.
FILE NOT FOUND	If you were looking for a file on tape, and END-OF-TAPE marker was found. If you were looking on disk, no file with that name exists.
FILE NOT OPEN	The file specified in a CLOSE, CMD, PRINT#, INPUT#, or GET#, must first be OPENed.
FILE OPEN	An attempt was made to open a file using the number of an already open file.

FORMULA TOO COMPLEX	The string expression being evaluated should be split into at least two parts for the system to work with, or a formula has too many parentheses.
ILLEGAL DIRECT	The INPUT statement can only be used within a program, and not in direct mode.
ILLEGAL QUANTITY	A number used as the argument of a function or statement is out of the allowable range.
LOAD	There is a problem with the program on tape.
NEXT WITHOUT FOR	This is caused by either incorrectly nesting loops or having a variable name in a NEXT statement that doesn't correspond with one in a FOR statement.
NOT INPUT FILE	An attempt was made to INPUT or GET data from a file which was specified to be for output only.
NOT OUTPUT FILE	An attempt was made to PRINT data to a file which was specified as input only.
OUT OF DATA	A READ statement was executed but there is no data left unREAD in a DATA statement.
OUT OF MEMORY	There is no more RAM available for program or variables. This may also occur when too many FOR loops have been nested, or when there are too many GOSUBs in effect.
OVERFLOW	The result of a computation is larger than the largest number allowed, which is 1.70141884E+38.
REDIM'D ARRAY	An array may only be DIMensioned once. If an array variable is used before that array is DIM'd, an automatic DIM operation is performed on that array setting the number of elements to ten, and any subsequent DIMs will cause this error.
REDO FROM START	Character data was typed in during an INPUT statement when numeric data was expected. Just re-type the entry so that it is correct, and the program will continue by itself.
RETURN WITHOUT GOSUB	A RETURN statement was encountered, and no GOSUB command has been issued.
STRING TOO LONG	A string can contain up to 255 characters.
SYNTAX ERROR	A statement is unrecognizable by the Commodore 64. A missing or extra parenthesis, misspelled keywords, etc.
TYPE MISMATCH	This error occurs when a number is used in place of a string, or vice-versa.

UNDEF'D FUNCTION	A user defined function was referenced, but it has never been defined using the DEF FN statement.
UNDEF'D STATEMENT	An attempt was made to GOTO or GOSUB or RUN a line number that doesn't exist.
VERIFY	The program on tape or disk does not match the program currently in memory.

APPENDIX J

MUSIC NOTE VALUES

This appendix contains a complete list of Note#, actual note, and the values to be POKED into the HI FREQ and LOW FREQ registers of the sound chip to produce the indicated note. The table shows values based on both a system clock of 1.02 MHz (shown as NTSC) and 0.985 MHz (shown as PAL).

MUSICAL NOTE		OSCILLATOR FREQ (NTSC)			OSCILLATOR FREQ (PAL)		
NOTE	OCTAVE	DECIMAL	HI	LOW	DECIMAL	HI	LOW
0	C-0	268	1	12	278	1	22
1	C#-0	284	1	28	294	1	38
2	D-0	301	1	45	312	1	56
3	D#-0	318	1	62	331	1	75
4	E-0	337	1	81	350	1	94
5	F-0	358	1	102	371	1	115
6	F#-0	379	1	123	393	1	137
7	G-0	401	1	145	417	1	161
8	G#-0	425	1	169	441	1	185
9	A-0	451	1	195	468	1	212
10	A#-0	477	1	221	496	1	240
11	B-0	506	1	250	525	2	13
16	C-1	536	2	24	556	2	44
17	C#-1	568	2	56	589	2	77
18	D-1	602	2	90	625	2	113
19	D#-1	637	2	125	662	2	150
20	E-1	675	2	163	701	2	189
21	F-1	716	2	204	743	2	231
22	F#-1	758	2	246	787	3	19

MUSICAL NOTE		OSCILLATOR FREQ (NTSC)			OSCILLATOR FREQ (PAL)		
NOTE	OCTAVE	DECIMAL	HI	LOW	DECIMAL	HI	LOW
23	G-1	803	3	35	834	3	66
24	G#-1	851	3	83	883	3	115
25	A-1	902	3	134	936	3	168
26	A#-1	955	3	187	992	3	224
27	B-1	1012	3	244	1051	4	27
32	C-2	1072	4	48	1113	4	89
33	C#-2	1136	4	112	1179	4	155
34	D-2	1204	4	180	1250	4	226
35	D#-2	1275	4	251	1324	5	44
36	E-2	1351	5	71	1403	5	123
37	F-2	1432	5	152	1486	5	206
38	F#-2	1517	5	237	1575	6	39
39	G-2	1607	6	71	1668	6	132
40	G#-2	1703	6	167	1767	6	231
41	A-2	1804	7	12	1873	7	81
42	A#-2	1911	7	119	1984	7	192
43	B-2	2025	7	233	2102	8	54
48	C-3	2145	8	97	2227	8	179
49	C#-3	2273	8	225	2359	9	55
50	D-3	2408	9	104	2500	9	196
51	D#-3	2551	9	247	2649	10	89
52	E-3	2703	10	143	2806	10	246
53	F-3	2864	11	48	2973	11	157
54	F#-3	3034	11	218	3150	12	78
55	G-3	3215	12	143	3337	13	9
56	G#-3	3406	13	78	3535	13	207
57	A-3	3608	14	24	3746	14	162
58	A#-3	3823	14	239	3969	15	129
59	B-3	4050	15	210	4205	16	109
64	C-4	4291	16	195	4455	17	103
65	C#-4	4547	17	195	4719	18	111
66	D-4	4817	18	209	5000	19	136
67	D#-4	5103	19	239	5298	20	178
68	E-4	5407	21	31	5613	21	237
69	F-4	5728	22	96	5946	23	58
70	F#-4	6069	23	181	6300	24	156
71	G-4	6430	25	30	6675	26	19
72	G#-4	6812	26	156	7071	27	159
73	A-4	7217	28	49	7492	29	68

MUSICAL NOTE		OSCILLATOR FREQ (NTSC)			OSCILLATOR FREQ (PAL)		
NOTE	OCTAVE	DECIMAL	HI	LOW	DECIMAL	HI	LOW
74	A#-4	7647	29	223	7938	31	2
75	B-4	8101	31	165	8410	32	218
80	C-5	8583	33	135	8910	34	206
81	C#-5	9094	35	134	9439	36	223
82	D-5	9634	37	162	10001	39	17
83	D#-5	10207	39	223	10596	41	100
84	E-5	10814	42	62	11226	43	218
85	F-5	11457	44	193	11893	46	117
86	F#-5	12139	47	107	12600	49	56
87	G-5	12860	50	60	13350	52	38
88	G#-5	13625	53	57	14143	55	63
89	A-5	14435	56	99	14985	58	137
90	A#-5	15294	59	190	15876	62	4
91	B-5	16203	63	75	16820	65	180
96	C-6	17167	67	15	17820	69	156
97	C#-6	18188	71	12	18879	73	191
98	D-6	19269	75	69	20002	78	34
99	D#-6	20415	79	191	21192	82	200
100	E-6	21629	84	125	22452	87	180
101	F-6	22915	89	131	23787	92	235
102	F#-6	24278	94	214	25201	98	113
103	G-6	25721	100	121	26700	104	76
104	G#-6	27251	106	115	28287	110	127
105	A-6	28871	112	199	29970	117	18
106	A#-6	30588	119	124	31752	124	8
107	B-6	32407	126	151	33640	131	104
112	C-7	34334	134	30	35640	139	56
113	C#-7	36376	142	24	37759	147	127
114	D-7	38539	150	139	40005	156	69
115	D#-7	40830	159	126	42384	165	144
116	E-7	43258	168	250	44904	175	104
117	F-7	45830	179	6	47574	185	214
118	F#-7	48556	189	172	50403	196	227
119	G-7	51443	200	243	53400	208	152
120	G#-7	54502	212	230	56575	220	255
121	A-7	57743	225	143	59940	234	36
122	A#-7	61176	238	248	63504	248	16
123	B-7	64814	253	46	-	-	-

FILTER SETTINGS

Location	Contents
54293	Low cutoff frequency (0 - 7)
54294	High cutoff frequency (0 - 255)
54295	Resonance (bits 4 - 7) Filter Voice 3 (bit 2) Filter Voice 2 (bit 1) Filter Voice 1 (bit 0)
54296	High Pass (bit 6) Bandpass (bit 5) Low pass (bit 4) Volume (bits 0 - 3)

APPENDIX K

SPRITE REGISTER MAP

Register # Dec	Hex	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
0	0	S0X7							S0X0	SPRITE 0 X Component
1	1	S0Y7							S0Y0	SPRITE 0 Y Component
2	2	S1X7							S1X0	SPRITE 1 X
3	3	S1Y7							S1Y0	SPRITE 1 Y
4	4	S2X7							S2X0	SPRITE 2 X
5	5	S2Y7							S2Y0	SPRITE 2 Y
6	6	S3X7							S3X0	SPRITE 3 X
7	7	S3Y7							S3Y0	SPRITE 3 Y
8	8	S4X7							S4X0	SPRITE 4 X
9	9	S4Y7							S4Y0	SPRITE 4 Y
10	A	S5X7							S5X0	SPRITE 5 X
11	B	S5Y7							S5Y0	SPRITE 5 Y
12	C	S6X7							S6X0	SPRITE 6 X
13	D	S6Y7							S6Y0	SPRITE 6 Y
14	E	S7X7							S7X0	SPRITE 7 X Component
15	F	S7Y7							S7Y0	SPRITE 7 Y Component
16	10	S7X8	S6X8	S5X8	S4X8	S3X8	S2X8	S1X8	S0X8	MSB of X COORD.
17	11	RC8	ECM	BMM	BLNK	RSEL	YSCL2	YSCL1	YSCL0	Y SCROLL MODE
18	12	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	RASTER
19	13	LPX7							LPX0	LIGHT PEN X
20	14	LPY7							LPY0	LIGHT PEN Y
21	15	SE7							SE0	SPRITE ENABLE ON/OFF
22	16	N.C.	N.C.	RST	MCM	CSEL	XSCL2	XSCL1	XSCL0	X SCROLL MODE

Register # Dec	Hex	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
23	17	SEXY7							SEXY0	SPRITE EXPAND Y
24	18	VS13	VS12	VS11	VS10	CB13	CB12	CB11	N.C.	SCREEN Character Memory
25	19	IRQ	N.C.	N.C.	N.C.	LPIRQ	ISSC	ISBC	RIRQ	Interrupt Requests
26	1A	N.C.	N.C.	N.C.	N.C.	MLPI	MISSC	MISBC	MRIRQ	Interrupt Requests MASKS
27	1B	BSP7							BSP0	Background Sprite Priority
28	1C	SCM7							SCM0	Multicolor Sprite Select
29	1D	SEXX7							SEXX0	SPRITE EXPAND X
30	1E	SSC7							SSC0	Sprite-Sprite Collision
31	1F	SBC7							SBC0	Sprite-Background COLLISION

COLOR REGISTERS

32	20	Border
33	21	Background 0
34	22	Background 1
35	23	Background 2
36	24	Background 3
37	25	Sprite Multicolor 0
38	26	Sprite Multicolor 1
39	27	Sprite 0 color
40	28	1
41	29	2
42	2A	3
43	2B	4
44	2C	5
45	2D	6
46	2E	7

Only colors 0-7 may be used in multicolor character mode.

COLOR CODES

0	0	BLACK	8	8	ORANGE
1	1	WHITE	9	9	BROWN
2	2	RED	10	A	LT RED
3	3	CYAN	11	B	GRAY 1
4	4	PURPLE	12	C	GRAY 2
5	5	GREEN	13	D	LT GREEN
6	6	BLUE	14	E	LT BLUE
7	7	YELLOW	15	F	GRAY 3

APPENDIX L

COMMODORE 64 SOUND CONTROL SETTINGS

This handy table gives you the key numbers you need to use in your sound programs, according to which of the Commodore 64's 3 voices you want to use. To set or adjust a sound control in your BASIC program, just POKE the number from the second column, followed by a comma (,) and a number from the chart...like this: POKE 54276,17 (Selects a Triangle Waveform for VOICE 1).

Remember that you must set the VOLUME before you can generate sound. POKE 54296 followed by a number from 0 to 15 sets the volume for all 3 voices.

It takes 2 separate POKEs to generate each musical note...for example POKE 54273,34 : POKE 54272,75 designates low C in the sample scale below.

Also...you aren't limited to the numbers shown in the tables. If 34 doesn't sound "right" for a low C, try 35. To provide a higher SUSTAIN or ATTACK rate than those shown, add two or more SUSTAIN numbers together. (Examples: POKE 54277,96 combines two attack rates (32 and 64) for a combined higher attack rate...but...POKE 54277,20 provides a low attack rate (16) and a medium decay rate (4).

SETTING VOLUME — SAME FOR ALL 3 VOICES		
VOLUME CONTROL	POKE 54296	Settings range from 0 (off) to 15 (loudest)

VOICE NUMBER 1

TO CONTROL THIS SETTING	POKE THIS NUMBER	FOLLOWED BY ONE OF THESE NUMBERS (0 to 15...or 0 to 255 depending on range)													
TO PLAY A NOTE		C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#
HIGH FREQUENCY	54273	34	36	38	40	43	45	48	51	54	57	61	64	68	72
LOW FREQUENCY	54272	75	85	126	200	52	198	127	97	111	172	126	188	149	169

WAVEFORM	POKE	TRIANGLE	SAWTOOTH	PULSE	NOISE
	54276	17	33	65	129

PULSE RATE (PULSE WAVEFORM)		
HI PULSE	54275	A value of 0 to 15 (for Pulse waveform only)
LO PULSE	54274	A value of 0 to 255 (for Pulse waveform only)

ATTACK/DECAY	POKE	ATK4	ATK3	ATK2	ATK1	DEC4	DEC3	DEC2	DEC1
	54277	128	64	32	16	8	4	2	1
SUSTAIN/RELEASE	POKE	SUS4	SUS3	SUS2	SUS1	REL4	REL3	REL2	REL1
	54278	128	64	32	16	8	4	2	1

VOICE NUMBER 2

TO PLAY A NOTE		C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#
HIGH FREQUENCY	54280	34	36	38	40	43	45	48	51	54	57	61	64	68	72
LOW FREQUENCY	54279	75	85	126	200	52	198	127	97	111	172	126	188	149	169

WAVEFORM	POKE	TRIANGLE	SAWTOOTH	PULSE	NOISE
	54283	17	33	65	129

PULSE RATE (PULSE WAVEFORM)		
HI PULSE	54282	A value of 0 to 15 (for Pulse waveform only)
LO PULSE	54281	A value of 0 to 255 (for Pulse waveform only)

ATTACK/DECAY	POKE	ATK4	ATK3	ATK2	ATK1	DEC4	DEC3	DEC2	DEC1
	54284	128	64	32	16	8	4	2	1
SUSTAIN/RELEASE	POKE	SUS4	SUS3	SUS2	SUS1	REL4	REL3	REL2	REL1
	54285	128	64	32	16	8	4	2	1

VOICE NUMBER 3

TO PLAY A NOTE		C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#
HIGH FREQUENCY	54287	34	36	38	40	43	45	48	51	54	57	61	64	68	72
LOW FREQUENCY	54286	75	85	126	200	52	198	127	97	111	172	126	188	149	169

WAVEFORM	POKE	TRIANGLE	SAWTOOTH	PULSE	NOISE
	54290	17	33	65	129

PULSE RATE (PULSE WAVEFORM)		
HI PULSE	54289	A value of 0 to 15 (for Pulse waveform only)
LO PULSE	54288	A value of 0 to 255 (for Pulse waveform only)

ATTACK/DECAY	POKE	ATK4	ATK3	ATK2	ATK1	DEC4	DEC3	DEC2	DEC1
	54291	128	64	32	16	8	4	2	1

SUSTAIN/RELEASE	POKE	SUS4	SUS3	SUS2	SUS1	REL4	REL3	REL2	REL1
	54292	128	64	32	16	8	4	2	1

TRY THESE SETTINGS TO SIMULATE DIFFERENT INSTRUMENTS

Instrument	Waveform	Attack/Decay	Sustain/Release	Pulse Rate
Piano	Pulse	9	0	Hi-Lo, Lo-255
Flute	Triangle	96	0	Not applicable
Harpsichord	Sawtooth	9	0	Not applicable
Xylophone	Triangle	9	0	Not applicable
Organ	Triangle	0	240	Not applicable
Calliope	Triangle	0	240	Not applicable
Accordion	Triangle	102	0	Not applicable
Trumpet	Sawtooth	96	0	Not applicable

MEANINGS OF SOUND TERMS

ADSR — Attack/Decay/Sustain/Release
Attack — rate sound rises to peak volume
Decay — rate sound falls from peak volume to Sustain level
Sustain — prolong note at certain volume
Release — rate at which volume falls from Sustain level
Waveform — "shape" of sound wave
Pulse — tone quality of Pulse Waveform

NOTE: Attack/Decay and Sustain/Release settings should always be POKEd in your program **BEFORE** the Waveform is POKEd.

APPENDIX M

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