Fig.12 (left): a field-expedient vertical antenna supported by a squid pole. *Source: www.vk5pas.com/squid-poles.html*

Fig.13 (below): David's Yagi antenna (on the left; the TV antenna on the right is also a Yagi).

• the end-fed antenna, one of the simplest and easiest to get started with

• the magnetic loop antenna (Fig.14)

There are vast numbers of variations on all of those designs.

All antenna designs have advantages and disadvantages; there is no perfect antenna. For example, dipole antennas are large, especially for the lower HF frequencies. Magnetic loop antennas have a narrow resonance range (high Q) and must be retuned as you make slight adjustments to the frequency (some can do this automatically).

It has been said that "the best antenna is the one you have at the moment". Any antenna, no matter how primitive, is better than nothing; even a 10m or so length of random wire with an antenna tuner is better than nothing and can get you on the air. The higher off the ground it is, the better.

An important consideration for an antenna is the take-off angle. Operation near salt water also significantly improves range.

There is a German brand of thin wire for portable antennas called DX-Wire (**www.dx-wire.de**), which is lightweight and contains reinforcement. Quality antenna wire can be obtained from DXCommander (**siliconchip.au/link/abss**). However, by all means, try regular wire for your antenna experiments. Some people swear by speaker wire, split in two to double your length!

Antenna couplers/tuners can be purchased or made yourself. One DIY design by Peter Parker VK3YE is shown in the video "Yet another QRP L match antenna coupler" at **https://youtu.be/JwVuvu-C30c** You can search YouTube for "VK3YE coupler" without quotes to find his other designs.

It is possible to generate hundreds of volts on an antenna during transmission, so as a safety measure, they should not be touched during transmission and should be kept out of reach of people and animals.

You can simply follow some basic rules to make your own basic dipole or long-wire antennas. However, experimenters can model more advanced designs with free software such as MMANA-GAL. A free basic Windows version for non-commercial use is at **http://gal-ana.de/basicmm/en/** (see Fig.17 and the video "Our Obsession with Ham Radio Antennas" at **https://youtu.be/MSNvaDzCA1c**).

Fig.15: David's radio shack (not the author).

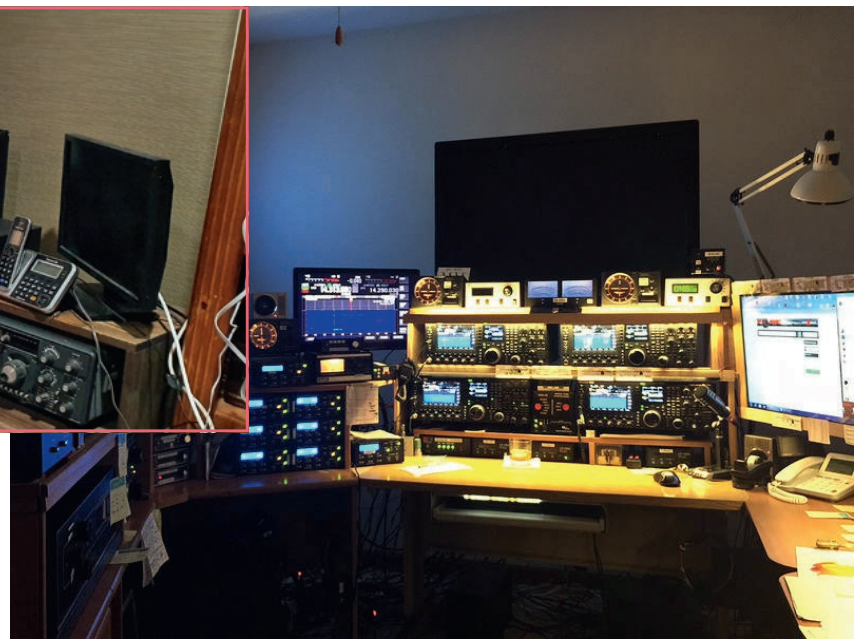


Fig.16: Stan "Stax" Schwartz (www.qrz.com/db/KE5EE) lives in Molina, Florida and has an impressive antenna farm and shack, the latter shown here. If you have the money and the land, why not?

Fig.14: a magnetic loop antenna. *Source: https://w.wiki/93Y4 (GNU FDL).*

Another free antenna modelling program is 4nec2 (www.qsl.net/4nec2). For a Linux version of NEC2, see www.xnec2c.org

EZNEC (https://eznec.com) is also free and has many tutorials, but there is no support or updates from the author, W7EL, as he has retired.

There are also many online calculators and software for all aspects of radio ham activities.

Generally, resonant antennas can be shortened to half or a quarter of a wavelength; fractions such as one-third or one-eighth are unsuitable for various reasons. An end-fed antenna should not be one-quarter wavelength long, as described online at siliconchip.au/link/abst and siliconchip.au/link/absu

Amateur Gary Watson, ZL3SV in New Zealand has a 640m-long antenna made from power line cable and hardware, as it is designed to support such great spans. See the video titled "HAM RADIO MONSTER ANTENNA – ZL3SV" at https://youtu.be/7ah95zW9-WM and his website at https://angelsnz.net/zl3sv.htm

A local ham, David, showed me his shack (Fig.15) and Yagi antenna (Fig.13).

Standing wave ratio (SWR)

The SWR measures the amount of power the antenna reflects back to the transceiver. Such power is not propagated, so the SWR should be kept as low as possible. It is minimised by correct antenna tuning and the correct use of baluns or ununs (more on them later). In general, aim for an SWR of less than 1.5:1, which indicates a 4% power loss. 2:1 represents an 11.1% power loss, while 3:1 is a 25% power loss.

For much more detail on this, see the PDF at siliconchip.au/link/absv

DIY end-fed antenna projects

The end-fed antenna is just a length of wire that may or may not be resonant depending on the frequency and whether it is fed via a balun or antenna coupler/tuner. If resonant, it can be a half-wave antenna, a so-called EFHW (end-fed half-wave).

The end-fed antenna is very versatile and cheap to make. One example is in the article by Peter Parker VK3YE at siliconchip.au/link/absw

A good video about end-fed antennas titled "End Fed Antennas – Portable, Emergency, Stealth Installations" is at https://youtu.be/Fk2vahBnfbQ

Another simple end-fed antenna project from EARC is described in the PDF at siliconchip.au/link/absx

A "squid pole" is like a telescopic fishing pole and comes in lengths up to around 10m. It is suitable for elevating lengths of lightweight wire (like hookup wire) for use in portable operations or even for home use (as I am currently doing). The Haverford squid pole is an example; see siliconchip.au/link/absy

Not all wire lengths are ideal for end-fed antennas. The best lengths are discussed at siliconchip.au/link/absz

Antenna analysers

A vector network analyser (VNA) was, until recently, an extremely expensive item of laboratory equipment to measure the amplitude and phase of a signal as it goes through a circuit. Such devices are now available to hobbyists at affordable prices. Of course, hobbyist-grade VNAs are not as good as expensive laboratory devices but they are still useful.

They are great for various amateur radio applications, such as measuring antenna SWR, impedance, frequency response, cable losses, and filter measurements.

The NanoVNA is an inexpensive VNA that uses open-source software and has a large support base. See our review from April 2020 (siliconchip.au/Article/13803). If purchasing one, make sure you get the appropriate adaptor leads for your application.

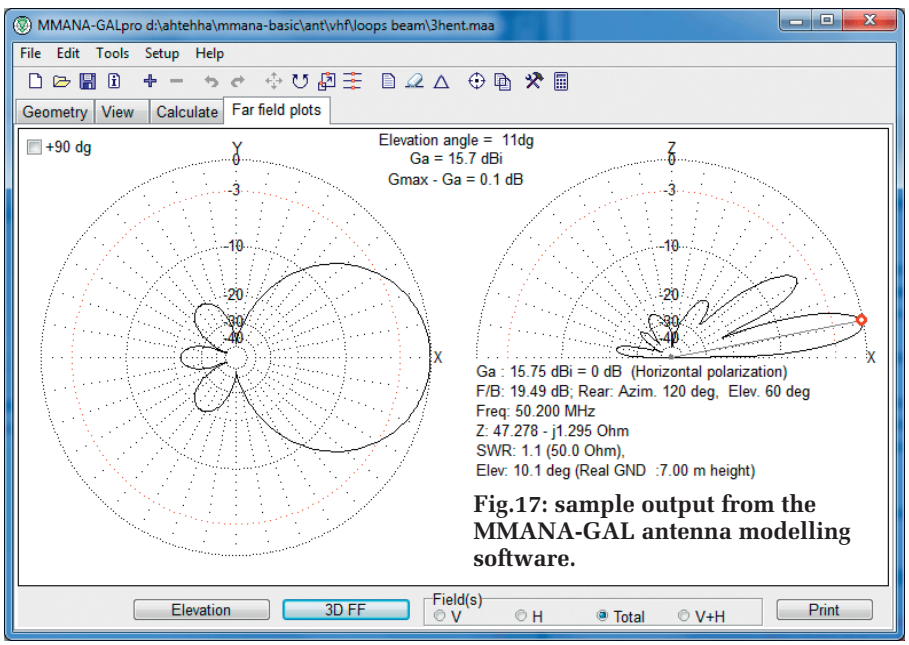


Fig.17: sample output from the MMANA-GAL antenna modelling software.

The Mini 1300 is a similar antenna analyser, optimised for that purpose.

Other devices for analysing antennas are RigExpert (**https://rigexpert.com**) and several from MFJ Enterprises (**siliconchip.au/link/abt0**). The SARK-100 is a public domain design available as various kits (**https://sites.google.com/view/sark100**), while the SARK-110 is a more advanced version (**www.sark110.com**).

Antennas in difficult situations

Most people are limited in how large an antenna they can use, so there are many ideas for compact antennas. Try searching for "stealth antennas" or "HOA antennas". Some people build antennas in their roof spaces (not suitable with a metal roof or with aluminium sarking). Others use hollow, non-metallic flagpoles, although domestic flagpoles are not terribly common in Australia.

There is a video titled "How to Build an All Band in an HOA Stealthy Backyard Broadband Antenna – Corey Ruth, KD3CR" at **https://youtu.be/lu3SDp7ZvXw**

The PDF at **siliconchip.au/link/abt1** describes a 'broadband butterfly terminated dipole' (BBTD) antenna, invented by Bonnie Crystal KQ6XA. It is a type of 'travelling wave' antenna that is non-resonant and thus broadband in nature.

Vertical antennas can be useful in restricted spaces. Peter Parker VK3YE discusses several designs on his YouTube channel (search for "VK3YE vertical" without quotes). These designs are typically used with a squid pole (mentioned earlier).

Magnetic loop antennas are also helpful in space-restricted circumstances but are resonant over only a small range of frequencies and need constant retuning with frequency changes. See the video by Peter Parker titled "100 watt 7 MHz magnetic loop for units and apartments" at **https://youtu.be/Cv_RnLpZ9gw**

Lightning protection

As a general rule, it's a good idea to disconnect the antenna from your rig when it is not in use and, if possible, lower it to minimise the possibility of damage from nearby or direct lightning strikes. Lightning surge protectors are available to place in the antenna feed line to direct excessive charge buildup to ground, but are unlikely to do much in the event of a direct strike – see Fig.18.

Remember that lightning strikes can travel many kilometres; there are limits to what you can do to avoid being hit. Do not operate a ham station during an electrical storm. For further information, see **siliconchip.au/link/abt2** (PDF) and **www.arrl.org/lightning-protection**

Baluns and ununs

'Balun' is short for balanced/unbalanced and describes a type of transformer used for RF impedance matching. The awkwardly-named 'unun' is a similar device with unbalanced windings at both ends. Some antenna designs require a balun or unun between the transceiver and the antenna, but not all do.

In ham radio, a balun matches the impedance of a balanced antenna to an unbalanced feed line (like a coaxial cable). In contrast, ununs match an unbalanced antenna to an unbalanced feedline. The feedline connects to the transceiver, which has a 50Ω impedance. The objective is to minimise SWR and losses.

Some antenna tuners require their use, as impedance matching may not

A short history of amateur radio

Amateurs have been involved in radio since Hertzian waves were discovered and utilised for communications by Marconi in the 1890s, although no licence was required then. The first commercial devices for amateur radio use (transceiver and receiver) were sold in 1905 – see below.

This is perhaps the first commercial ham radio set, in an advertisement from Scientific American, November 25th 1905, page 427.

In 1908, US amateurs started the Columbia University Amateur Radio Club. The Wireless Institute of Australia was established in 1910. In 1912, the US Government passed the Radio Act, which restricted amateurs to wavelengths of 200m or less (1500kHz or more) to preserve the radio spectrum.

Those frequencies were considered useless for commercial, military and maritime services, but amateurs discovered they could be used for long-distance communication via the ionosphere. Amateurs first communicated between the USA and Europe on 200m in 1921.

After that, amateurs were shifted to shorter wavelengths, such as 150m/2MHz, as the commercial and other importance of the medium-wave bands was recognised. In 1924, three shortwave bands were allocated to amateurs: 3.75MHz/80m, 7MHz/40m and 14MHz/20m. In 1927, 28MHz/10m was added, which amateurs still use today.

John Iringle was a 14-year-old ham radio operator from Chicago in 1922. He is in his shack with the equipment he made. *Source: http://hdl.loc.gov/loc.pnp/cph.3b39715*

Fig.18: a lightning surge protector that can direct excessive charge buildup to the ground to minimise damage from a lightning strike.

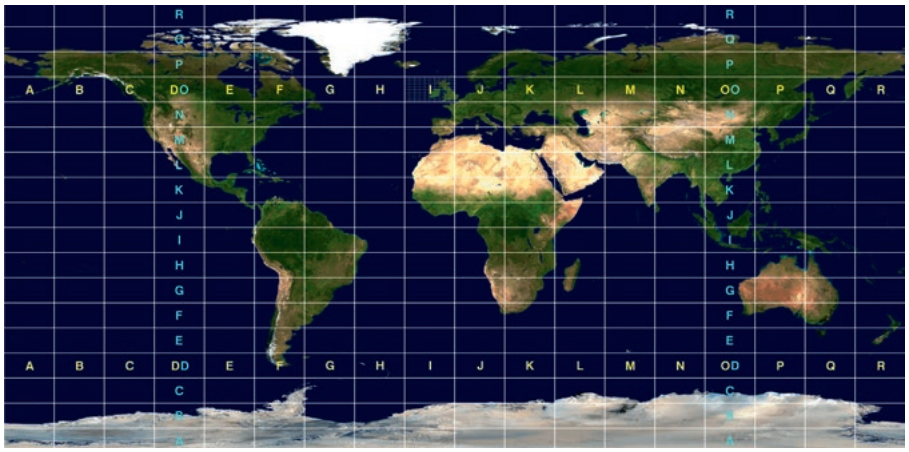


Fig.19: the 324 Maidenhead fields of the world. *Source:* https://w.wiki/93Y6

be possible with the antenna tuner alone. In other cases, such as the Icom AH-705 tuner I got with my radio, an external balun or unun is unnecessary; it appears capable of tuning and matching just about anything (within reason).

A balun is stated to have a certain ratio, which relates to the ratio of turns of the windings. The impedance transforms according to the square of the winding ratio. So a 3:1 turns balun will give a 9:1 impedance ratio, allowing you to match a 450Ω antenna or feedline impedance to a 50Ω transceiver.

There are a great many designs for these devices online; they are pretty easy to make, or you can buy them. They are basically a ferrite toroid with wires wound around it. One example of a DIY balun for an end-fed antenna is the "49:1 Impedance transformer for EFHW antenna" – siliconchip.au/link/abt3

We also found an unun kit available at siliconchip.au/link/abt4 – see the video titled "TEST: Mini 49:1 UNUN (EFHW antenna)" at https://youtu.be/OOe5EvYjiW0

Beacons

The International Beacon Project (www.ncdxf.org/beacon) has a system of transmitters worldwide, including Australia and New Zealand, that send out signals for monitoring propagation conditions. The beacons transmit on 14.100MHz, 18.110MHz, 21.150MHz, 24.930MHz and 28.200MHz.

Digital modes

The large variety of digital modes that hams can use includes:

- Digital mobile radio (DMR), a digital voice mode.
- D-STAR digital voice mode for Icom, Kenwood & FlexRadio systems.
- FreeDV (https://freedv.org), an open-source amateur digital voice mode.
- FT8, supported by WSJT-X, is a popular mode for weak signal text message communications.
- Echo is a mode supported by WSJT-X for moonbounce activities (see PDF at siliconchip.au/link/abt6).
- PSK Reporter (https://pskreporter.info) shows reception reports for a large variety of digital modes. Map data can be seen at siliconchip.au/link/abtg
- Reverse Beacon Network (www.reversebeacon.net) maps reception reports and propagation paths from stations heard by listening stations.
- VarAC (www.varac-hamradio.com) is a peer-to-peer chat program for hams developed by Irad Deutsch 4Z1AC.
- WSJT-X (https://wsjt.sourceforge.io/wsjtx.html) is a software suite that can utilise many popular digital modes such as FST4, FST4W, FT4, FT8, JT4, JT9, JT65, Q65, MSK144, WSPR and Echo.
- With WSPR (Weak Signal Propagation Reporter), a station sends out an extremely low-power digital signal that others hear and report via the internet. It enables the determination of current propagation paths. The mode is unsuitable for conversations. It is supported by WSJT-X. Some people run WSPR all the time; you can even buy a dedicated low-power transmitter to do so (www.zachtek.com/wspr-tx). You can find maps at siliconchip.au/link/abth

For additional information on digital radio, see our articles on that subject in the April and May 2021 issues (siliconchip.au/Series/360).

Maidenhead Locator System

The Maidenhead Locator System, also known as the QTH locator, grid locator or grid square, among other names, is a system used by hams to indicate their approximate location for various applications (see Fig.19). The world is divided into 324 Maidenhead fields, which themselves are further divided into 100 squares. The locator for any address can be determined at siliconchip.au/link/abt7

Using ham radio in emergencies

After Cyclone Tracy hit Darwin in 1974, communications and power were lost. It was hams who first reestablished comms links to authorities. The story is detailed at **https://armag.vk6uu.id.au/1984-dec-AR.html** (pages 14-15).

Also, from the WIA, "Amateur Radio notably handled emergency communications for the 1939 Black Friday bushfires, Cyclone Tracy in Darwin 1974, Ash Wednesday bushfires 1983, the Newcastle Earthquake 1989, and the Black Saturday disaster in February 2009. There have been numerous other rescues and searches."

The Wireless Institute Civil Emergency Network (WICEN; **https://wicen.org.au**) is an organisation of Australian hams that provides emergency communications in the event of a failure of public communications infrastructure.

The Bendigo Amateur Radio and Electronics Club (**www.barec.net.au**) also practices emergency preparedness. A report on one of their exercises is at **siliconchip.au/link/abtd**

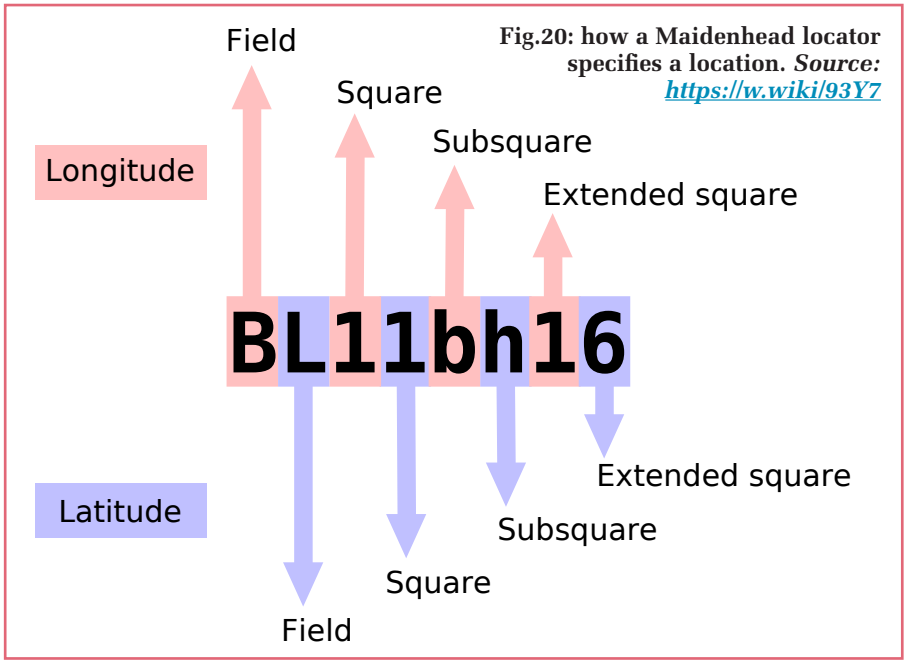


Fig.20: how a Maidenhead locator specifies a location. *Source:* https://w.wiki/93Y7

Fig.21: Hiro, VK3EHG demonstrates 'working' an amateur satellite.

Entering the SILICON CHIP office address gives a grid square ID of QF56pf. The coding of the Maidenhead locator is demonstrated in Fig.20. There are four pairs of numbers; the subsquare and extended square pairs are used for additional precision.

Amateur radio activities

The following is a small sample of possible activities apart from QSOs (conversations) and digital modes.

| Amateur satellite

It is possible to contact other hams via satellite with as little as a handheld rig. Satellite QSOs were demonstrated at the recent Rosebud Radiofest near Melbourne by Hirotaka (Hiro) Horiuchi, VK3EHG (see Fig.21). It is also possible to use SSTV to contact hams on the International Space Station.

| Distance records

A complete list of VHF and UHF distance records for Australia is available at siliconchip.au/link/abti

A record was set in the 50-54MHz band at 28,397km, between VK6JQ and TL8MB. In the THF band at 324GHz, the longest distance obtained was between VK3KH and VK3XPD with a range of 25m (they probably could have just shouted!).

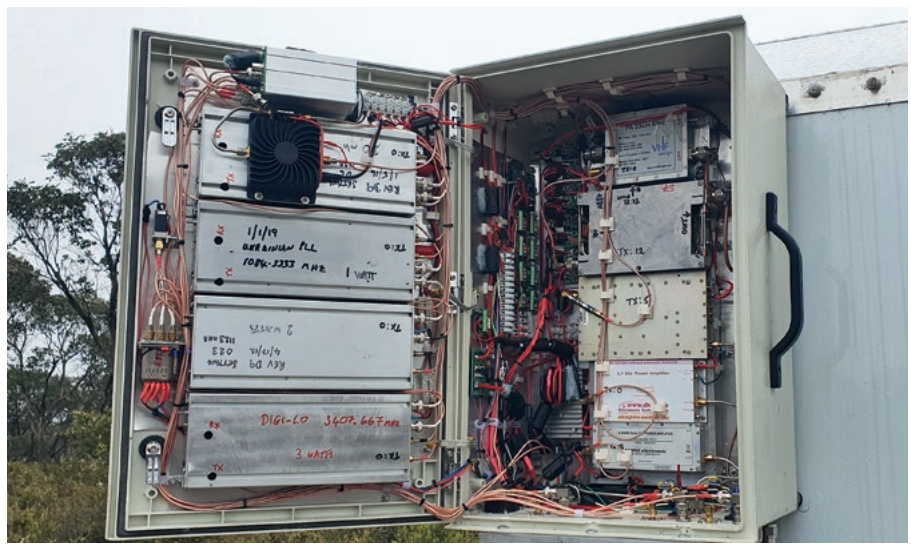
| Field days

There are many field day contest activities. Typically, the objective is to make as many contacts as possible on given frequencies.

One I visited at McLaughlins Lookout in the Wombat State Forest was run by EMDRC member Peter Forbes VK3QI, about 80 minutes' drive from Melbourne. The contest was run for VHF and UHF frequencies 50MHz to 24GHz. Around 500 contacts were

Fig.22 (left): a partial view of the (foggy) Field Day site showing some antennas, including two dishes and an equipment van. The top dish has a 24GHz amplifier and transverter behind it, while the lower dish contains preamps and an antenna for 1.2GHz – 10GHz.

Fig.23 (below): the transverters and amplifiers for 1.2GHz to 10GHz.



made over the 24 hours of the contest – see Figs.22-24.

Hamfests and radiofests

You can find a schedule on the Hamfests Australasia Facebook page (siliconchip.au/link/abt8).

Moonbounce

This activity is for advanced amateurs. Signals are bounced off the moon and returned or used to establish contact with other amateurs. There is an ABC news story about an Australian moonbounce pioneer Ray Naughton, VK3ATN at siliconchip.au/link/abt9

Another Australian pioneer was Doug McArthur VK3UM – siliconchip.au/link/abta

Outdoor activities

IOTA, Islands On The Air (www.iota-world.org) "...promotes radio contacts with stations located on islands around the world..."

POTA, Parks On The Air (https://parksontheair.com/) is "...for international portable amateur radio operations that promote emergency awareness and communications from national/federal and state/provincial level parks."

SOTA, Summits On The Air (siliconchip.au/link/abtb) "...is an award scheme for radio amateurs and shortwave listeners that encourages portable operation in mountainous areas."

Amateur radio organisations and societies

- Wireless Institute of Australia (WIA; www.wia.org.au)
- New Zealand Association of Radio Transmitters (NZART; www.nzart.org.nz)
- American Radio Relay League (ARRL; www.arrl.org)
- International Amateur Radio Union (IARU; www.iaru.org)
- Australian Ladies Amateur Radio Association (ALARA; www.alara.org.au/index.html)
- The Radio Amateur Society of Australia (RASA; https://vkradioamateurs.org)

Radiosondes

Some hams track, find, reprogram and repurpose radiosondes launched by the Australian Bureau of Meteorology (BoM) for weather measurements (see Fig.25).

For example, they launch radiosondes twice daily from Tullamarine airport. They can be tracked via https://sondehub.org and they eventually come down.

If found, they can be reprogrammed and then used for ham balloon launches, radio orienteering (ARDF; https://ardf.org.au), or "foxhunting", where one or more of these devices are hidden in the bush, and others have to find it. Note that these items are disposable, and the BoM does not want them back.

WWFF

"The WWFF program encourages amateur radio operators to operate portable equipment from designated parks and/or protected nature areas around the world..." (visit the www.wwffaustralia.com).

Hamclock

Hamclock (siliconchip.au/link/abtj) is a free app for the Raspberry Pi and other Unix-like systems that provide important information for hams.

Specialised bands

Specialised bands available to advanced amateurs, such as 2200m (ULF, 135.7-137.8kHz), 630m (VLF, 472-479kHz) and bands between 23cm (UHF, 1240-1300MHz) and 1.25mm (EHF, 241-250GHz). They usually require custom-made equipment, although the recent Icom IC-905 all-mode microwave transceiver covers 144MHz (2m), 440MHz (70cm), 1200MHz (25cm), 2400MHz (13cm), 5600MHz (5cm) and 10GHz (3cm).

That concludes our article, to find out more, we have placed useful links, YouTube channels and videos in a PDF (siliconchip.au/Shop/6/376). SC

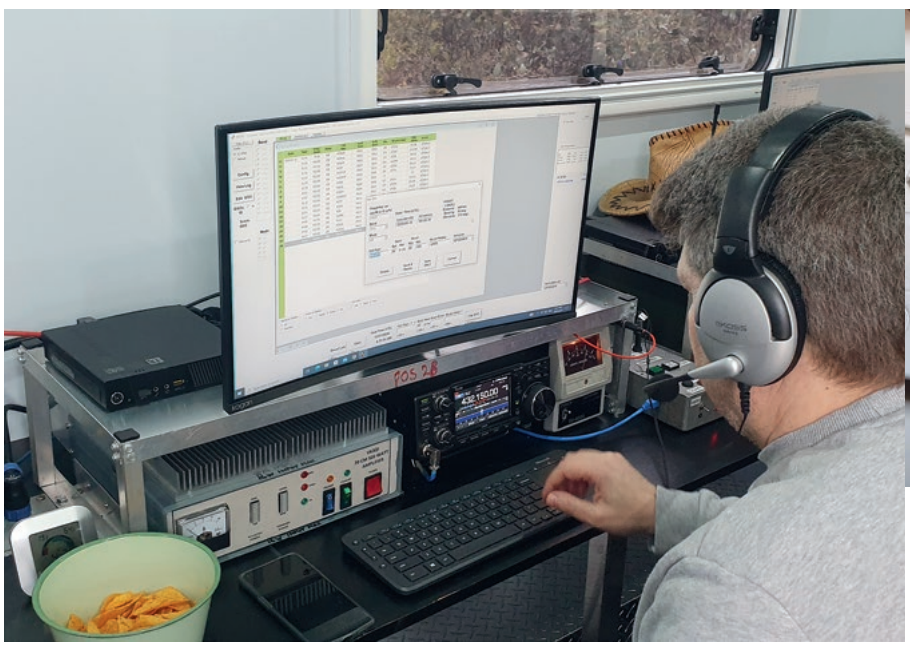


Fig.24: a ham radio operator using a transceiver inside the equipment van.

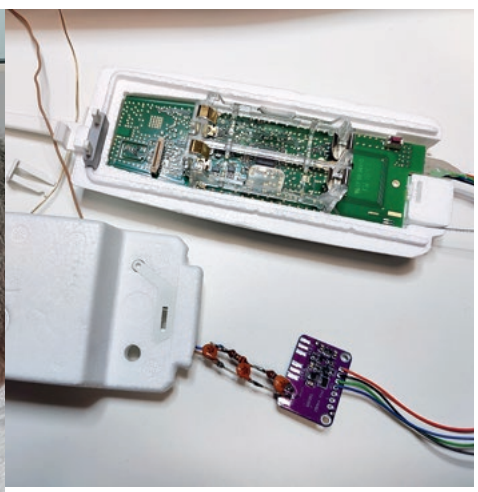
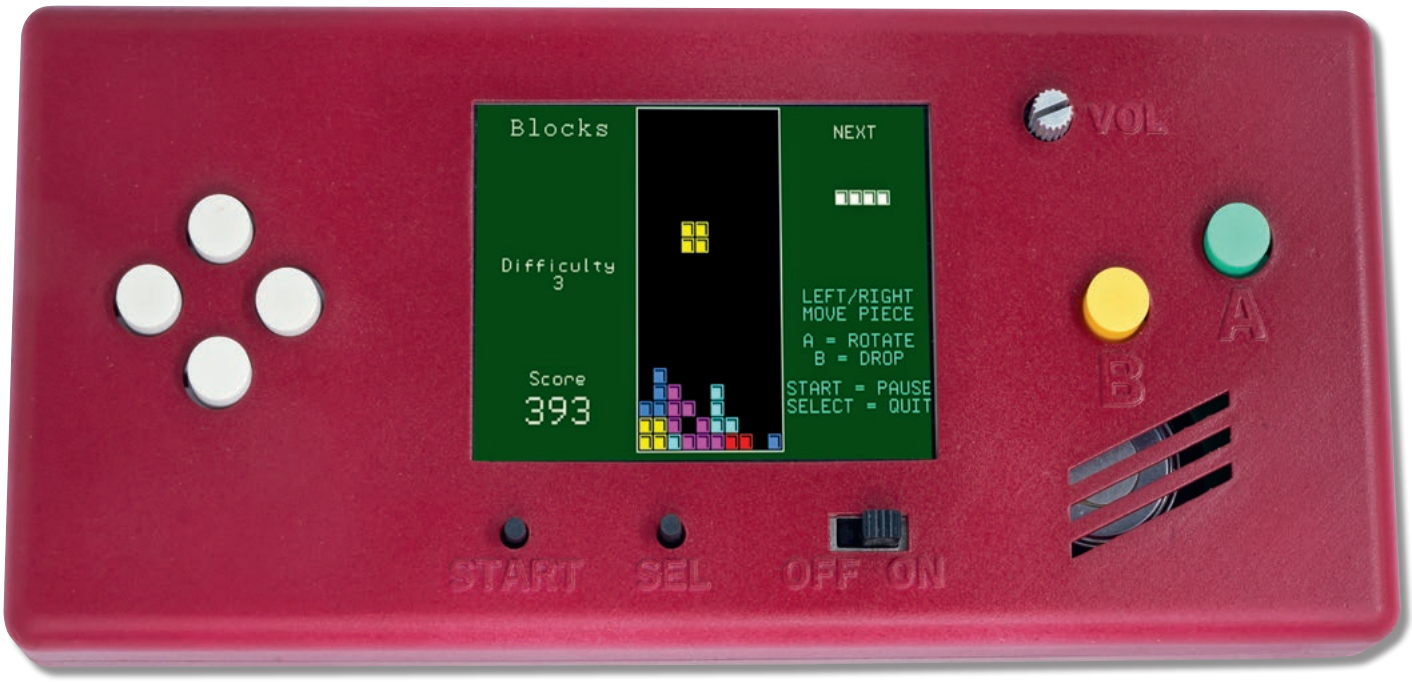


Fig.25: a disassembled Vaisala RS41 radiosonde, a type that can be reprogrammed. *Source:* https://0xfeed.tech/2022/05/repurposing-vaisala-rs41-radiosondes-for-amateur-radio-high-altitude-balloon-tracking/

The Pico Gamer



The Pico Gamer is a PicoMite powered 'retro' game console packed with nine games including three inspired by Pac-Man, Space Invaders and Tetris. With its inbuilt rechargeable battery and colour 3.2-inch (81mm) diagonal LCD screen, it will keep you entertained for many hours.

The Pico Gamer was inspired by the Game Boy series from Nintendo, introduced in 1989. They were small handheld battery-powered devices, initially with tiny monochrome screens and an eight-bit CPU. Over time, more feature-rich versions were introduced, and the series became a massive success, with over 100 million sold across all variants.

The Pico Gamer is a marked upgrade on the original Game Boy, with a colour LCD screen, a dual-core 252MHz 32-bit processor, 2.5MB of internal game storage and a USB interface. It is easy to build, using just a handful of components, and fits nicely into a custom 3D-printed case.

We based our design on the layout of the Game Boy Advance, with the control buttons on either side of the screen in a horizontal layout. Such a design is a natural fit for a handheld game console and has since been adopted by many other consoles.

There are eight buttons on the console: four direction buttons (up, down, left & right) on the left, two control buttons (start and select) under the screen and two auxiliary buttons (A and B) on the right.

An important feature is the built-in rechargeable lithium-ion battery; the original Game Boy used four AA cells. The Pico Gamer's battery can last over eight hours, which is plenty for a long road trip, and can be recharged in under four hours using the built-in USB connector. It could even be recharged from a portable USB power pack in a pinch.

The 3.2-inch LCD screen has a 66×50mm active area containing 320×240 pixels. It can display over 65,000 colours, which most games use to good effect. The screen is also touch-sensitive, although currently, no games use that feature. New games can be programmed in BASIC, so perhaps one of our readers will come up with one that does!

The Pico Gamer has a mono audio amplifier and speaker for sound effects. Most games use them to create various beeps, squeaks and explosions. However, it is good enough to reproduce more complex sound effects and music, and some games do both. To see a gameplay video, visit:

siliconchip.au/Videos/PicoGamer

The processor

The Pico Gamer is powered by the Waveshare RP2040-Plus. This is a pin-for-pin compatible clone of the Raspberry Pi Pico, with a few important upgrades.

Firstly, it includes a lithium-ion battery charger, so that's one less feature that needs to be designed into the circuit. It also uses a high-speed flash memory chip, so the RP2040 processor can be reliably overclocked to 252MHz, which is required for the more processor-intensive games.

Finally, the RP2040-Plus has a 4MB flash memory chip rather than the 2MB of the standard Pico. This is important because we store the games in this flash memory, and the standard Pico has space for a limited number of games. However, the RP2040-Plus with 4MB can fit dozens of games, and you will be unlikely ever to fill that up.

Features & Specifications

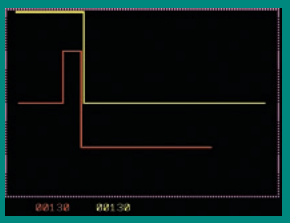
- Dimensions: 198 × 90 × 22mm
- Weight: 300g
- Battery: internal 1100mAh LiPo battery
- Runtime: approximately eight hours
- External power/charging: 5V via USB at 260mA
- Display: 66 × 50mm LCD, 320 × 240 pixels, 65,535 colours
- Audio: 340mW from a 28mm diameter speaker
- Internal storage: 14.5MB★ (sufficient for hundreds of games)
- External storage: SD card up to 32GB, formatted as FAT16 or FAT32
- Sound test and demonstration
- Button test
- File Browser
- A selection of pre-installed games (see the panel opposite)

★ *or 2.5MB if 4MB RP2040-Plus is used, sufficient for 30+ games*

Games included in the Pico Gamer firmware

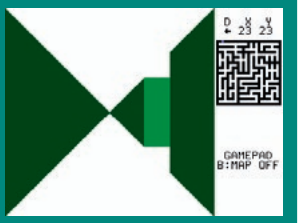
PETSCII Robots

In this complex strategy and exploration game, your goal is to enter the settlement and destroy the robots. The trick is finding the right tools and learning how to use them.



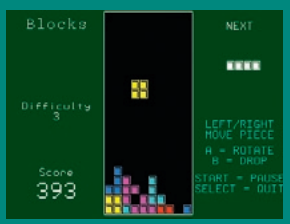
Lazer Cycle

You are on a fast Lazer Cycle, and so is your opponent. They will try to make you crash into a wall or track, and you try to do the same to them. It is a race to the death.



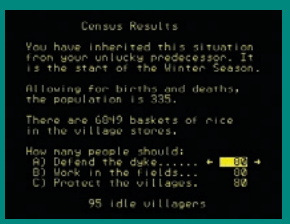
3D Maze

You are stuck in a 3D maze; your job is to explore and find a way out. You can call up a map to help, but it is not as easy as it looks.



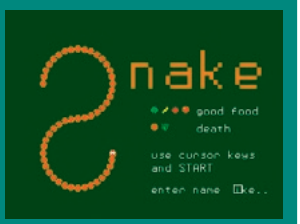
Pico Blocks

Similar to the ever-popular Tetris game, your job is to rotate and position colourful blocks falling from the sky into a neat carpet, where they will vanish. If your pile gets too high, you will lose.



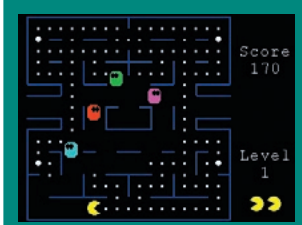
Kingdom

You are the ruler of the Yellow River kingdom and must allocate resources between feeding the hungry people & defending against thieves. Don't get it wrong, because the people might revolt.



Snake

Guide your snake around the board, eating the good food and avoiding the bad. As you eat, your snake will get longer. You will need all your skills to avoid crashing into a wall!



Pico Man

Inspired by the addictive Pac-Man game, you race around a maze, eating little dots while being chased by four ghosts. Eating a Power Ball gives you special powers, so you can pursue the ghosts instead!

Pico Vaders

Based on the classic Space Invaders from the 1980s, you are faced with hordes of invaders who drop a steady stream of bombs while you dodge back and forth with your cannon, trying to shoot them down.

Circle One

This game's objective is to eat the apples and grow while your opposition (the computer) will try to do the same. The one who grows to the maximum size wins. It is a simple but entertaining game that is perfect for young children.

Using a standard Raspberry Pi Pico in the Pico Gamer would be possible. While it would work, you would have to keep it tethered via a USB cable for power. Also, you will need to install a custom version of the software because the software we supply is optimised for the 4MB (or 16MB) of flash on the Waveshare module.

PicoMite software

The software loaded onto the RP2040-Plus includes the PicoMite firmware we introduced in January 2022 (siliconchip.au/Article/15177). This is a powerful BASIC (MMBasic) interpreter for the Raspberry Pi Pico, with support for peripherals such as an LCD screen, SD card, sound etc. Because the BASIC language is built into the PicoMite, all games are written in BASIC.

The latest versions of the PicoMite firmware provide an A: drive, which acts like an SD card that cannot be removed. This allows us to store programs, music files, images etc internally, without the need for external storage like an SD card.

If you wish, you can plug an SD card (or microSD card in an SD card adaptor) into the socket on the LCD screen, and it will be available as "drive B:". The menu system will allow you to switch to this drive and run games from it. However, this is not a requirement, and usually, the internal file system (drive A:) is sufficient to store all the games.

The PicoMite also implements flash slots as alternative storage places for programs. There are three of them, and when a program is run from one of these, it does not need to be loaded into the main program memory, so it executes quickly. The Pico Gamer's menu program is stored in the first flash slot, so it is always ready to run.

Acknowledgments

The Pico Gamer is based on the work of many people from around the world. The concept of a Game Boy lookalike using the Raspberry Pi Pico

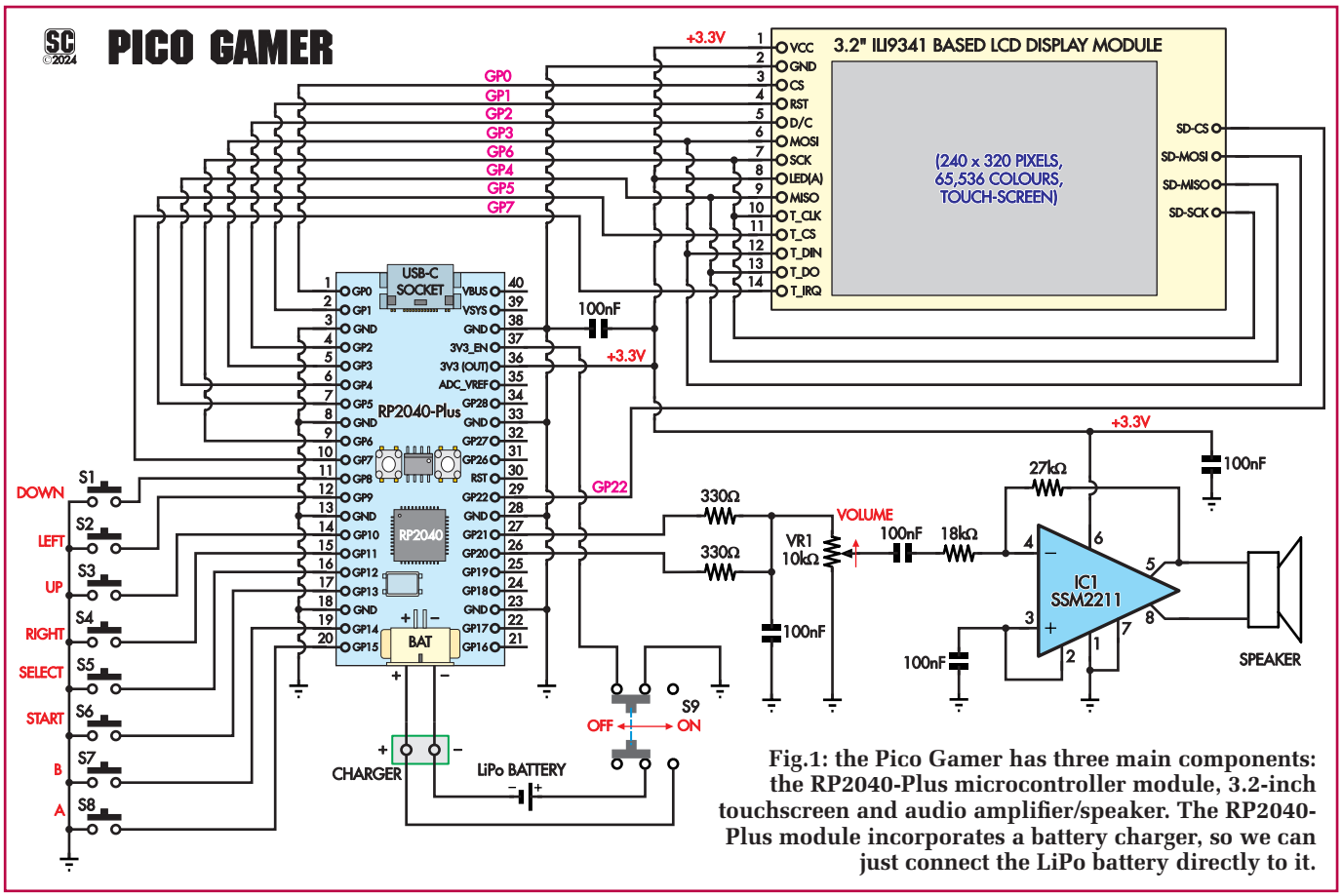


Fig.1: the Pico Gamer has three main components: the RP2040-Plus microcontroller module, 3.2-inch touchscreen and audio amplifier/speaker. The RP2040-Plus module incorporates a battery charger, so we can just connect the LiPo battery directly to it.

was pioneered by Tom Williams in the UK, and he designed the Game*Mite with some help from Australian Mick Gulovsen.

He published his design on The Back Shed Forum (**siliconchip.au/link/absd**) and it has been quite successful, with several hardware clones and many extra games added to its repertoire.

The games themselves came from authors including Martin Herhaus (Germany), Harm (Netherlands), Tom Williams (UK) and Geoff Graham (Australia). Tom Williams also wrote most of the utility programs. You can contact these authors on The Back Shed Forum with suggestions and bug reports if you need to.

We have kept the hardware features of the Pico Gamer compatible with the Game*Mite, so games and programs written for one will run on the other. If you wish, you can even load Tom's full firmware package for his Game*Mite onto the Pico Gamer, and it will run equally well.

Circuit details

As you would expect, the circuit (Fig.1) is dominated by the RP2040-Plus module. The eight game buttons connect directly to the processor, pulling the associated input pin low when pressed. Programs running on the Pico Gamer configure these pins as inputs with internal pullup resistors, so external resistors are not required.

The power switch in the off position disconnects the battery and disables the power supply in the RP2040-Plus. The latter is done so that the Pico Gamer will shut down even if it is connected to a USB power supply.

The battery charger in the RP2040-Plus will terminate at 4.2V, the correct voltage for standard LiPo batteries, so it will not overcharge them. When the Pico Gamer runs on battery power, the protection circuit within the battery will automatically disconnect the load so you cannot damage the battery by accidentally leaving the console on.

The LCD screen is connected to the processor via an SPI bus, which drives the display, touch controller and SD card socket. The LCD and the audio amplifier are both powered by the RP2040-Plus via its 3.3V output. This is used because the Pico's onboard DC-to-DC converter ensures a constant output voltage regardless of the battery voltage, which can vary from 4.2V to about 2V.

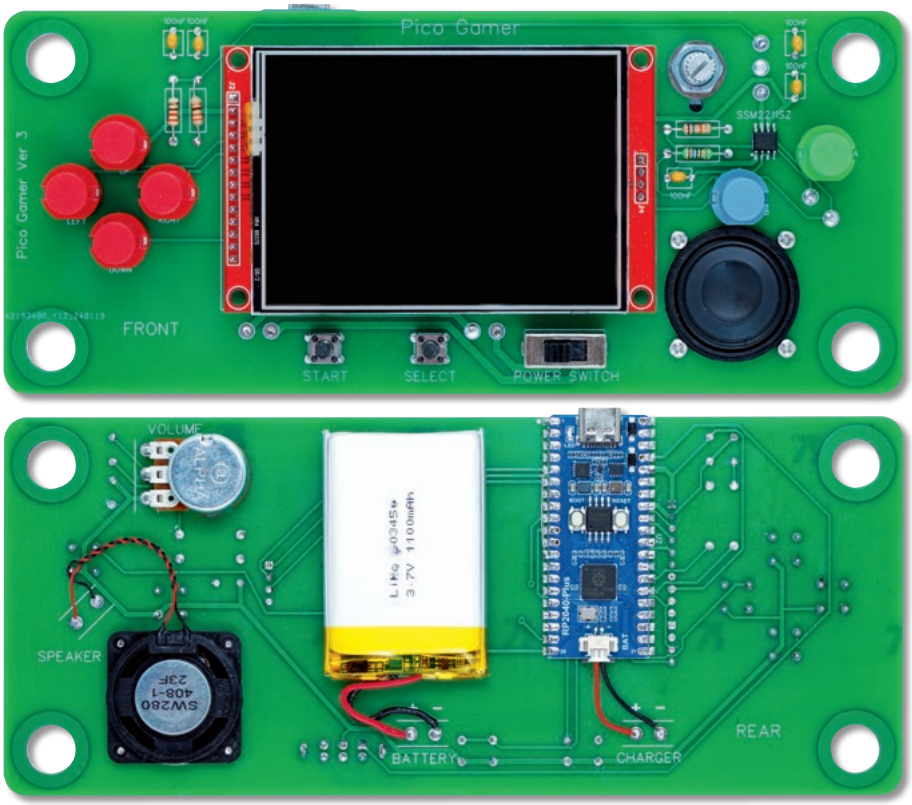
The sound output is generated as stereo pulse width modulated (PWM) signals from digital output pins GP20 and GP21. These signals are filtered and summed by the two 330Ω resistors and the 100nF capacitor. The resultant mono audio is fed to an SSM2211SZ audio amplifier, which drives the speaker in a bridged configuration.

With a 3.3V power supply, the SSM2211SZ does not generate much power, but the volume is ample for a handheld device.

Sourcing the parts

We are offering kits that include all parts except the battery (which can't be sent by airmail). There is the option of no case (if you want to print your own), a basic case that you can paint any colour and a more expensive black case that shouldn't need to be painted. So that's one way to get the parts to build the Pico Gamer.

You can get a suitable 1100mAh 3.7V LiPo battery from your local Altronics store (Cat S4724) or a local seller on eBay.



The front of the PCB has the 3.2-inch LCD screen, buttons, switches, audio amp IC & passive components. The rear of the PCB holds the RP2040-Plus, battery, volume potentiometer & speaker. It is necessary to solder the RP2040-Plus flush with the PCB so that the USB connector aligns with the cutout in the case.

If you want to gather the rest of the parts yourself, here are suggestions:

The core of the Pico Gamer is the Waveshare RP2040-Plus, available from Waveshare (**www.waveshare.com**), Amazon and Australian distributors such as Little Bird Electronics (**littlebirdelectronics.com.au**) and Core Electronics (**core-electronics.com.au**). You only need the 4MB version; make sure you purchase it without header pins, as it must be soldered flush with the PCB.

The battery charger socket on the RP2040-Plus is a two-pin Molex PicoBlade with a 1.25mm pitch. The matching plug with attached wires is commonly used in drones and can be purchased from drone suppliers (such as **www.dronepartsgarage.com.au**). Note that many battery connectors on offer are JST-style connectors, such as JST-SH or JST-XH, which are incompatible.

Another way to get a matching connector is to buy a battery on eBay that comes fitted with a PicoBlade connector. You can then cut this off and use it as the charging cable, while the now unterminated battery leads can be soldered directly to the PCB.

The LCD is a 3.2-inch panel with a 320×240 pixel resolution using the ILI9341 controller. There are many on offer on eBay and AliExpress, but make sure the vendor's photo matches Fig.4 (shown at the end of the article), as there are some incompatible designs that will not physically fit.

You can purchase the display without the touch interface, which would work fine as no games currently use that feature. However, you will only save about a dollar, so you might as well get it regardless.

The large, coloured tactile switches have 8mm diameter buttons and can be purchased from Altronics, Jaycar or RMS Components in Australia and New Zealand, as well as international suppliers. We found that the Altronics version had a better 'clicky' feel, but your preference might differ.

The tactile switches for the start and select functions need a relatively long shaft of around 9mm, with a total height of 13mm (including the button base). These can be found on eBay and AliExpress. Alternatively, you can purchase a longer-shaft version from Altronics (Cat S1119) and trim it to a total height of 13mm.

The volume potentiometer is a standard 16mm logarithmic type sold by Altronics (Cat **R2233**) and on eBay and AliExpress. The value is not critical; it can be in the range of 10kΩ to 50kΩ, but its depth must be less than 10mm to fit in the case, and it should have an 8mm-long knurled shaft as it is used without a knob in this design.

The loudspeaker used in this design is the DB Unlimited SW280408-1 (Mouser Cat **497-SW280408-1**, DigiKey Cat **2104-SW280408-1-ND**). This was chosen as it's small but has decent sound quality and is easy to mount using four small screws.

Even if you don't have a 3D printer, getting custom-designed 3D-printed case pieces is relatively easy. The two STL files defining the top and bottom halves of the case can be downloaded from the SILICON CHIP website and sent off for fabrication.

There are numerous online 3D printing services but we recommend JLCPCB. You only need to upload the files to their website and select their SLA process using LEDO 6060 resin (**https://jlc3dp.com/3d-printing-quote**). They will then make and ship the case to you within a few days.

The 6060 resin is strong, with no warping, and the surface is smooth in a slightly translucent off-white colour. However, note that this material can yellow slightly with age, so you might want to spray paint it. The 6060 resin readily accepts paint. An ideal paint for this purpose is Rust-Oleum Satin 2X Ultra Cover, available from Bunnings in many colours.

Alternatively, you could use one of JLCPCB's more expensive materials that are dyed or otherwise immune to yellowing, for example, "Black Resin" or "Imagine Black". We offer one of those options in our kits for those who don't want to mess around with paint and like the 'stealthy' appearance.

Construction

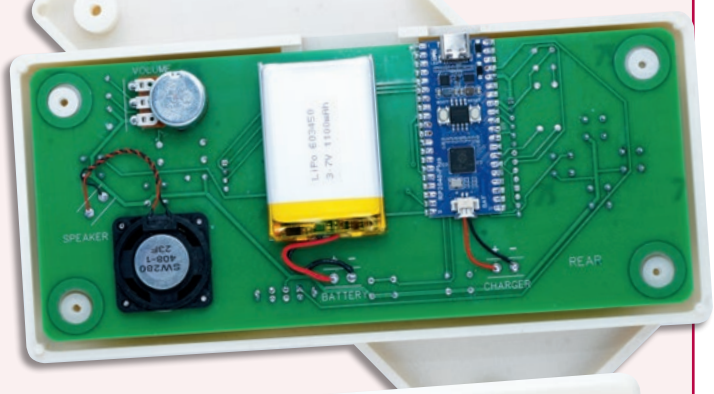
Only a few components are involved in the Pico Gamer, so construction can be completed in an hour or two. Four components (the RP2040-Plus, battery, volume potentiometer and speaker) mount on the rear of the PCB, with the rest on the front side. The PCB is marked FRONT and BACK to help with the orientation.

The Pico Gamer PCB is coded 08104241 and measures 188 × 80mm.

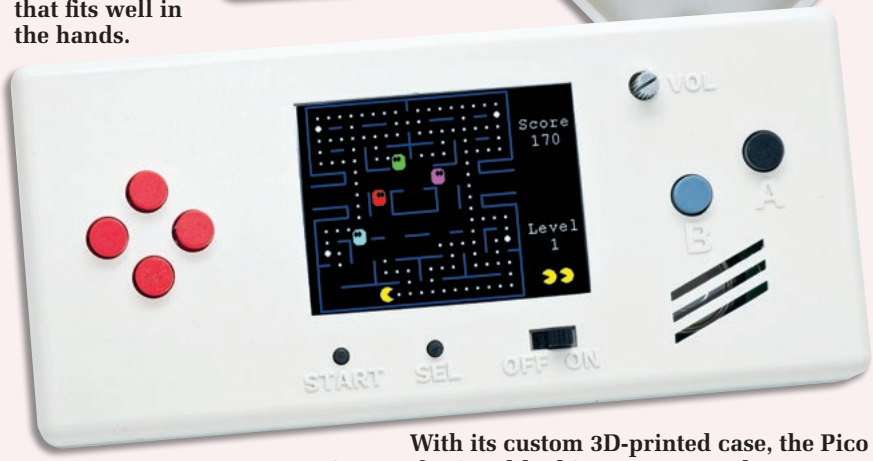
Parts List – Pico Gamer

1 double-sided PCB coded 08104241, 188 × 80mm
1 custom 3D-printed case in two pieces (upper and lower), 199×90×26mm (see text)
1 Waveshare RP2040-Plus module with 4MB or 16MB flash memory, without header pins **[Waveshare SKU 20290 (4MB) or 23503 (16MB)]**
1 3.2in LCD touchscreen, 320×240 pixels, with ILI9341 controller and SD card socket
1 900-1100mAh 3.7V LiPo cell **[Altronics S4724]**
1 SSM2211SZ 1.5W audio amplifier, SOIC-8 (IC1) **[DigiKey, Mouser, RS]**
6 SPST momentary tactile switches with 8mm diameter buttons, 5×5mm pitch, in various colours (S1-S4, S7, S8)
[Altronics S1094/5/6/8/9 or Jaycar SP0720/1/2/3/4]
2 SPST momentary tactile switches, 4×6mm pitch, 13mm height (S5, S6)
1 PCB-mount miniature DPDT slide switch (S9)
[Altronics S2060, Jaycar SS0823]
1 DB Unlimited SW280408-1 8Ω loudspeaker
[Mouser 497-SW280408-1, DigiKey 2104-SW280408-1-ND]
1 10kΩ logarithmic potentiometer with 8mm spline shaft **[Altronics R2233]**
5 100nF 50V X7R multi-layer ('monolithic') ceramic capacitors, 5mm pitch
1 4-pin header, 2.54mm pitch
1 2-pin Molex PicoBlade plug, 1.25mm pitch, with attached leads
4 M3 × 16mm panhead machine screws
4 M2 × 6mm panhead machine screws
1 can of spray paint (**optional**; see text for recommendations)
1 double-sided foam adhesive tape strip or pad **[eg, from Bunnings]**

Resistors *(all ¼W 1% or 5% axial)*
1 27kΩ 1 18kΩ 2 330Ω



The PCB fits neatly into the 3D-printed case. When the two halves of the case are screwed together, it has the optimal dimensions for a handheld game console with a smoothly rounded shape that fits well in the hands.



With its custom 3D-printed case, the Pico Gamer is a professional-looking game console. It comes with nine games, including some inspired by Pac-Man, Space Invaders and Tetris, that work well with its colourful 3.2-inch LCD screen. The inbuilt rechargeable battery lets you play for up to eight hours at a time.

During construction, refer to the overlay diagrams, Figs.2 & 3, to see which parts go where. You can also check the photos.

Start with the SSM2211SZ audio amplifier chip, which is in a small 8-pin surface mount package that is much easier to fit when no other components are in the way. This mounts on the front side of the PCB and should be soldered using the standard technique for SMD ICs.

Apply a little flux paste to the PCB pads and place a small amount of solder on a corner pad. Position and hold down the IC, observing the dot marking pin 1, and tack solder one of the pins using the solder on the pad. Check and correct the IC's alignment, then tack solder the pin in the opposite corner.

With the IC secured, apply more flux paste and, with the bare minimum of solder on your iron, place its tip on the end of each pin, letting the solder flow around the pin and the solder pad. Finally, inspect your work with a strong magnifier (×10 or ×20) and correct any problems with more flux paste and solder-wicking braid.

Next, you should install the RP2040-Plus on the rear side of the PCB. This sits flush on the PCB, making it a surface-mounted component. Ensure that it is aligned centrally on the solder pads and that the USB socket is at the top, protruding over the edge of the PCB.

The battery charger plug and cable can be soldered now. Note that the colour of the wires (red/black) crimped to the connector might not match the polarity marked on the RP2040-Plus. Check this, and make sure that the lead from the + side of the connector goes to the pad marked + on the PCB regardless of the wire's colour.

Next, fit the resistors and capacitors. There are nine in total, and none are polarised, so installation should be easy. The parts list includes resistor colour codes, but you can also use a DMM set to measure ohms to verify their values.

Installing the LCD screen

The next component to install should be the LCD panel. For height reasons, it is not socketed; instead, the pin headers go through the holes in the PCB and are soldered on the other side. These displays are notoriously

sensitive to static discharge, so make sure that you ground yourself before unwrapping it and avoid handling it too much, especially its connecting pins.

Most LCD panels are supplied with the main connector header pins installed, but you will need to add a four-pin header for the SD card interface in the locations marked SD-CS etc. Then insert the LCD panel into position on the front side of the PCB and push it down until it is flush with the PCB.

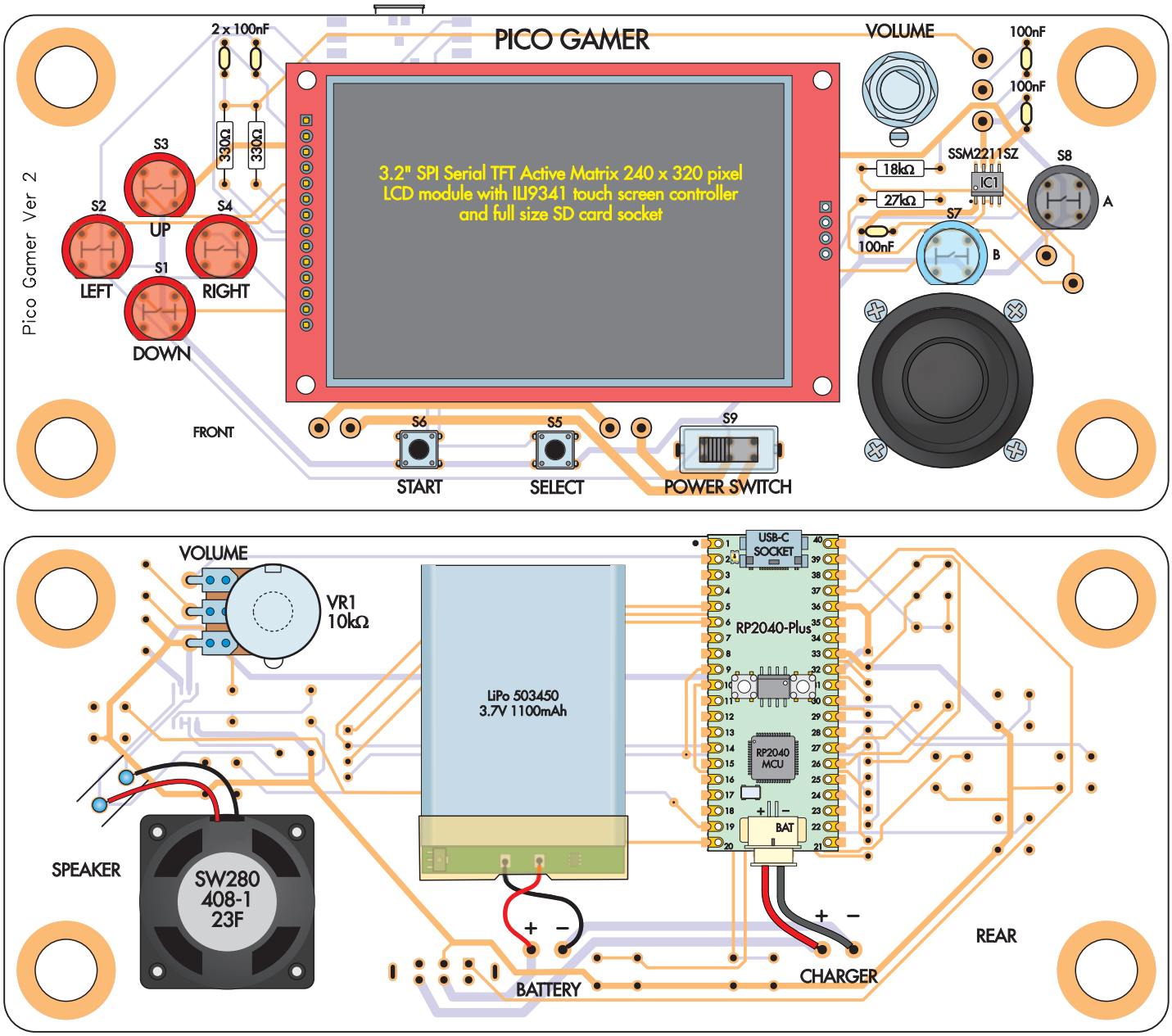
Turn the PCB over and temporarily place it in the top section of the 3D-printed case, ensuring it sits correctly on the four mounting pillars. Next, push down on the LCD screen's header pins until the LCD glass is flush with the case's front bezel. You can then solder and trim the pins.

The reason for this operation is to ensure that the LCD's glass will sit flush with the front bezel while compensating for minor variations in the 3D printing of the case. Don't force the LCD hard against the case, as that could interfere with the touch function; a flush contact is all that is required.

Next, fit the volume potentiometer by inserting it through the back of the board, with its locating pin in the hole provided, then tighten the supplied nut over the washer to hold it in place. After that, bend the solder tabs towards the PCB and directly solder them to the pads provided.

Now attach the speaker to the rear of the PCB, with the front of the speaker cone facing through the hole. The speaker is held in place by four M2 machine screws inserted from the front side of the PCB which self-tap into the speaker's mounting holes; nuts and washers are not required. Once it is securely in place, solder its two wires to the nearby terminals.

After that, mount the coloured button switches, the long shaft tactile



Figs.2 & 3: there are components mounted on both sides of the board. As there are not too many, it shouldn't take long to assemble. They are all pretty easy; IC1 is surface mounting, but its pins are wide enough to be soldered individually.