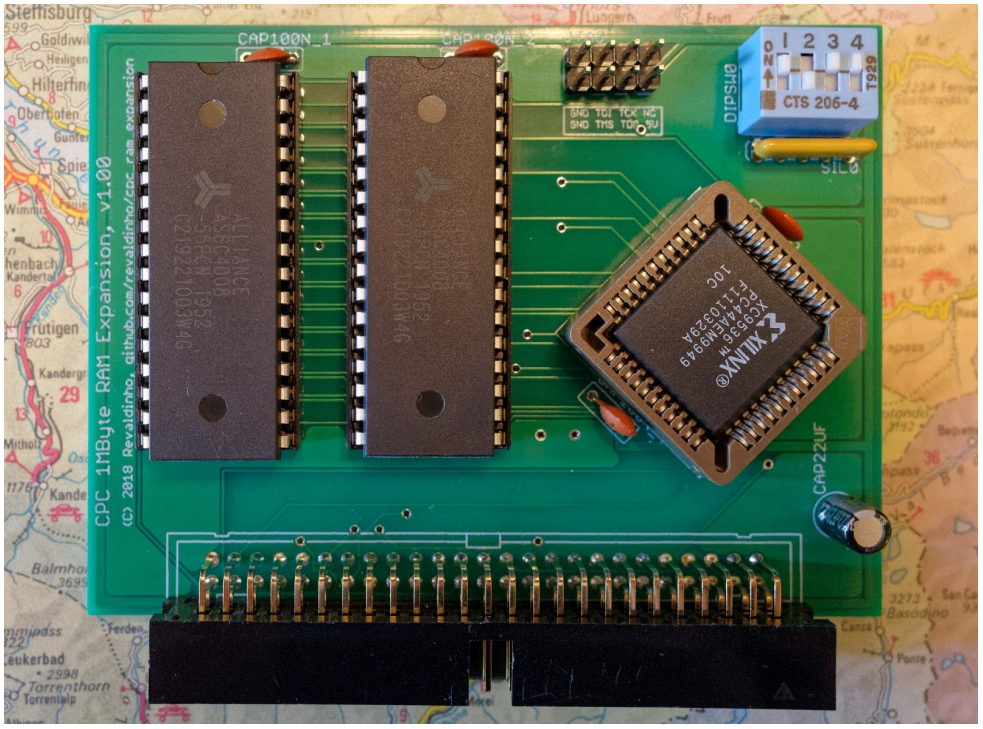
Revaldinho Universal 1MByte RAM Card

User Guide and Technical Manual

Summary

This is a 1MByte memory expansion card which is suitable for all Amstrad CPC computers.



On all CPCs the board provides three expansion configurations

- 64KByte mode (for 464/664), to provide maximum compatibility with the CPC6128
- 512KByte mode, using Dk'Tronics expansion scheme
- 1MB mode, using the RAM7/Yarek addressing scheme.

Like other RAM cards, it provides full DK'Tronics compatibility when used with the CPC464 and CPC664 and this is sufficient to run the vast majority of software which can use the additional RAM, including CP/M Plus, demos such as Phortem and Batman Forever and many games.

The card also provides a unique 'shadow mode' which enables perfect Amstrad CPC6128 video mode C3 operation on CPC 464/664 computers. These older machines can now run FutureOS and other software which previously would run only on CPC6128s and later machines. In shadow mode the maximum expansion provided by the card is reduced to 960KBytes, as one 64KByte bank is needed to shadow the base RAM.

Shadow mode can also enable a 464 to run entirely from the card RAM without using base RAM other than for the video display. This may be useful for reviving or at least diagnosing CPC464s with faulty internal RAM.

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User Guide

Installing the Card

The card is supplied with an MX4 type connector rather than an edge connector, so requires an expansion board or ribbon cable connection to hook up to the computer. All modern expansion boards have the same pin-out which mimics IDC connectors on a ribbon cable. The RAM card connector is keyed, to ensure that it will fit only in the correct orientation in a matching socket, such as the ones installed in the Revaldinho CPC Expansion Boards. Some other expansion boards use cheaper non-keyed connections which make it possible to insert the card the wrong way round. For those boards, take care to insert the card so that the component side of the board (including the DIP switch) is facing the rear of the Amstrad CPC computer.

The card draws approximately 100mA of current when running with a 5V supply. This should be handled by a standard CPC power supply and although cards are tested down to 4.5V to allow for some voltage drop over old edge connectors, it's a good idea to clean the connectors on your CPC to minimize this. If your expansion board allows an external power supply to be used, then it's recommended to connect one, particularly if you are using a number of different peripherals as well as the RAM card.

Once the card is physically installed, it's necessary to configure it appropriately before switching on the computer. This is done by setting the 4 DIP switches on the top level of the circuit board.

Recommended Configurations

Computer	**DIP1**	**DIP2**	**DIP3**	**DIP4**	**Expansion**	**Application**
CPC 6128/Plus	OFF	OFF	ON	ON	1MB	All
CPC 464/664	ON	OFF	ON	ON	960KB	FutureOS
CPC 464/664	OFF	ON	OFF	ON	64KB	CPC 6128 games [1]
CPC 464/664	OFF	ON	ON	OFF	512KB	CP/M+ [2], DK'Tronics silicon disk
CPC 464/664	OFF	ON	ON	ON	1MB	SymbOS

The table above shows the most common DIP settings needed for different CPC models and software. Other settings are possible and described in more detail below.

DIP Switch Settings

The board has four DIP switches which are grouped into two pairs

- DIP1 and DIP2 determine the card mode
- DIP3 and DIP4 determine the RAM expansion size

Changing DIP settings while the computer is running is likely to cause a crash, but even if it doesn't you should always reset the computer after a change.

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[1] May also require the CPC 6128 upper BASIC and lower Firmware ROMs to be installed.
[2] See Compatibility Tips for CPC 464/664 Computers

Setting the Card Mode

The card has 4 operating modes shown in the table below.

Mode	DIP1	DIP2	Mode	C3 Video	Comment
0	OFF	OFF	6128 Mode	Amstrad	Always use this mode for CPC6128 & Plus computers[3]
1	OFF	ON	DK'Tronics Mode	DK'Tronics	Basic DK'Tronics compatible expansion for CPC464/664
2	ON	OFF	Shadow Mode	Amstrad	Enhanced mode expansion with perfect Amstrad C3
3	ON	ON	Full Shadow Mode	Amstrad	Enhanced mode expansion with perfect Amstrad C3

For CPC 6128, CPC Plus and late 'cost reduced' CPC 464[3] models, always select mode 0.

The other modes are all intended for the vast majority of older CPC 464 and 664 computers. These computers do not handle expanded memory as cleanly as the CPC 6128, so the RAM card needs to overdrive some of the key CPU signals at critical moments to write-protect the CPC's internal memory and to remap some of that memory in one specific configuration. Modes 1-3 are the only modes suitable for CPC 464/664 computers, and all implement the electrical overdrive operation.

The main difference between modes 1-3 is the way in which the C3 video mode is handled. There is a choice between DK'Tronics handling of the C3 video mode and true CPC 6128-type handling. Most software is perfectly happy with the DK'Tronics implementation. Mode 1 implements this and is good for running CP/M+ using the DK'Tronics software to provide a 256KByte RAM disk for example.

Some software needs a perfect implementation of the Amstrad C3 mode and FutureOS is perhaps the best example of this. To be able to run this software chose either mode 2 or mode 3. There is no obvious difference to the user between these two modes. In both modes 2 and 3 all CPU writes to base memory are also sent to the shadow bank in the expansion board. Mode 3 disables all CPU reads from base RAM and replaces them with read data from the expansion board, whereas mode 2 does this only for reads from the upper 16KB of base memory. Both schemes provide the perfect C3 mode operation.

Since mode 3 replaces all CPU reads from base RAM with data from the expansion board, it's possible that using this mode could revive a CPC 464/664 with faulty base RAM. If the faulty RAM is in the video address space, then unfortunately there will still be a corrupted screen display because it's not possible for the expansion board to service reads to the CRTC chip. Even so, in theory at least, it would be possible to boot and run a CPC 464/664 in this way which might at least help with fault diagnosis.

[3] Use this mode also for very late model CPC 464 computers which have the very small motherboard and ASIC in place of the original gate array ICs.

Setting the RAM Configuration

As well as the operating modes, there are four possible RAM configurations described in the table below.

Config.	DIP3	DIP4	RAM Expansion	Comment
0	OFF	OFF	0 KB	Effectively disables the RAM card
1	OFF	ON	64 KB	Maximum CPC6128 compatibility mode
2	ON	OFF	512KB	DK'Tronics expansion
3	ON	ON	1 MB (or 960KB)	RAM7/Yarek expansion

In configuration 0, the RAM card is completely disabled. There may be rare cases where a CPC 464/664 needs to run in an unexpanded RAM mode, but you shouldn't normally need to select this mode.

Configuration 1 is provided to give CPC 464/664s maximum compatibility with the CPC 6128. In this mode all expanded memory accesses are mapped to the same 64KByte expansion bank. This configuration can be used with both DK'Tronics and Amstrad C3 video modes (above) with no effect on the size of the expansion.

Configuration 2 models a 'standard' DK'Tronics 512KByte expansion scheme. DK'Tronics sold several different expansion cards back in the 80s including a 64KByte RAM expansion, a 256KByte expansion and a 256KByte silicon disk. All of these conformed to this scheme and the RAM expansion and silicon disk could be used together for a total of 512KBytes. In configuration 2, the card replicates this scheme exactly and the original DK'Tronics RAM expansion (bank management) and silicon disk software work without modification. This configuration can be used in conjunction with both DK'Tronics and Amstrad C3 video modes without affecting the size of expansion RAM available.

Configuration 3 provides the maximum memory expansion. This uses the RAM7/Yarek scheme which extends the DK'Tronics standard. Most legacy software able to access expanded RAM will be able to run in this mode even if it doesn't access the full 1MByte. Only more modern software will make full use of this mode, but that does include the operating systems SymbOS and FutureOS as well as a number of demos. On a CPC 464/664, FutureOS will need one of the two shadow modes 2 or 3 to be selected in conjunction with this configuration because it specifically needs the full Amstrad C3 video operation; other software will be ok with any of modes 1-3. When one of the shadow modes is selected, the maximum RAM expansion available in this configuration is reduced to 960KBytes because one 64K bank is needed to shadow the CPC's base memory.

Note that in all cases the total RAM of the CPC is the internal 64K base memory + the additional RAM Expansion. So in 512KB mode for example, the CPC actually has 576KBytes of RAM. This is true for all machines including the CPC 6128 and Plus because the built-in 64KByte expansion in these machines is disabled when an additional RAM card is added.

Compatibility Tips

CPC 464/664 Computers

To upgrade a CPC 464/664 computer to full CPC 6128 specification you will need to add a memory expansion card but also change both the BASIC and lower Firmware ROMs. Some games check for the ROM types to determine the machine type or RAM size for example.

Even with the CPC 6128 ROMs installed, you may find some software won't run due to other subtle hardware differences including the keyboard scanning arrangement. DK'Tronics recognized this and provided a set of RSXes as a workaround as part of their RAM expansion software. In particular the |EMULATE command deals with differences in the keyboard map. On some CPC 464s you must install and run the RSX before you can boot into CP/M+ for example (otherwise it returns a message to the effect "CP/M+ does not support this environment").

For most legacy CPC software, running in DK'Tronics compatibility mode (mode 1) and either 512K or 64K RAM configurations is recommended because older software wasn't written to target the Yarek/RAM7 addressing scheme.

More recent software is likely to be able to use the full 1MByte mode.

CPC 464 Plus Computers

The CPC 464 Plus and CPC 6128 Plus share the same ASIC and motherboard, but there are differences in components fitted to the two boards. Obviously the CPC464 Plus is missing the additional 64KByte RAM bank of the CPC 6128 Plus, but less obviously this affects the way in which expansion RAM is handled in the video mode C3.

The CPC 464 Plus should always use the RAM card mode 0 (non-overdrive mode) but by default the C3 video mode will behave as it would on an older CPC 464 with a DK'Tronics expansion. However, it is possible to update the CPC 464 Plus to inherit the same clean RAM expansion handling as the CPC 6128 and by adding a single component. On page 18 of the Service Manual[4], "Gate Array / Output Interface Schematic Diagram" you will see a note at the bottom of the page to the effect that resistor R128 (10Kohm) needs to be added for the board to recognize an on-board 64K expansion (ie 128K rather than 64K). Adding this resistor will also update the RAM handling to that of the CPC 6128, and the 1MByte RAM card will do the rest. In this way the CPC 464 Plus can gain the full 1MB expansion and run FutureOS and other C3 mode dependent software.

[4] The Amstrad CPC Plus Service Manual can be found here: http://www.cpcwiki.eu/manuals/Service%20Manual%20Amstrad%20Plus.zip

Technical Manual

The following sections describe in more detail the various RAM expansion schemes and how the card implements different compatibility modes.

DK’Tronics Mode Operation

The board is fully compatible with the DK'Tronics/Amstrad bank switching schemes described in the DK'Tronics Peripheral Technical Manual.

In this scheme there are 8 possible 64K banks, and each bank is split into 4 16K blocks.

Selecting a 64K bank is done by writing to the Z80 IO address 0x7Fxx with an 8 bit dataword.

Bit position	7	6	5	4	3	2	1	0
Value	0	1	c	c	c	b	b	b

The two MSBs of the byte must be set to 01 and then the rest of the byte is divided into two 3 bit fields:

- ccc - picks one of 8 possible 64K banks
- bbb - selects a block switching scheme within the chosen bank

In true DK’Tronics mode operation, the maximum RAM expansion size is limited to 512KBytes.

Within any one 64KByte bank, RAM is divided up into 4 16KByte blocks numbered from 0 (the lowest 16KBytes) to 3 (the highest 16KBytes).

The bank switching schemes for the 6128 and Plus machines are illustrated in the table below, where

- '-' indicates access to internal RAM
- 0-3 indicate access to the relevant block in the selected external expansion bank

	Block Scheme (bbb)							
Address	**000**	**001**	**010**	**011**	**100**	**101**	**110**	**011**
0xC000-0xFFFF	-	3	3	3	-	-	-	-
0x8000-0xBFFF	-	-	2	-	-	-	-	-
0x4000-0x7FFF	-	-	1	**	0	1	2	3
0x0000-0x3FFF	-	-	0	-	-	-	-	-

Bank 0 would normally select the single internal 64K expansion bank in a 6128, but when the card is attached this bank is disabled and the first bank in the external expansion is accessed instead.

In the special case '**' marked in column '011' internal memory at 0x4000-0x7FFF is remapped to 0xC000-0xFFFF. This is the special ‘C3’ mode referred to in the user guide, and is handled internally in the CPC 6128 and Plus machines, but not in the CPC 464/664.

Whenever expansion RAM is accessed, the card asserts the ‘RAMDIS’ signal on the CPC’s edge connector. On the CPC 6128 this is sufficient to disable all read and write access to internal base RAM. However, on the CPC 464/664 this signal disables only internal memory reads - i.e. all writes to expansion RAM will also go to internal base memory, thereby corrupting it. Much of the complexity in all CPC 464/664 RAM expansion cards goes into dealing with this situation.

DK-Tronics expansions and other modern reimplementations deal with this problem by backdriving the A15 and MREQ* signals coming out of the CPU.

On all expansion RAM writes the cards detect a memory request and then quickly overdrive MREQ* fast enough that the gate array does not initiate an internal memory access. This effectively write-protects the internal RAM when accessing expansion memory.

Overdriving the A15 signal is used in mode C3 to do the internal remapping. When these cards detect an access to internal RAM block 1 in C3 mode, the A15 signal is overdriven to ‘1’ to turn it into an access to internal RAM block 3 instead. This works very well for write operations to internal memory, and this is sufficient to run software which uses this mode only to write to video memory.

Unfortunately, this does not work for software which uses this mode to remap CPU read accesses from (internal RAM) block 1 to block 3. This is due to the way in which the CPC handles ROM and RAM accesses. If the upper ROM is disabled when one a read access is made, then all is well - the RAM address will be remapped and the RAM data from the uppermost block will be returned correctly to the CPU. However, if upper ROM is enabled when a read access is made then the gate array will assume that ROM data is required and return ROM rather than RAM data. This prevents standard DK’Tronics cards or re-implementations performing a perfect C3 mode emulation, and hence these cards are unable to run FutureOS and other software which is dependent on that.

Implementation and Extension of DK'Tronics Mode in the Universal Card

For maximum compatibility with older software this card provides modes which will operate exactly as described above. Under the hood, there are some slight differences in the way the electrical back-driving is done.

Firstly the card chooses to overdrive the RD* signal rather than the MREQ* signal to write-protect base RAM. The RD* signal is interpreted as 'write not read' by the CPC's gate array IC. When a write to expansion RAM is detected the card forces RD* low so that the gate array instead thinks a read is being performed. The gate array will still initiate an internal RAM access but now it's a non-destructive read and the card's assertion of the RAMDIS signal means that the internal RAM data never makes it to the CPU bus.

Overdriving RD* was chosen for electrical reasons. When the signal is overdriven there is an electrical conflict between the CPU and the CPLD on the expansion card. With TTL logic it's easier to win a conflict by driving to '0' rather than '1'.

There is no alternative to overdriving A15 to '1' (in conflict with the CPU driving it to '0') in C3 mode. To provide some more robust operation here the CPLD gangs two output pins together to drive this particular signal.

In this way full DK'Tronics compatibility is provided on all models of Amstrad Computer including the CPC464 and 664. This mode of operation still suffers from the same C3 mode limitations as the original of course. The solution to this is the shadow mode described later.

Reduced Expansion RAM Addressing - maximum 6128 compatibility configuration.

In a standard Amstrad CPC6128, there is 64K of base RAM and only a single 64K expansion bank.

Selection of that RAM bank is still done by writing a byte to the Z80 IO address 0x7Fxx.

Bit position	7	6	5	4	3	2	1	0
Value	0	1	X	X	X	b	b	b

In this case bits 3-5 are ignored: all accesses to expansion RAM are sent to the only available 64K expansion bank. The 3 LSBs are still used to select the block access mode.

The card provides an option to limit the RAM expansion to 64KBytes for any legacy software which assumes this reduced addressing scheme. This provides maximum CPC 6128 compatibility when expanding a CPC 464/664.

Expanded RAM Addressing - the RAM7/Yarek Scheme

The Amstrad/DK'Tronics bank addressing scheme only allows 8 64KByte banks to be selected, limiting RAM expansions to a maximum of 512KBytes.

The RAM7/Yarek scheme expands this by more strictly controlling the Z80 IO port addressing used to select expansion RAM.

In the original scheme, writes to the Z80 IO port 0x7Fxx selects the expansion RAM bank & block mode.

In the RAM7/Yarek scheme the range of IO port addresses 0x7FF0 - 0x7FFF are used to select expansion RAM banks, with the 4 LSBs of the IO port address being interpreted as additional RAM bank selection bits.

This 1 MByte card provides 16 banks of 64KBytes each.

- Banks 0-7 are accessed by writing the RAM configuration register at Z80 IO address 0x7FFE.
- Banks 8-15 are accessed by writing the RAM configuration register at Z80 IO address 0x7FFF.

Shadow Mode Operation

Shadow mode operation applies only to CPC 464/664 computers.

The previous sections have described the various RAM addressing options and DK'Tronics emulation of the C3 video mode and its limitations in running some software, most notably FutureOS. This section describes in more detail the unique shadow mode which finally enables a perfect C3 video mode to be implemented on the CPC 464/664 and for software which requires it to run on these machines where previously they were confined to the CPC 6128 and later models.

In shadow mode, the card keeps an exact copy of the CPC's base RAM contents in a single bank of the expansion RAM: whenever the CPC writes to base memory the card copies that transaction also into the chosen bank in the expansion RAM. Block 7 is chosen as the shadow bank, leaving blocks 8-15 free to operate normally in the 64KByte and 512KByte RAM expansion modes for maximum compatibility. When running in 1MByte mode, block 7 is not available as an expansion RAM block and any reads or writes to this block are aliased to Block 6 instead. This is detected by modern OSes and identified as a 64KByte 'hole' in the 1MByte map, reducing the maximum capacity of the card to 960KBytes.

When the CPC is running in the video C3 mode, all writes to block 1 of internal RAM are remapped to block 3 by overdriving the A15 bit to '1', exactly as the DK'Tronics hardware would. At the same time these writes are copied also to block 3 of the shadow bank on the expansion card.

The key difference between shadow mode and DK'tronics mode is for the read operations. On DK'Tronics cards remapping block 1 reads to block 3 is not reliable because the data returned depends on whether upper ROM is enabled or not. Frequently ROM data is returned instead of the required RAM data and this causes, for example, corruption of the screen pointer in the FutureOS GUI. It may also cause crashes in other software.

Since the expansion RAM is keeping a perfect copy of the internal RAM data in shadow RAM, it no longer needs to do any overdriving of the A15 signal for read operations. Instead, when a C3 read from block 1 is

detected the card disables internal memory by asserting RAMDIS and returns the data from block 3 (i.e. the remapped address space) in the expansion card shadow bank instead. In this way the gate array doesn't see A15 high during the read and does not attempt to enable any of the ROMs.

Shadow mode provides perfect Amstrad CPC 6128 C3 mode emulation for older CPC 464/664 computers and is the only way to run C3 dependent software on these machines.

Full Shadow and Partial Shadow Modes

The card offers two versions of the shadow mode.

In partial shadow mode, all writes to base memory are copied to the shadow bank but only CPU reads from block 1 (addresses 0x4000-0x7FFF) are taken from the shadow bank.

In full shadow mode, again all writes to base memory are copied to the shadow bank but this time the shadow bank is used to service all CPU reads from base memory. The RAMDIS signal is permanently asserted while in full shadow mode, disabling CPU reads from base memory completely.

Both modes have been tested across a range of voltage on a small number of CPC 464 machines with no discernable difference in reliability between them. These tests have included specific RAM tests (DK'Tronics, Duke's RAM512KB test, the FutureOS RAM test program and so on) as well as running various OSes, demos and games. In full shadow mode, the card passes the tests in Gerald's test ROM which is often seen as the best test of base memory.

It's not practical to replicate all CPC environments though, as the '464 went through a number of motherboard revisions, three gate array/asic types (in two different technologies) and was built with Z80, CRTC and RAM components from a number of different manufacturers over its production lifetime. Additionally these machines are now 30 years old and some will have aged better than others. Since there are subtle differences in timing between the two shadow modes, you may find that one works better than the other with a particular CPC 464/664.

When running in full shadow mode, the CPC's internal RAM is only used by the CRTC chip to drive the video display. This means that it's possible that an old CPC with faulty internal RAM can be revived by using this mode. If the RAM problems are in an area access by the video controller then of course there will still be corruption on screen, but the rest of memory for program execution should work perfectly so it should at least be possible to boot and run the system which will either make it usable or help in diagnosing the exact RAM issue.

Test Suite

In developing the card the hardware has been tested across a voltage range of 4.25V to 5.5V using the following test suite running on a CPC 6128 and a CPC 464 (high key model).

- RAM Test Software
  - Duke's RAM512KB test
  - FutureOS RAM test
  - TEST.BIN
  - RAMTEST.BIN/RAMTEST.BAS (included in the GitHub distribution)
  - Gerald's RAM Test ROM (Full shadow mode only)
- OS and Applications Software
  - CP/M+ [5] with BBC BASIC and Borland TurboPascal
  - FutureOS with the Gianna Sisters game (shadow modes only)
  - DK'Tronics Silicon Disk
  - DK'Tronics RAM Expansion RSXes
- Games
  - Chase HQ [6]
  - Double Dragon
  - Gryzor
  - Hard Drivin'
  - Prehistorik II
  - R-Type [7]
  - Robocop
  - ZapTBall [7]
- Demos
  - Batman Forever[8]
  - Phortem

Any cards sold as built and tested by Revaldinho are run through the RAM tests and a subset of the rest of the test suite at a fixed 4.5V voltage on a CPC 464, checking all the main board operating modes.

[5] Booting CP/M+ requires use of the DK'Tronics |EMULATE RSX first on a CPC 464
[6] Not compatible with FutureOS ROMs - disable or remove these before running
[7] Requires the CPC 6128 lower and upper ROMs to be installed
[8] Not compatible with all CRTC types - this is not a RAM/Firmware issue

Validated Configurations

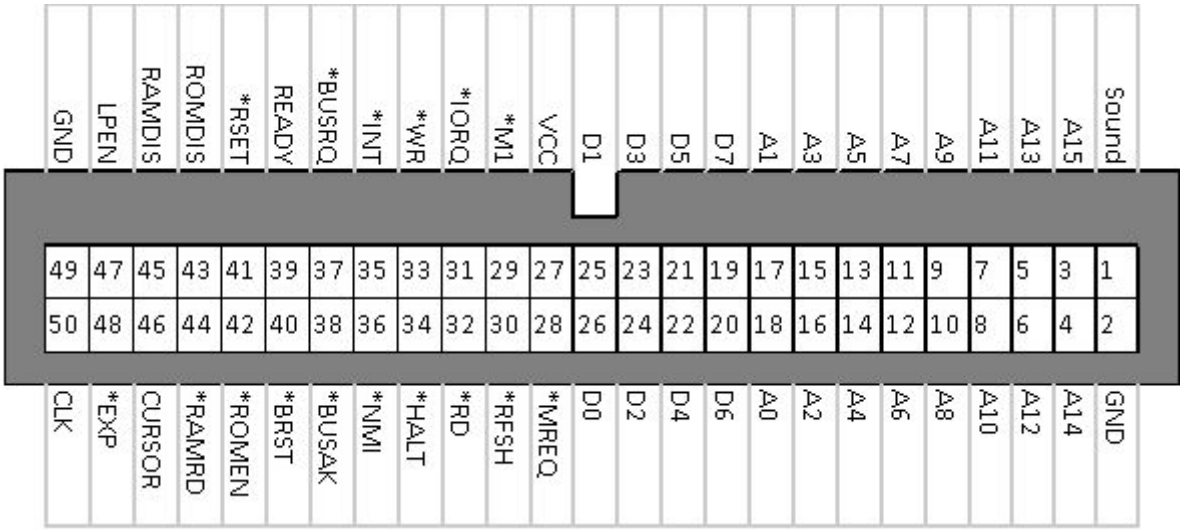
The following computer configurations have been verified using the previous generation 512KByte card, on which this 1MB version is based.

	Mode 0		Mode 1		Modes 2 & 3	
Computer	**Expansion**	**C3 Mode**	**Expansion**	**C3 Mode**	**Expansion**	**C3 Mode**
CPC 464	NA	NA	512K	DK'T	448K	Amstrad
CPC 664	NA	NA	512K	DK'T	448K	Amstrad
CPC 464 [ASIC]	512K	DK'T	NA	NA	NA	NA
CPC 464 Plus	512K	DK'T/ Amstrad[9]	NA	NA	NA	NA
CPC 6128 Plus	512K	Amstrad	NA	NA	NA	NA
KC Compact	NA	NA	512K	DK'T	NA	NA

Power Requirements

At 5V the card draws approximately 100mA from the power supply.

Card Connector Pin-Out



Pins on the card connector are numbered as shown above, looking into the pins of the connector.

This is the standard arrangement for most popular modern expansion boards, including the open-source Revaldinho boards, Mother X4 and LambdaBoards - see the CPC-WIKI for more details.

[9] Refer to the CPC Plus section in the Compatibility Tips above

Downloads

Some of the key software mentioned in the text above can be downloaded from the web.

- DK'Tronics Silicon Disk and RAM expansion RSXes
  - http://www.cpcwiki.eu/index.php/Dk%27tronics_memory_expansion
- Duke's 512KB Test (testing DK'T and Amstrad C3 modes)
  - https://github.com/M4Duke/z80
- FutureOS Homepage
  - http://futureos.cpc-live.com
- SymbOS Homepage
  - http://www.symbos.org
- Richard Russell's Z80 BBC BASIC Page
  - http://www.bbcbasic.co.uk/bbcbasic/z80basic.html
- Gerald's CPC base RAM Test
  - http://www.cpcwiki.eu/forum/amstrad-cpc-hardware/quick-and-dirty-ram-test-for-cpc/

Additional Resources

All source code and further documentation for this card and other related CPC projects are made available on Github: https://github.com/revaldinho/cpc_ram_expansion

License