

SC-3000
Survivors

SC-3000 Survivors Mk II Multicart

User Manual



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Foreword / Welcome

Congratulations on acquiring your very own SC-3000 Survivors Mk II Multicart! We are pleased to be able to share treasures from our childhood with you. For some of you the Multicart may be your first look at the SC-3000. For others, it will be a nostalgic trip down memory lane. Enjoy ☺

Note: The Mk II SC-3000 Survivors Multicart will ONLY work on a Sega SC-3000. It does not work on a SG-1000, SG-1000 II, or Mark III even though it can play SG-1000 ROMs.

Disclaimer

We take no responsibility for any damage caused to you, your property, your favourite cat, dog, pet bird, Uncle Bob, or Aunt May by the use or misuse of the SC-3000 Survivors Mk II Multicart. We've done our best to come up with a Vintage computer project that is safe and simple, but you use the multicart at your own risk.

Copyright

The SC-3000 Survivors Mk II Multicart contains some 1980s copyrighted software. All rights remain the property of the original copyright holders. The multicart design, layout, and menu system are the property of SC-3000 Survivors.

Vintage Electronic Components

Your SC-3000 is over 27 years old. Sometimes these machines work a few times then develop faults after being in storage for years. So before you flame us about destroying your precious SC-3000, just remember that there is a good chance that the problem is just co-incidence now that you are using the system more. Let us know what has gone wrong, and we'll do our best to help you.

Anti-static Precautions

The Multicart PCB components are reasonably resistant to static electricity, but avoid touching the components. Touch a metal window-frame or similar with your finger before handling the PCB. Only handle the edges of the PCB. If you toss it around like a Frisbee whilst rubbing your socks on the carpet then you get what you deserve ☺

Hobby Project

The SC-3000 Survivors Multicart is the culmination of hundreds of hours work by the SC-3000 Survivors Crew. We've spent years collecting and preserving the software included on the Multicart, and had to learn all about SC-3000 architecture, basic electronics, digital logic design, Z80 Assembler, and PCB design and manufacture to make this happen.

We'd love to discuss the Multicart with you, and we're happy to try to assist with any SC-3000 related problems you may have. But please remember this is a hobby project. We have real lives, jobs, and families who like to see us from time to time ☺ So give us a bit of time to reply.

The SC-3000 Survivors Team

sc-3000.com and sc3000-multicart.com

Using your Multicart

Quick-start Guide

We assume you all know how to set up your SC-3000 and get it working with a TV. So the quick start guide is really simple.

1. Set up your SC-3000 and make sure it works with one of your existing games carts
2. Carefully insert the SC-3000 Survivors Mk II Multicart into the SC-3000 cart slot
3. Turn power on. The Survivors logo will display, followed by the Boot Menu
4. Menus are Keyboard or Joystick controlled. Use up / down / left / right joystick or cursor keys and the joystick button or space / CR to select a menu item
5. If you are running a tape game or playing VGM music you can return to the Boot Menu by pressing the red Reset button on the SC-3000's keyboard
6. If you are running a cartridge game you can return to the Boot Menu by gently pressing the black Reset button on the Multicart followed by the Red Reset button on the SC-3000's keyboard. If that fails, then turn power off, wait 10 seconds, and turn power back on.

See the Multicart Reset Button sections below for more information.

7. Have fun ☺

To return to Boot Menu from a SG-1000 ROM game:

1. Gently press black Reset Button on Multicart (try not to jiggle the cart). Note that the screen may freeze and the SC-3000 may make funny sounds at this point - this is normal. If you are lucky, the boot menu will appear immediately.
2. If boot menu does not appear, then press Reset button on SC-3000 keyboard
3. If that doesn't work, then repeat steps 1 & 2
4. If that doesn't work, then turn SC-3000 off. Wait a few seconds. Turn back on.

Steps 1-3 above should work around 80% of the time. It seems strange the first few times, but you will get used to it. Or you can turn the SC-3000 off every time if you prefer.

To return to Boot Menu from Tape Software or EPSGMOD Player

If you are running a tape game or playing VGM music you can press the SC-3000's red reset button on the keyboard to return to the boot menu at any time. You do NOT need to use the black reset button on the Multicart to return from tape software or the EPSGMOD Player.

Why is the Multicart Reset Button a little unpredictable?

That is expected behaviour with this design. The Z80 CPU reset line is not passed to the cart port. So the best we could do was to get the cart reset button to restore the boot menu block. The boot menu block reset handler and vblank handlers both contain code to keep the boot menu locked in and return back to \$0000. So if you press the button at just the right time sometimes it resets automatically through vblank. But it all depends on what the CPU was doing when you press that black reset button on the cart 😊

We discussed possible alternative designs that may have worked better, but they would have involved a major redesign of the PCB.

Overview of the Menus



Tape Software

This is a collection of around 75 pieces of tape software which was available in New Zealand and Australia from 1984 to 1988. It works by loading up a hacked copy of the Basic IIIB ROM then calling custom routines for each game to load from the Multicart instead of tape.

There are some excellent games in there, some average games, some poor games, some utilities and educational software, and a pile of type-in software from the Sega Computer Magazines. This should give you a good feel for what home computing was like back in 1980s New Zealand 😊

Basic IIIB

This is a full copy of the Basic IIIB in case you want to load your own tape software through the cassette-in port or do your own programming.

Music Editor

The Music Editor is hard to use without the plastic keyboard overlay and some musical talent. But Sega released a demo tape with 10 demo music tracks on it. We hacked the Music Editor ROM to automatically load those tracks. Just select option 4 Play from the Music Editor menu.

VGM Music Tracks / EPSGMod Player

The SC-3000 was never developed to its full potential. However it has the same sound capabilities as the Master System and other contemporary 8-bit systems. So we included some nice music tracks.

ROMs (Bank 0 Autoscans)

There are two EPROMs on the Multicart. ROM 0 is the left hand EPROM. If you have a programmer, you can add your own SG-1000 / SC-3000 images to ROM 0. The autoscans system looks through the 32 blocks in the EPROM and if it recognises the game you will see the game title appear in the list.

ROMs (Bank 1)

ROM 1 contains the Boot Menu system, the Tape Software, and a selection of Korean ROMs from the Samsung Gam*boy and Taiwanese ROMs from the Aaronix SG-1000 II clone.

About

A few facts about the multicart, plus the SC-3000 Survivors Demo featuring digitized sound and photos.

Print 64 Menu vs Text Mode

Mike Hadrup was the last editor of Sega Computer Magazine in New Zealand from 1987 to 1988. He was only 18 at the time, but he wrote a lot of really cool toolkit to extend the Basic Interpreter for the SC-3000. One of these utilities was Print 64 (published in Sega Computer Magazine October 1987).

By default, the menu system uses the SC-3000's Text Mode display. This can display 40 characters across by 24 rows down. This is good, but it looks a bit boring and you can't fit much text on the Multicart Boot Menu. In particular, it means that if we want two columns in the menus then we have to use short names for some games.

That is where Print 64 comes in. It works in Screen 2 graphics mode, but it paints two characters into each 8 x 8 pixel block on the screen. The characters are only 3 pixels wide each (with the 4th pixel column being whitespace). So the text is a lot smaller, but it is still looks good on a CRT. And because it works in graphics mode, you can also mix graphics like the Survivors logo on the same screen as the Print 64 Text.

Unfortunately, the text really is **very** small. All of our testers said they preferred to use the Text Mode screen. So Text Mode is selected by default. Choose the 'Print64 / Text Mode Menu' option from the Main Menu screen to switch between the Text Menu and the Print64 Menu.

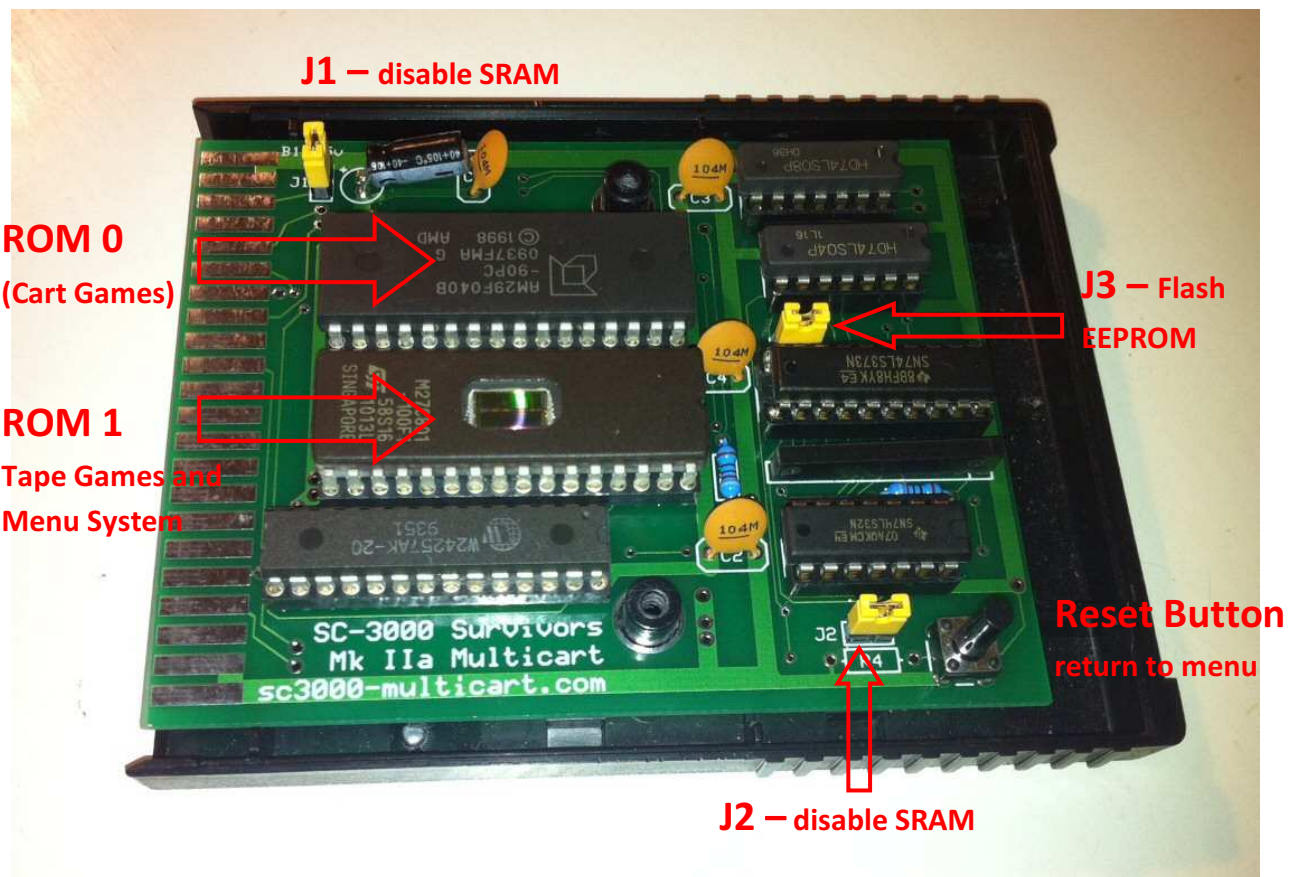


Normal Text Mode Menu



Print 64 Menu – 64 characters wide

PCB Layout - Multicart Jumpers and the EPROMs



Most of you will never need to adjust your Multicart. And unless you have a good reason, you should probably leave the jumpers and the EPROMs alone.

By default ROM 1 is a ST-Micro 27C801 8Mbit EPROM which contains the Boot Menu system, the Tape Software, and a selection of interesting Korean and Taiwanese game ROMs. ROM 1 MUST always be installed in the Multicart.

ROM 0 can contain either a 27C801 8Mbit EPROM, or an AMD 29F040B 4Mbit Flash EEPROM. The 27C801 can hold 32 SG-1000 or SC-3000 ROM images. The Flash chip can only hold 16 SG-1000 or SC-3000 ROM images. (The picture above shows a 29F040B Flash chip)

The Multicart has 32KB of SRAM on-board. All of the official SG-1000 / SC-3000 releases should work fine with that. But if you like living on the edge you can remove J1 and J2 and then the cart will just use the 2KB of SRAM on the SC-3000's motherboard. Note that the Tape Software will NOT work with only 2KB of SRAM.

If you want to use a 29F040B Flash chip in the ROM 0 slot instead of a 27C801 EPROM, then you may wish to remove J3. This makes the boot menu auto-scan system for ROM 0 work a little better.

You can remove the EPROMs by GENTLY inserting a small flat blade screw driver under the EPROM and GENTLY levering it up. Take anti-static precautions and be careful to not bend the pins.

Care of your Multicart

Making your own Cartridge Case

We recommend you remove the plastic cartridge case from a spare games cart and put the Multicart inside the case. **If you do not have a spare cartridge case, then put the PCB back in the anti-static bag and bubble wrap bag it arrived in and store it in a drawer or a box when not in use.**

Existing games carts are easy to open. There are two Philips-head screws hiding underneath the cart label. You can just poke your screwdriver through the existing label and undo the screws.



You will need to drill a hole for the Multicart Reset button and make a couple of cuts to allow the case to close once the Multicart is mounted inside it.

We included a sticky label with your Multicart.

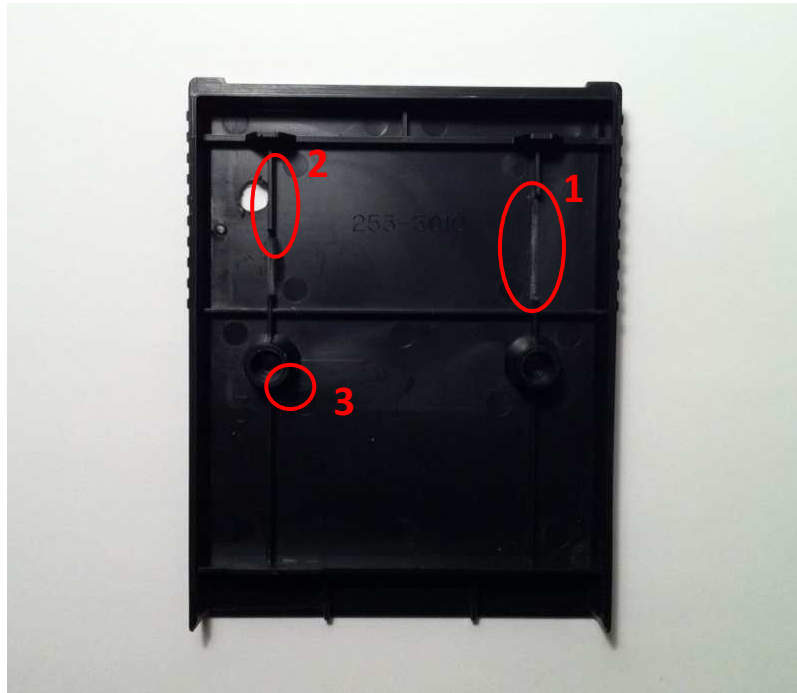
Place it on top of the lid of the case. Do NOT stick it to the cart yet (or you won't be able to screw the cart together later). The hole in the label shows you where the Reset Button switch goes.

Use a sharp nail or screwdriver or similar to mark the center of the hole onto the top of the case. Drill a small 2-3mm hole first, then enlarge it with a 6mm drill bit.

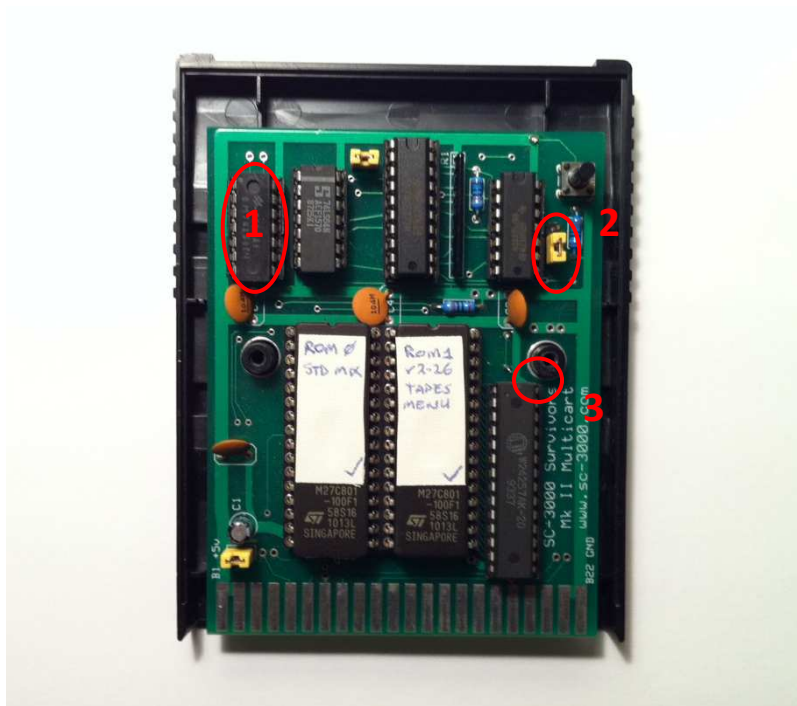


You will need to make some cuts to the underside of the cart lid to allow it to close.

1. Cut the reinforcing ribbing over the 74LS08 IC
2. You *may* have to cut the reinforcing ribbing over J2
3. You *may* have to shave the plastic slightly by this screw hole as the socket for the 32KB SRAM *may* rub on it. But if the cart screws shut then don't worry about it.



The photo below shows the components that rub on the lid unless you make the above cuts. Do NOT try to trim the cart or the bottom half of the case.



Care of EPROMs / Exposure to sunlight / Cart Cases

The multicart has two 27C801 8MBit (1MByte) EPROMs.

An EPROM is a Read Only Memory chip that can be erased by exposing it to a UV light for a few minutes. That is why the EPROMs have tape over the top center of the DIP packages. There is a little quartz window there that lets UV light in when you want to erase the chip.



In dark conditions (like inside a computer case), an EPROM should hold its data for a good 25 to 30 years. And they are even reasonably resistant to direct sunlight. But the fact is that the more sunlight they get, the quicker you are likely to start dropping data. So always keep the tape over the erasure window, and preferably find a donor cartridge case to mount it in.

If you do not have a spare cartridge case, then put the PCB back in the anti-static bag it arrived in and store it in a drawer or a box when not in use.

You can find out more about EPROMs on Wikipedia

<http://en.wikipedia.org/wiki/EPROM>

Troubleshooting

VERY IMPORTANT: If you attempt the following cleaning or respringing instructions, then please read the instructions **VERY carefully**, and please make sure you **UNDERSTAND** what you are doing before you start. It is pretty simple to do, but if you're rough or bend the pins on your cartridge port you can break your SC-3000. **If you are not confident you understand the instructions then please do not attempt them. You have been warned 😊**

If it takes several attempts to read a games cart when you insert it

You may need to clean the SC-3000 cartridge slot. A good way to do this is to get a thin card and stretch a lint free cloth like an old white t-shirt or handkerchief over it, then dampen the material slightly and push it in and out of the cart slot. Finish up with a dry part of the cloth. Watch the following YouTube video in full and make sure you understand it.

<http://www.youtube.com/watch?v=0zMVOIkR4Jk>

The key safety points from the video are:

1. Slightly damp cloth, not dripping wet. Water and electronics don't mix. And disconnect the power :)
2. Lint free cloth. You don't want to leave lots of fluff in there
3. Make sure your card plus cloth is not too thick. You want a little bit of pressure on the contacts, but if it is too thick and you really have to force it in then you may bend the pins. But if too thin then you won't be cleaning much. Just experiment a little with card sizes.
4. Dry the cart port off at the end with a dry section of cloth. You may even want to leave for a few mins before turning back on.
5. Only push card / cloth in and out, not side to side

Check if your cart slot is loose / not holding the multicart properly

The SC-3000 Survivors Mk II Multicart is heavier than a regular cartridge. See if the cart is 'drooping' or angled downwards too far. If so, then your cart port may be a bit loose.

Using a donor cartridge case will help. And you can try jamming a little paper under the cartridge shell it make it a tighter fit. Don't use too much paper – you only want enough to give the case a little extra support.

It is possible to try respringing your cartridge connector by disconnecting the power then GENTLY depressing each pin on the cartridge port with a small screw driver to check it moves freely. Watch the following YouTube video in full and make sure you understand it.

<http://www.youtube.com/watch?v=zP5pWPeoXMg>

Be VERY careful. We know someone who bent the pins and broke their SC-3000 by doing this.

Writing your own EPROMs / Flash EEPROMs

The Multicart will play all the known official SC-3000 / SG-1000 ROMs and many of the Korean / Taiwanese ones for the Samsung Gam*boy and Aaronix SG-1000 II clone too. If you have an EPROM programmer and UV Eraser, then you may change the ROM images stored on ROM 0.

Note – you should only remove the LEFT EPROM - ie. ROM 0. You should not remove the right EPROM (ROM 1) unless we have sent you a new binary image for the menu system / tape games.

ROM 0 has 32 slots of 32KB available, so all you have to do is to use a Hex Editor to join 32 ROM images together. Or if you are using a 29F040B 4MBit Flash EEPROM, then join 16 ROM images together to make 16 slots of 32KB.

Make sure that each ROM image you use is exactly 32KB. You will have to pad out the 16KB and 8KB ROMs to 32KB otherwise some of the games won't line up on a 32K boundary and they won't work.

We have thoughtfully created a [video showing you how to use the HxD Hex Editor to create your ROM image containing 32 SC-3000 games](#). This was actually made for our original [Mk I Multicart do-it-yourself tutorial](#). But the process is identical for preparing an EPROM image for the ROM 0 socket on the Mk II Multicart.

<http://www.youtube.com/watch?v=KsMDQnOmm7E>

Here's a summary of the video for you

1. Find some SC-3000 and SG-1000 ROM images
Just go to Google and type something like
download SC3000 ROM images SG1000
Hunt around and you should find them. They are often grouped with Sega Master System ROMs
2. Copy the 32 ROMs that you want into a new folder
You will see why in a minute. We may have to modify some of them slightly or rename the files.
3. Rename your ROMs so they appear in alphabetical order
Just use Windows Explorer to rename the filenames. Some of the ROM downloads are likely to have names like "SG1000_CongoBongo.sc" etc. Just rename to something like CongoBongo.sc
4. Check File Sizes. Discard any ROMs over 32KB in size (32,768 bytes) and be prepared to modify any smaller than 32KB in size. We are going to just append all these ROM images together, so they have to be exactly the right size.

5. Download HxD from <http://www.mh-nexus.de/>
Open any small ROMs in HxD to make them bigger. For each small ROM:
Ctrl-End
Edit->Insert Bytes
4000 hex bytes for 16KB ROMs, 6000 hex bytes for 8KB ROMS
Fill FF
Save File. Close File.
6. Do a paranoid file size check.
Highlight all 32 ROMs in Windows Explorer. Properties. There should be 32 files and 1,048,576 bytes in total. If not, then one or more of the files is the wrong size. Check the file properties one by one. Each individual file should now be 32,768 bytes long.
7. Concatenate all the files together in HxD
Extras->File Tools->Concatenate
Select all the roms, reorder as required
Output FileName First32Roms_Concat.bin
8. Right click on our new First32Roms_Concat.bin file. Properties. That should be 1,048,576 bytes in total.
9. We are ready to burn our image onto our new 8MBit EPROM.

Programming the SC-3000 Survivors Mk II Multicart

The Multicart has a simple memory architecture. The top 32KB (\$8000..\$FFFF) is always mapped to RAM and the bottom 32KB (\$0000..\$7FFF) is mapped to a 32KB slot in one of the EPROMs. You can then swap the bottom 32KB in and out of memory by writing a control byte to port \$e0.

This control byte is the value stored and output by the 74LS373 8-bit latch, and those pins are connected to other logic control chips on the PCB.

Note: when you turn the cart on, block 31 in ROM 1 is always selected by default and this is where the menu system is stored.

Read the chapter titled 'How does the SC-3000 Survivors Mk II Multicart work?' for more detail about the Multicart architecture.

Control Byte format

- Q0..Q4 controls the A15 to A19 address lines on the EPROMs. So these 5 bits let you select a 32KB logical block within one of the EPROMs. Q0 => A15, Q1 => A16, Q2 => A17, Q3 => A18, Q4 => A19
- Q5 is not connected to anything
- Q6 ROM 0 / ROM 1 select (0 =>ROM 0, 1 => ROM 1)
- Q7 Enables / Disables latch
If the latch is disabled, then pull up resistors ensure that block 31 in ROM 1 is selected

Assembler Examples

Eg. To enable the latch, select ROM 0, and block 13 within ROM 0 you would do

```
ld a, %10001101
```

```
out($e0), a
```

Eg. To enable the latch, select ROM 1, and block 27 within ROM 0 you would do

```
ld a, %11011011
```

```
out($e0), a
```

Note: This code **MUST** be executed from RAM. You can't run it from ROM because as soon as you update the latch you swap out the block where the code was executing from.

Software Included on the Mk II Multicart

The Mk II Multicart can play all the known SC-3000 or SG-1000 ROMs, and it comes with over 70 pieces of tape software.

Note: You will need to find and add SG-1000 ROMs yourself using an EPROM programmer

The cart will **NOT** ship with any SG-1000 ROM games like Congo Bongo, Star Jacker etc. Those are easy to find on the Internet, and we don't want any nasty letters from the companies who hold the copyrights to the SG-1000 games.

Basic IIIB

This is a full copy of the Basic IIIB in case you want to load your own tape software through the cassette-in port or do your own programming.

Music Editor

The Music Editor is hard to use without the plastic keyboard overlay and some musical talent. But Sega released a demo tape with 10 demo music tracks on it. We hacked the Music Editor ROM to automatically load those tracks. Just select option 4 Play from the Music Editor menu.

Tape Software

Mike Boyd Tape Games

- Burglar Bill (Jet Set Willy style game)
- Burglar Bill II
- Caverns of Karanor (Jet Set Willy style graphic adventure)
- Caverns of Karanor (infinite lives cheat mode)
- Decimator (Defender clone)
- Moonbase Alpha (graphic adventure plus digitized speech)
- Sir Roderick's Quest (graphic adventure)
- Sorceror's Apprentice (Mike Boyd graphic adventure with 80 screens to explore)

Arcade Packs by Stephen Coupe

- Arcade Pack I - Astro (Asteroids clone)
- Arcade Pack I - Gloopa
- Arcade Pack I - Shootout
- Arcade Pack II - AFOS (Tron light cycle style game)

- Arcade Pack II - Splat (Frogger clone)
- Arcade Pack II - Trojans
- Arcade Pack III - 1986 (Donkey Kong style game)
- Arcade Pack III - Bomber
- Arcade Pack III – Blackjack

Text / Graphic Adventures

- Castaway
- Castle of Fear
- Death Satellite
- Mars Adventurer
- Orb of Power
- The Tomb of Nozar
- Time Capsule
- Transylvania Castle of Horror
- Underworld of Kragon
- Young'ns

Other SC-3000 Tape Games (Commercial)

- Aerobat (vector graphics Cesenna 152 flight simulator)
- Astro Defense (Timegate Software)
- City Lander
- Deadly Jewel of Antark
- Delta Fighter (large 8-way scrolling game area - shoot the planes, bomb the crap out of the ground installations)
- Demon Gobbler
- Dungeons Beneath Cairo (early RPG game)
- Froggy
- Gold Miner (Donkey Kong / QBert crossover set in Haunted Gold Mine)

- Help (Crazy Crypt)
- Laser Blast
- Lumberjack
- Mars Mobile
- Monopoly
- Munchman (Pacman clone)
- One Day Cricket
- Pandamonium
- Satellite Salvage
- The House
- Towers of Hanoi
- Vermin Invaders
- Vortex Blaster (vertical space shooter plus digitized speech)
- Educational / Utility SC-3000 Tapes
- Hangman
- Rocket Maths
- Spelling Tutor
- Sprite Generator (John Sands)
- Tank Addition
- Watch Me Draw
- Word Processor

SC-3000 Demos

- Color Mixing Basic Demo
- The Great Wave off Kanagawa (Japanese Art Basic Demo)
- Sega Basic Demo
- Otani Oniji II / Scowling Man Basic Demo
- What is Print 64? Demo

Sega Magazines / Home Brew

The following were all type-in programs from Sega Magazine from 1984 to 1988

- Artificial Intelligence
- Aircraft
- Astro Attack
- Balune
- Bubble Trouble
- Candy Kid
- Colditz
- Connect 4
- Delta Race
- Fireman
- Gunslinger
- HypnoQix
- Indy GP
- Jet Ranger (Basic / Machine code game from Sega Computer Magazine)
- Karate Champs (Basic game from Sega Computer Magazine)
- Sea Battle
- Serpent
- Shoot 'Em Up
- Star Wars
- Tank Battle
- The Dog (picture of The Dog from Footrot Flats)

EPSGMOD / VGM Music Player

The SC-3000 was never developed to its full potential. However it has the same sound capabilities as the Master System and other contemporary 8-bit systems. So we included some nice music tracks.

- En Vard Fyra Javel (finalist in 2011 SMS Power Music Competition)
- Run Under Fire
- Air Wolf Theme
- Smooth Criminal
- M.A.S.H. Theme
- Star Wars Theme
- Beat It
- Bad

SC-3000 Survivors Demo

A short demo featuring a sample of Axel-F recorded via the SC-3000's cassette-in port, plus pictures of your friendly Survivors crew and a mystery guest.

Korean / Taiwanese ROMs

You will have to add your own 'official' SG-1000 / SC-3000 ROMs to the multicart yourself. But the following dumps from the Korean Samsung Gam*boy and Taiwanese Aaronix SG-1000 II clone are included with the multicart. They were never available for the SC-3000, and they all required minor tweaking to run on the multicart.

- The Black Onyx (English Translation by Bruce Tomlin and KingOfCrusher)
- Cabbage Patch Kids
- Circus Charlie
- Comic Bakery
- Gunsmoke
- Gunsmoke (infinite lives cheat)
- Hyper Sports II
- Magical Tree
- Xevious
- Yie Ar Kung Fu

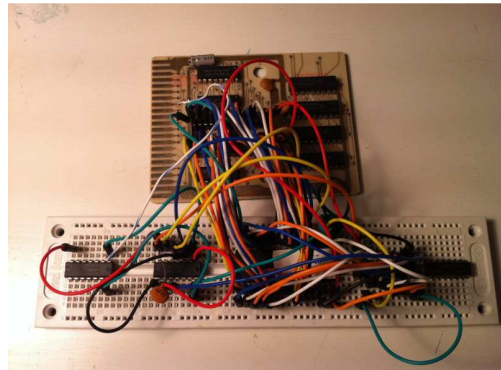
History

The SC-3000 Multicart idea was born in June 2010. I had just bought some blank Basic IIIB PCBs (no ROM) from a guy in France and I thought I'd try burning a couple of my favourite games to play on the SC-3000. I hadn't heard of a multi-cart before and it just came up briefly in discussion with a couple of friends. That sounded pretty cool as an 'all-in-one' multicart design suits the SC-3000 really well as the games are small enough to fit all your favourites on a single multicart. So the next few months was spent bouncing ideas around, reading up on TTL logic, ordering various bits and pieces, and generally figuring out how the hell this sparky stuff works :)

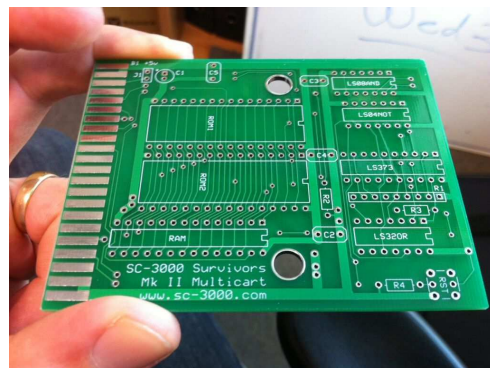
The Mk I DIP switched based multicart was a proof of concept to see if it could be done. But the long term goal was always a Boot Menu version and (if we were really lucky) instant loading tape games. The original plan was to get the Mk II Multicart working on the breadboard then to hack together some homebrew multicarts by stuffing a pile of extra wires and chips into a Basic IIIB case.

The first half of the plan worked great. The breadboard tests were a success! But there was no way in hell this was **ever** going to fit inside a cartridge case, and it would be a nightmare to manually attach wires to all the TTL logic chips. We needed... a circuit board.

The next 3 months was spent in refining the boot menu system and learning how to create and manufacture a PCB design. It is pretty straightforward once you've done one, but it is one hell of a learning curve when you're starting from scratch. Still, we got there in the end and Futurlec did a really nice job on the PCBs.



The original Mk II Multicart with Boot Menu breadboard layout



The Mk II Multicart PCB, hot off the press from Futurlec (Aug 2011)

We did not originally plan to make the Multicart available for public sale. After all, who wants to program EPROMs in this day and age? But in October 2011 the crew at SMS Power found out about the project and asked us to write about it. It turned out there was enough interest in the dev forums to justify a small one-off production run for the SC-3000 enthusiasts out there. It took a solid 6 months of hard work to make that happen, but it was worth it. We're very pleased with how the multicart has turned out. Instant loading tape games are brilliant, and if you trick out a couple of these carts you can have all the known SG-1000 compatible games at your fingertips. Awesome 😊

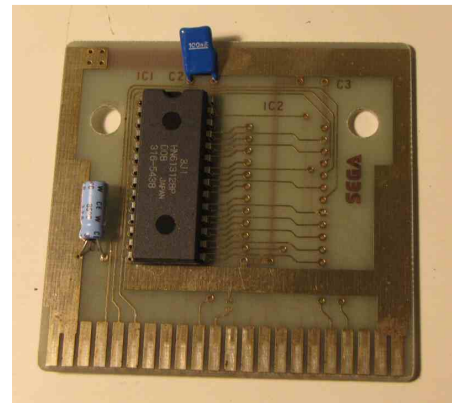
How does the SC-3000 Survivors Mk II Multicart work?

Home computers like the SC-3000 are simple enough that you can build one in your own garage. The SC-3000 Survivors MkII Multicart uses some [old skool](#) tricks and parts that have been around since the dawn of home computing. And with a bit of luck you will even be able to understand how and why it works.

How a SC-3000 games cartridge works

SC-3000 Games cartridges are very simple - they don't have much in them. Check out the following picture of a Yamato games cart.

There are only three components on that board. The 4.7uF electrolytic capacitor is designed to smooth out any major fluctuations in the power supply from the SC-3000. The 0.1uF ceramic or polyester capacitor is designed to decouple the ROM and smooth out any noise in the system caused by the rapidly changing voltage states at the ROM input and output pins.



Yamato Circuit Board

The big black thing in the middle of the circuit board is the ROM chip that contains all the program code and screen data for the game. Almost all the SC-3000 games carts contain a single 28 pin ROM chip that holds either 16KB or 32KB.

The sole purpose of that circuit board is to supply that ROM chip with power and to connect the address and data lines from the Z80A CPU to the pins on the ROM.

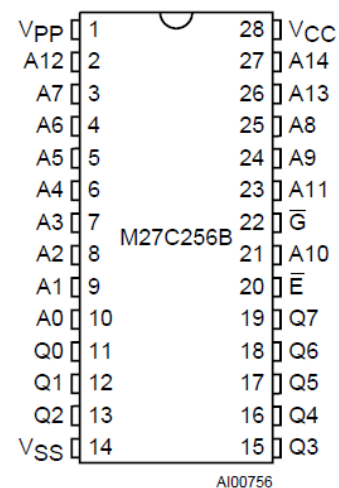
The original 256KBit / 32KB ROM has 28 pins in total (see diagram). 15 of these are address pins - A0 to A14. That allows the SC-3000 to address all of the lower 32KB of memory space (0000 to 7FFF) in the ROM (as $2^{15} = 32,768$).

For example, say the computer needs to access the memory stored in position 14,297. That is 011011111011001 in binary. So the CPU just turns the voltage to the corresponding pins on or off. ie.

$A0 = 5v, A1 = 0v, A2 = 0v, A3 = 5v, A4 = 5v,$

$A5 = 0v, A6 = 5v, A7 = 5v, A8 = 5v, A9 = 5v,$

$A10=5v, A11=0v, A12=5v, A13=5v, A14=0v$



32KB ROM Pinout (256KBit)

Bank Switching / Memory Mapping / Paging

The Z80A is an 8 bit processor and only has a 16 bit address range. That means it can never directly address more than 64KB of memory. That wasn't a problem for the SC-3000 as all its games cartridges were 32KB or smaller. (Well, mostly anyway - there are a couple of ROM dumps floating around that are 40KB, but there are generally smaller versions of those games available, so we will ignore those). So the games carts usually just had a single ROM chip which was hard wired into the lower 32KB of memory, and the SC-3000 had 2KB of RAM located at the 48KB mark for storing temporary calculation results.

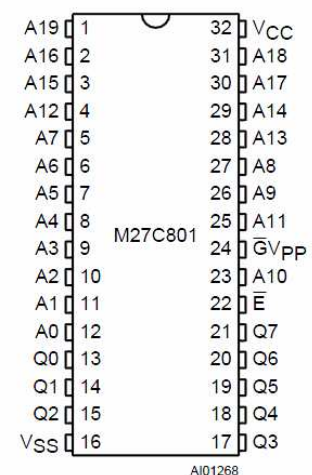
But newer 8 bit systems like the NES, the Sega Master System, Commodore C128, Amstrad CPC 6128 etc. soon needed more storage. They solved that problem with Bank Switching. Those systems could write out special instructions to a paging chip that would 'swap' part of the memory that the processor was connected to out to another portion of the ROM or RAM. Many SMS games, especially the later ones, required significantly more than 64KB to store all the game graphics and sound data, and each of these carts had a built in paging chip.

How the SC-3000 Survivors Mk II Multicart Paging works

The SC-3000 Survivors Mk II Multicart uses a very simple paging design (simpler than the SMS carts). We just swap out the bottom 32KB of memory space (\$0000 to \$7FFF) to a different portion of a large 8MBit (1MB) EPROM (actually two EPROMs, but pretend it is just one for now). The 8MBit EPROM is 32 times larger than the original 256KBit / 32KB ROM, so we can fit 32 games on it. And because we are only paging or swapping out the lower 32KB of memory, we don't need to make any changes to the RAM access which is always in the top 32KB of memory from \$8000 to \$FFFF.

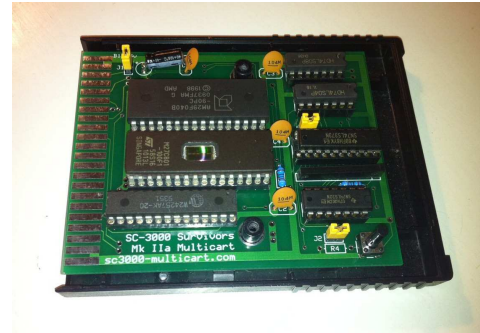
Our new 8MBit / 1MB EPROM has 32 pins in total. 20 of these are address pins - A0 to A19 (see diagram).

Now, see how the layout of the bottom 26 pins is identical to the original ROM? That lets the Sega control the bottom 15 address pins A0 to A14 as normal, but we control the +5v or 0v / GND signal to the A15 to A19 pins with a 74LS373 8-bit latch.



The main Mk II Multicart components are:

- 2 x 27C801 8MBit EPROMs
- 32KB SRAM
- 74LS373 8-bit latch
- Reset switch to restore the boot menu without having to switch power off
- J1 jumper between B02 and B03 pins to allow you to enable / disable the SC-3000's onboard 2KB SRAM and J2 enables / disables the 32KB SRAM on the multicart
- J3. When removed, this forces pin 31 on ROM 0 high. That ensures that if you put a 29F040 Flash EEPROM in there that /WE is forced high
- Various TTL glue logic chips



Why two EPROMs? Well, in the words of [Tim the Toolman](#), "More Power. Grunt grunt grunt." Well twice the storage space, anyway. We originally thought we'd be happy with 32 slots on a cart. We were mistaken :) Two EPROMs gives us 64 slots of 32KB to play with.

The 74LS373 8 bit latch does 3 things:

- It controls the A15 to A19 pins on the EPROMs to select another logical 32KB block
- It selects which of the two EPROMs is active at any one time (although the PCB will work happily with only the second EPROM installed)
- It enables / disables itself. This is a feedback loop for the Reset switch on the PCB which is there to get the boot menu back without powering off

The latch is mapped onto the SC-3000's I/O bus at port $\$e0$, which is free on the SC-3000. Actually, what it *really* does is latch the value on the data lines when A5, A6, and A7 are all high and /IOW is low. That means it will respond to writes to any port in the range $\$e0$ to $\$ff$.

The Reset switch behaviour is interesting. Unfortunately the SC-3000 does not pass the Z80 reset line out to the cartridge port. So the hard reset switch on the Multicart disables the 8 bit latch which selects the last slot on the second ROM because the PCB has pull up resistors on the 74LS373 output lines. This is where the boot menu goes. You then press the Reset button on the SC-3000 keyboard which triggers the Reset handler in the boot menu block which basically returns back to $\$0000$, cleans up the system, and displays the boot menu.

The game ROMs are all 32KB or smaller (16KB / 8KB). The SC-3000 is naturally set up for having the ROM in the lower 32KB of memory, and the RAM in the upper 32KB - either 2KB from C000 to C7FF (on-board) or 16KB ($\$8000$ to $\$BFFF$) or 32KB ($\8000 to $\$FFFF$) with the Basic carts. And there are no known SC-3000 carts that use a paging system - that started with the Master System.

Fun Fact: The original Mk I Multicart proof of concept was using a DIP switch, but I always envisaged using an 8-bit latch. However my original (bad) plan was to use an 8255 PPI. Blame the SF-7000 for that idea. The SF-7000 Super Control station is the only 'original' Sega peripheral to use paging. That has an IPL (Initial Program Loader) which is used to bootstrap the system and it uses an 8255 PPI to swap the IPL in / out of memory. That actually gave some of the original inspiration for the multicart design - I even bought a couple to use. But the damn things are huge, and too complex to initialize. I took one look at it and hunted around for a smaller standalone 8-bit latch, hence the 74LS373.

But the 8255 PPI was a really nice way of simplifying your I/O interface. Just map the PPI onto your I/O bus, then connect your peripherals to that. The SC-3000 uses a PPI for input/output from the keyboard, joysticks, printers, cassette port etc., and the SF-7000 uses one for the Floppy controller, IPL paging control etc.

The ROMs are all uncompressed which makes for a nice simple hardware design with a very basic paging system. Where we have been using compression is in the loading of tape games. Those *are* copied into the top 32KB of RAM, so some of those are compressed to save space. Plus we've been playing around with digitized photos and music files etc. so the aPLib compressor is very handy for that.

The Multicart is perfectly suited to running tape games. Those always run in the upper 32KB of RAM and expect to have the IIIB ROM in the lower 32KB. We just need to write a custom loader for each one to load from the multi-cart paging system instead of calling the tape load routines. Single-load tape games are easy. You just copy the data to \$9800, reset the basic pointers at \$8160, and jump into the basic RUN entry point.

Multi-load games with separate title screens etc. are harder and need the custom load treatment. But apart from loading from the multicart, the games load in the same sequence they did when loaded from tape, which is kind of neat.

Credits and Acknowledgements

The Multicart Project has been a journey of discovery. Thankfully the Internet is just full of information on Electronics Basics, TTL Logic, Z80 Architecture, SC-3000 Architecture etc. Here are some of the resources that helped us directly or indirectly along the way.

The SC-3000 Survivors Team

Thanks for putting up with the long development emails, guys :)

If you haven't already, then check out the [SC-3000 Survivors Website](#).

The SMS Power Team

I just want to say a big thank you to everyone who has supported [SMS Power](#) over the years and made it the place it is today.

In particular I'd like to mention the following SMSPower resources which were critical at various times during the build:

- Charles MacDonald's excellent [SC-3000 Hardware notes](#)
- [Maxim's assembler tutorial](#), [aPLib compression library](#), and commented [SF-7000 IPL source](#) were *very* handy when writing the multicart boot menu. I actually used the SF-7000 IPL as my start point as it already had a text mode display and keyboard matrix parser built in.
- MikeG for the awesome [SMS Reader tutorial](#)
That provided crucial insight early in the process as I was figuring out just how the hell this sparky stuff works
- Bock - the tireless [Ringmaster](#)

Books, Magazines etc.

- Mike Hadrup and the Sega Computer Magazines from 1986 to 1988
Mike was a teenager when was the Editor of the final Sega Computer Magazines, and he gave a lot of relevant background information about the SC-3000 hardware based on his personal experience and summarized from datasheets.
- Brian Brown's Programming the SC-3000 (1984)
- Some 1980s electronics project magazine to build a generic I/O controller for the Amstrad CPC based on an 8255 PPI

Miscellaneous Links

- [Z80 opcodes and instructions cheat sheet](#) (<http://www.z80.info/z80sean.txt>)
- [Z80 instruction set - more detail](#) (<http://z80-heaven.wikidot.com/instructions-set>)
- [MESS Debugger Help](#) (<http://mess.redump.net/debugger>)
- [http://wiki.xtronic.com/index.php/How EPROMS Work](http://wiki.xtronic.com/index.php/How_EPROMS_Work)
- <http://www.arlabs.com/help.htm>
- <http://www.seattlerobotics.org/encoder/mar97/basics.html>
- http://womblesretrorepairshack.blogspot.com/2008_12_01_archive.html
- <http://cgfm2.emuviews.com/>
- <http://msx.jannone.org/conv/>
- <http://www.seattlerobotics.org/encoder/jun97/basics.html>

- <http://tacashi.tripod.com/elctrncs/pcbworks/pcbworks.htm>
- <http://www.expresspcb.com>
- <http://www.futurlec.com>
- <http://lateblt.tripod.com/z80proj2.htm>
- <http://lateblt.tripod.com/index.htm>
- <http://lateblt.tripod.com/z80proj1.htm>
- <http://forum.allaboutcircuits.com/showthread.php?t=2517>
- http://www.allaboutcircuits.com/vol_4/chpt_3/7.html
- http://www.mattkrass.com/?page_id=763
- <http://www.asic-world.com/digital/logic1.html>
- <http://www.kpsec.freeuk.com/components/74series.htm>
- <http://www.kpsec.freeuk.com/components/ic.htm>
- http://www.allaboutcircuits.com/vol_4/chpt_7/5.html
- <http://www.sleepingelephant.com/v-web/bulletin/bb/viewtopic.php?p=15700&sid=b3c9d129e964407454f915b241241758>