

CRT Terminator DV1000 ISA

User Manual

2024-08-29

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Introduction

CRT Terminator Digital VGA Feature Card ISA 1000 is an 8-bit ISA expansion card that works on IBM PC compatibles all the way from the original IBM XT PC up to the hybrid ISA + PCI Pentium era motherboards.

The CRT Terminator board is an *expansion card*, which means that it does **not** function as a standalone display adapter. Instead, like the early MPEG decoder cards from the 90s, CRT Terminator leverages an existing VGA-compatible adapter, and connects into the **VGA Feature Connector** bus of the VGA card via a 2x13-pin ribbon cable.



This VGA Feature Connector bus bypasses the signal degrading digital-to-analog video conversion step (RAMDAC), and enables CRT Terminator to output a fully digital video signal. CRT Terminator converts and upscales this 8-bit palettized digital video into a True Color 24-bit RGB DVI-D output stream that is compatible with HD video on modern flat panel displays.

Two landmark features of CRT Terminator are *Multimode* and *StutterStop*. The *Multimode* feature enables CRT Terminator to be aware of many of the various nonstandard and quirky sized custom VGA video modes that DOS programs utilize, and whenever the VGA output video mode changes, CRT Terminator will readjust its video processing to produce a best matching upscaled resolution. That is, instead of outputting a single fixed output resolution, CRT Terminator will output **multiple** different video **modes** depending on the video input content.

Then, in coordination with the target display's upscaling circuitry, CRT Terminator is able to provide an upsampling result that closely resembles "surface area-based" upsampling, which provides vastly superior image quality of scaled up pixel art, compared to point sampling or bilinear filtering alone. For more information, see the later section [8. Video Upscaling with CRT Terminator](#).

The *StutterStop* feature is a unique hardware feature that carefully matches the vertical refresh rate of the upscaled video with that of the input video, down to the millihertz level. This ensures that the video upscaling subsystem will exhibit frame stuttering only on the order of once per several minutes, or even more

infrequently. This eliminates the presence of any periodic stuttering that is commonly observed in panning motion of video (assuming no stuttering was present in original produced video from the PC).

Enabling Multimode and StutterStop features require some level of nonstandard video mode support from the flat panel display. To allow for most degree of flexibility, CRT Terminator also provides the ability to normalize quirky video modes and output CVT and DMT compliant video signals as a fallback. These features are optionally activated via configuration switches, and we provide tables of our findings for compatibility.

In all cases, the degraded analog video output from the VGA adapter RAMDACs is bypassed. We find that even some of the oldest ISA VGA cards with a reputation of having an unusably blurry or soft analog video quality, such as ATI 28800 and Oak 037, gain a new life and are able to produce a crispy clear digital video output.

Thus the end result is a high quality digital video output with few compromises when viewed on a modern display.

Requirements

CRT Terminator requires the following:

- an IBM compatible PC, with a **free 8-bit ISA slot** for the CRT Terminator card,
- a VGA graphics adapter on the **ISA or PCI bus** that is equipped with **either** an
 - 8-bit IBM **VGA Feature Connector**: a 2x13-pin edge connector shaped Feature Connector bus, or
 - 8-bit **VESA Standard VGA Pass-Through Connector** (VSVPC, also called just *VESA Feature Connector*): a 2x13-pin flat cable pin header Feature Connector bus, with video **output** functionality.
- a flat panel display or video capture card with DVI-D compatible HD video input
- a passion for retro computing

Note: some VGA graphics adapters may require running a utility program from the adapter manufacturer to enable video output on the Feature Connector bus. (e.g. some variants of the S3 Trio 64)

Also, on some VGA adapters, such as the Voodoo 3, the Feature Connector on the board seems to only work for video input (as far as we are aware of at the time of writing), and unfortunately cannot be used to output video to CRT Terminator.

At the time of writing, we do not yet have good experience with the compatibility of different ISA VLB adapters, so we do not state these as supported yet. We recommend either using a ISA or a PCI graphics card.

Also, even though many AGP graphics cards have a VESA Feature Connector, it is unclear if any of these connectors can be used as output - at least in our testing we have not been able to output video from any. AGP graphics cards are currently not supported.

Technical Features

CRT Terminator offers the following features:

- outputs a DVI-D video signal (no audio) via the HD video receptacle.
- supports input video mode pixel clocks up to 37.5 MHz.
- supports output video mode pixel clocks up to 118.8 MHz (max FPGA vendor rated speed) and up to 75 Hz vertical refresh rate.
- overlocking support for unlocking output pixel clocks above 118.8 MHz.
- supports upscaling up to 1600x1200@57.4hz in CVT-Reduced Blanking v2 mode for pixel perfect 4:3 upscaling of DOS 320x200 and 320x240 input resolutions, for output on 1600x1200 and 1920x1200 displays.
- supports upscaling to 1440x1080@70hz in CVT-RBv2 mode (118.8 MHz) for output on 1920x1080 displays.
- supports all standard CGA, EGA and VGA input video modes with 2, 4, 16 and 256 colors.
- supports Super VGA input modes up to 800x600 resolution with up to 256 colors.
- implements a precisely synchronized 8-bit palettized video to 24-bit RGB video conversion.
- provides a robust video synchronization subsystem for various nonstandard quirky and hacked VGA video modes.
- normalizes quirky input video in various ways to make it more compatible with limitations of modern displays, most notably:
 - ensure ≥ 28 kHz horizontal refresh,
 - frame decimation to ensure ≤ 75 Hz vertical refresh,
 - clock doubling to ensure ≥ 640 pixels horizontal width,
 - smart upscaling to ensure pixel width $>$ pixel height,
 - removes malformed video shape, such as negative horizontal or vertical porch area
- supports intelligent detection and cropping of CGA/EGA/VGA video borders.
- enables single- and triple-buffered video upscaling for controlling output latency.
- provides three different video upscaling modes: *Passthrough*, *Fixed Resolution* and *Multimode*:
 - **Passthrough** mode outputs the input video signal unscaled with minimal processing, and less than a single scanline of processing latency.
 - **Fixed Resolution** mode upscales the input video for fast video mode switching and capture card compatibility.
 - **Multimode** output upscales the input video for best output quality from all input modes.
- supports configuration via a DOS command line utility.
- supports standard VGA 262,144 colors 6:6:6 256-color palettized modes as well as a new expanded 16 million 8:8:8 256-color palettized mode of operation.
- operation implemented using Gowin GW1NR series of FPGA board.
- ... and many more features ...

all packed into a single 8-bit ISA expansion card!

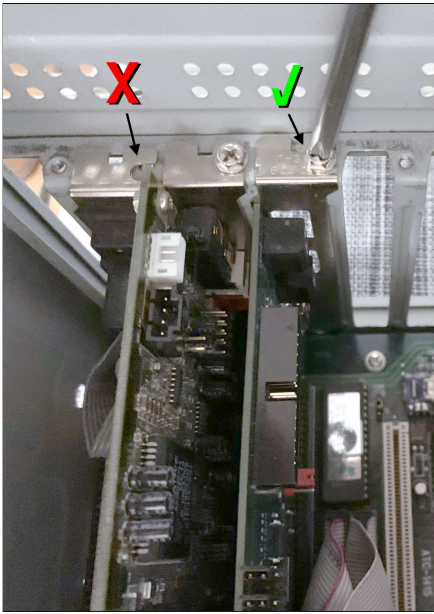
Installation

This section details the steps to install CRT Terminator.

Installing The CRT Terminator Card

CRT Terminator is an 8-bit ISA card, but may be freely installed in either an 8-bit ISA slot or a 16-bit ISA slot.

However, installation in "Slot 8" of the original IBM XT PC (the slot closest to the Intel CPU) is not supported due to [limitations](#) of that slot.



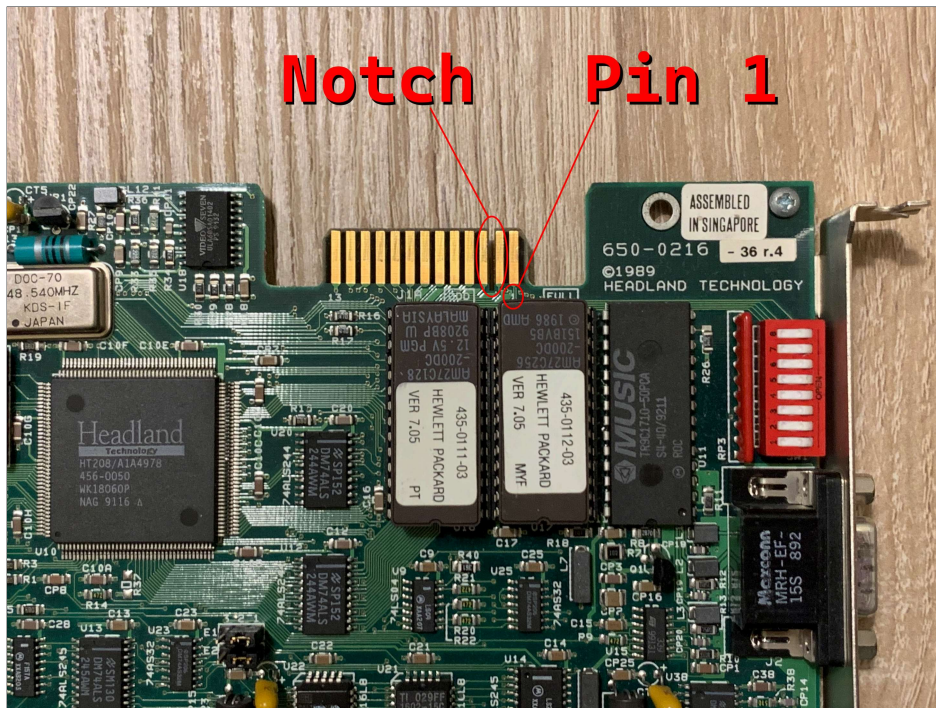
Be sure to fully screw in the CRT Terminator backplane to the chassis. This may seem a bit silly to point out, but since a part of CRT Terminator configuration will be done by flipping DIP switches at the back of the card, it is all too easy to accidentally unseat the card if flipping the switches while the card is not screwed in. Unseating the card during power-on could cause damage to the Feature Connector subsystem or the PC.

Bundled with the adapter are both styles of video cables for connecting CRT Terminator to the Feature Connector slot of your graphics card.

Installing The Video Cable To IBM Feature Connector

If you have an earlier ISA VGA graphics card that predates VESA standardization, it should have the IBM edge connector style Feature Connector interface.

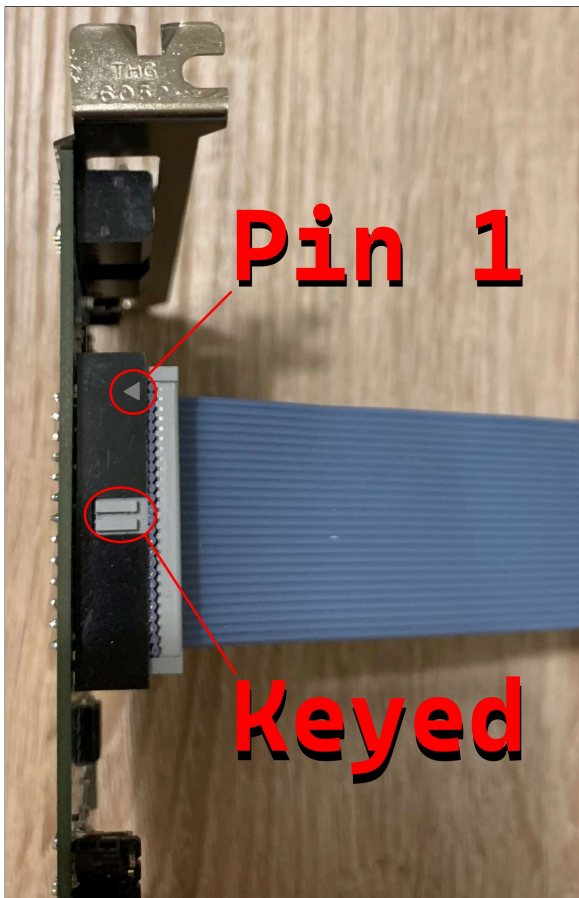
This interface should be keyed with a notch cut out between pins 2 and 3. Pin 1 is always on the narrow side of this connector, like this:



To connect to this IBM style edge connector, the CRT Terminator video cable with a female edge connector socket is used:

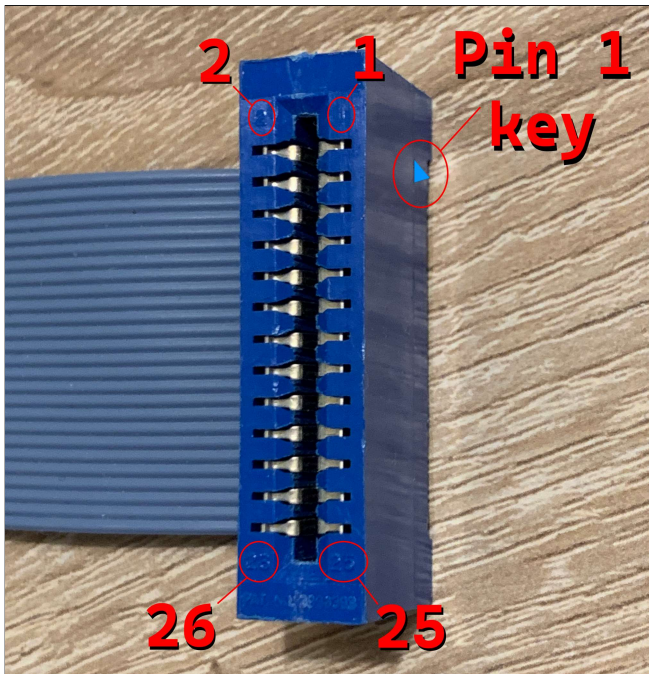


Connecting the cable to the CRT Terminator end is easy, because there is only one orientation that the cable fits. This orientation identifies which side of the cable will be Pin 1:

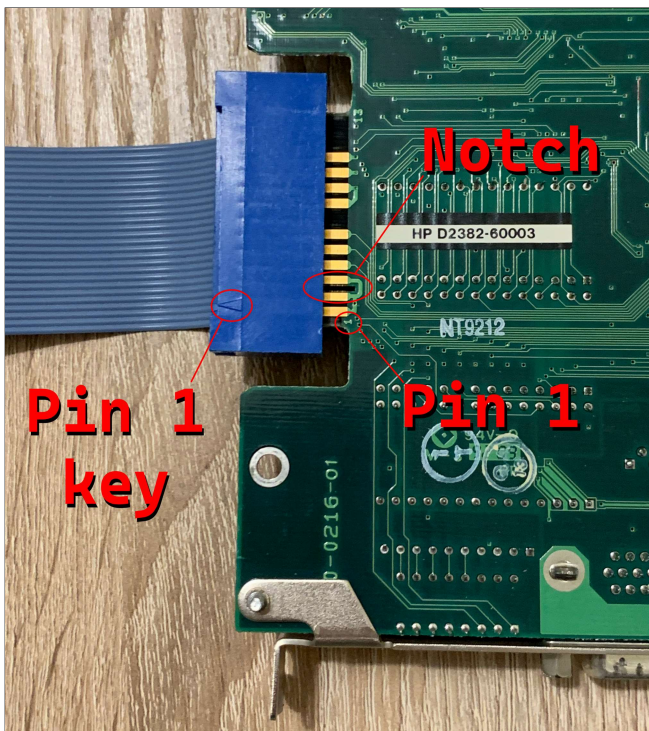


Due to manufacturing source, the side of the cable itself might not be colored to mark pin 1. So double check the pin 1 markers on the connectors to identify pin 1.

On the edge connector end, there will be similar markings as follows:



The connection on the VGA card is made as follows:



Be sure to fully push in the connector. (in the above image, the connector is shown seated only half-way to illustrate the position of the notch)

Make sure you positively identify pin 1 on both the cable and the VGA card when installing.

Installing the cable in incorrect orientation may damage the VGA card, CRT Terminator, PC and/or the PSU. Any damage resulting from incorrect installation will not be covered. So please be very careful to identify the correct cable orientation.

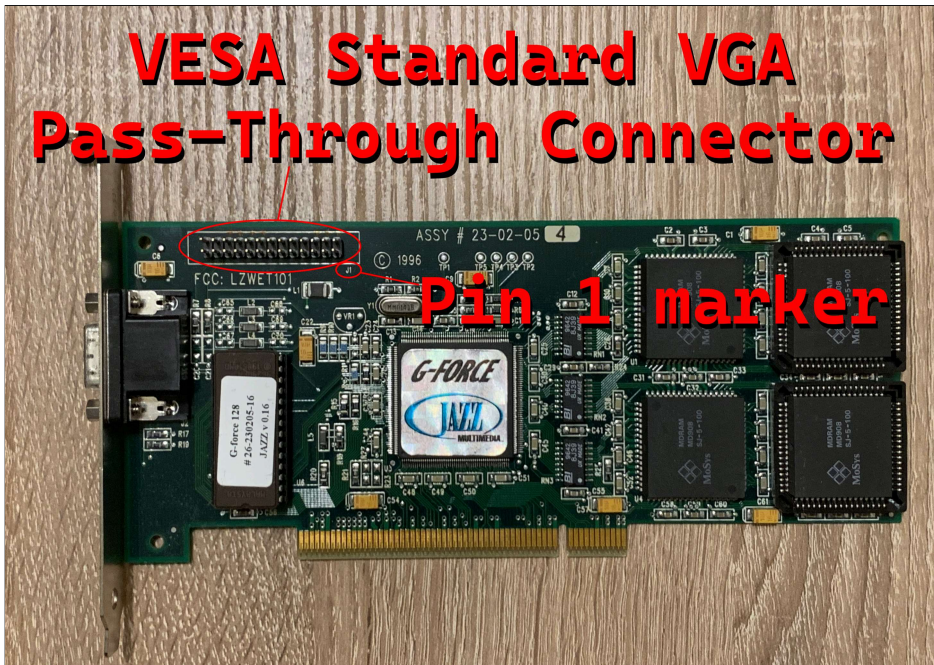
Installing The Video Cable To VESA Standard VGA Pass-Through Connector

If your VGA adapter is of a newer type (~1990-1991 and later), then it is likely to have the VESA Standard VGA Pass-Through Connector (VSVPC). This connector is colloquially also referred to as the *VESA Feature Connector*.

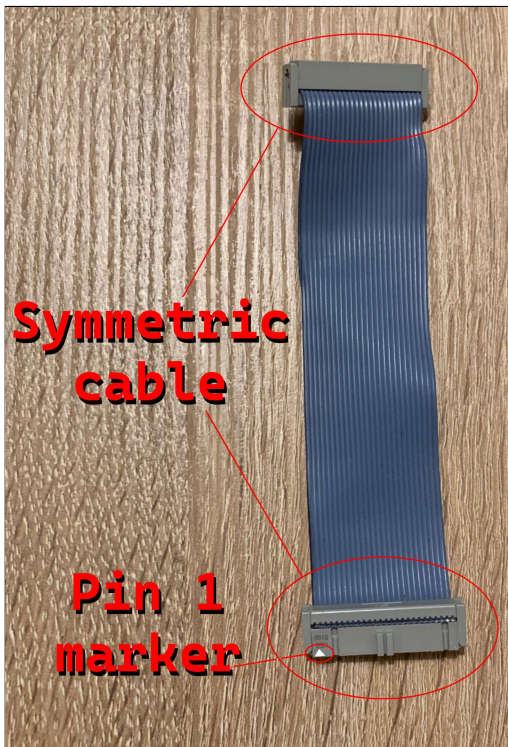
For more information on this connector, see [Appendix B](#).

This connector is a 2x13 pin grid male pin ribbon header connector, as seen below:

VESA Standard VGA Pass-Through Connector

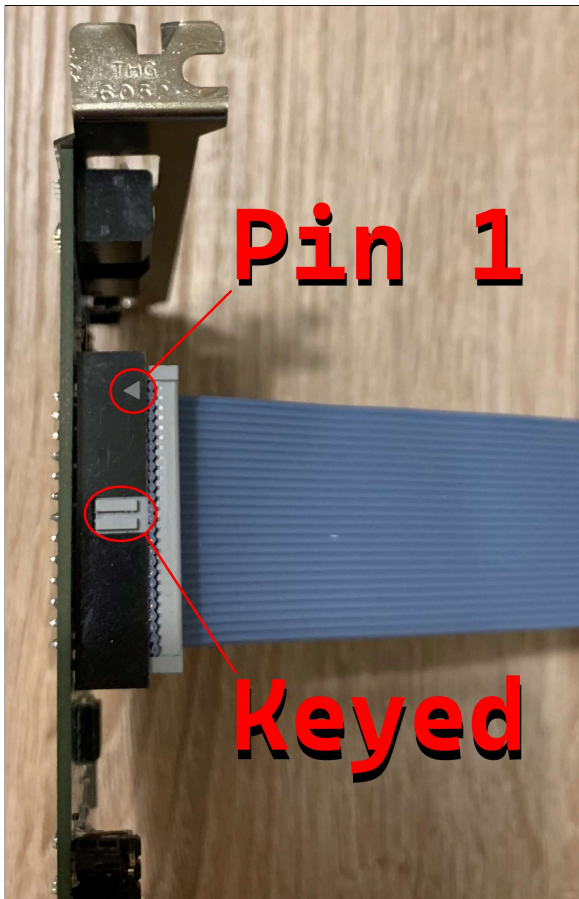


Use the following video cable to connect CRT Terminator to your VGA adapter with a VSVPC connector:



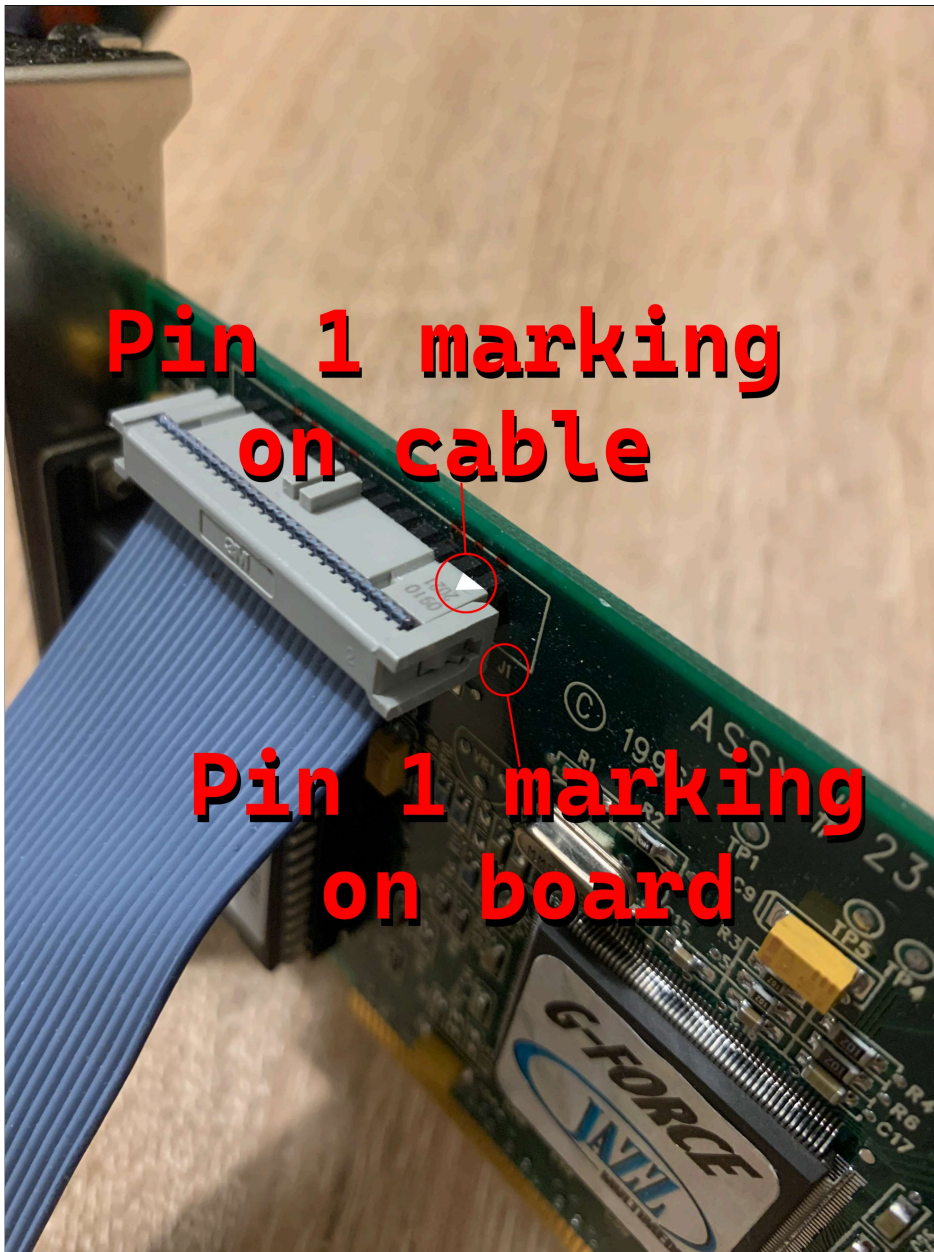
This cable is symmetric, you can plug either end to the CRT Terminator.

Connecting the cable to the CRT Terminator end is easy, because there is only one orientation that the cable fits. This orientation identifies which side of the cable will be Pin 1:



Note that the 2x13 pin VSVPC connector on the VGA adapter is **unkeyed**. That is, it is possible to connect the video cable to this connector incorrectly, rotated 180 degrees.

To avoid damaging the VGA card, CRT Terminator, PC and/or the PSU, take extra care to correctly locate and match pin 1 on both the cable and the VGA adapter board, like so:



If this cable is connected 180 degrees reversed **in incorrect orientation**, the high-speed video data pins will overlap with ground pins, **potentially causing a short**.

Any damage resulting from incorrect installation will not be covered. So please be very careful to identify the correct cable orientation.

If there is any doubt to the correct pin 1 orientation on the board, **we strongly recommend using a multimeter to identify the ground pins on the VGA board** as a means to double-check the correct installation orientation for the cable.

Warning! Even though VESA did standardize a common orientation and placement for the VSVPC connector for VGA cards, some VGA adapter vendors chose for no apparent reason to lay out the connector in a 180 degrees rotated orientation on the board. So be sure to **check the orientation** on each VGA adapter separately, instead of assuming a common orientation.

The VGA Terminator Dongle

Many older graphics adapters have an autodetection feature that identifies whether the currently connected display is a monochrome or a color monitor. This is done by identifying resistance on certain pins of the video output cable.

If no VGA video cable is connected, these adapters may boot up in monochrome mode, resulting in displaying grayscale colors also via the Feature Connector.

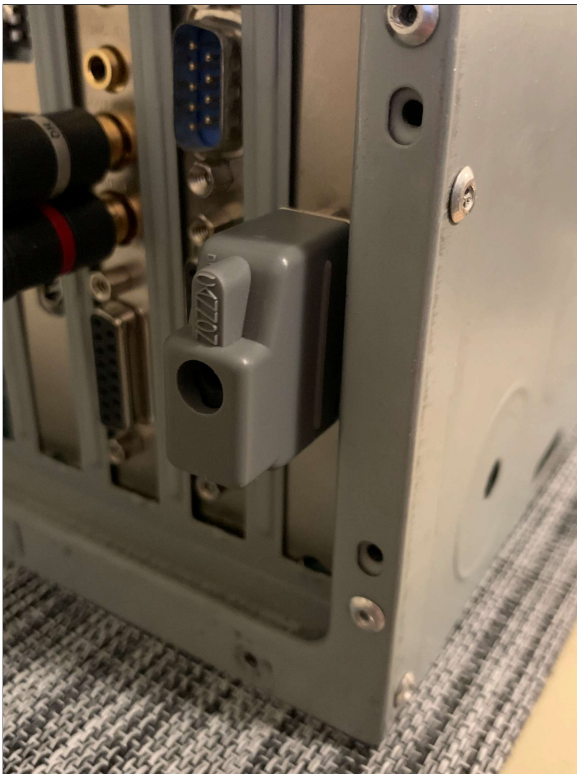
If you are not using any VGA monitors alongside CRT Terminator (e.g. in dual display or video capture setup) and your video output comes out monochrome, we will need to fool the VGA adapter into thinking that a color monitor would actually be connected.

To achieve this, the VGA terminator dongle was created. This dongle is a dummy block that attaches in the VGA output, and provides the needed identification to the graphics card to think it should output a color image.



This small terminator dongle is actually what gave CRT Terminator the idea for the name.

Just attach it at the end of the VGA adapter, like so:



If your VGA adapter provides color output even without the terminator dongle, or you want to use the VGA output for other purpose, then you can just leave the dongle in the box.

Configuration

CRT Terminator is configured via three different mechanisms:

- 6+1 jumper settings on the board (J1 through J7)
- 2x4 DIP switches at the back (DIPs 1.1-1.4 and 2.1-2.4)
- Software configuration using a supplied DOS real-mode utility

The jumper settings are used to configure CRT Terminator behavior with respect to the VGA adapter, i.e. they need to be reconfigured if changing to a different VGA adapter.

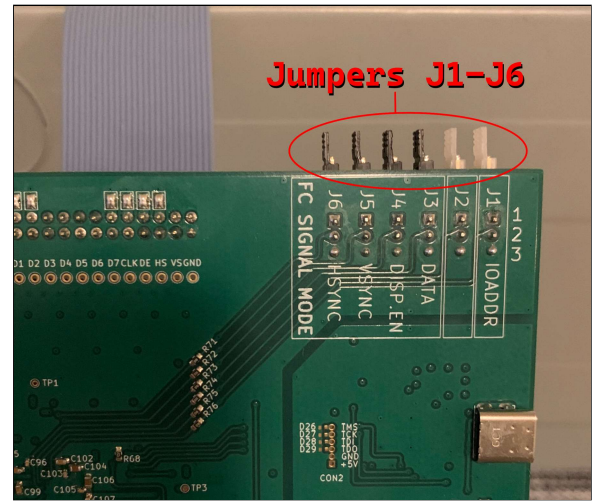
The DIP switches are used to configure CRT Terminator behavior with respect to the LCD display or video capture device that it connects out to. When changing the output device, these DIP switches will need to be reconfigured.

Finally, the software configuration is used to tune the behavior with respect to different software at runtime.

Jumper Settings

There are seven jumpers on the CRT Terminator DV1000 board. Jumpers J1-6 are located at the top edge of the card for easy access, whereas J7 is located on the board itself. The functionality of these jumpers are summarized in the following table.

Jumper settings J1-J7	Name	Description
J1	Reserved	Currently unused. Please set to 1-2 (N/C) .
J2	Automatic Video Sampling Phase Detection	Controls whether CRT Terminator will automatically analyze Feature Connector video sampling phase. 1-2 (N/C) : Enabled. State of jumpers J3-J6 will be ignored. 2-3 : Disabled. Sampling Phase will be manually defined by jumpers J3-J6.
J3	Pixel Data Sampling Phase	Configures the sampling phase that video Data bits are sampled at. 1-2 (N/C) : Sample at rising edge of pixel clock. 2-3 : Sample at falling edge of pixel clock.
J4	Display Enable Sampling Phase	Configures the sampling phase that video Display Enable line is sampled at. 1-2 (N/C) : Rising edge. 2-3 : Falling edge.
J5	Vsync Sampling Phase	Configures the sampling phase that video Vsync line is sampled at. 1-2 (N/C) : Rising edge. 2-3 : Falling edge.
J6	Hsync Sampling Phase	Configures the sampling phase that video Hsync line is sampled at. 1-2 (N/C) : Rising edge. 2-3 : Falling edge.
J7	Overclocking	Enables generating output video clocks beyond the manufacturer rated specification. 1-2 (OFF) : Overclocking Disabled. 2-3 (ON) : Enable overclocking.



Jumpers J1-J6 utilize a three pin scheme to define two different states. State 1-2 ("open", or jumper not connected, N/C above) is set when a jumper bridges the two pins closest to the board PCB. State 2-3 ("closed") is set when a jumper bridges the two pins farthest from the PCB.

It turns out that different VGA adapters utilize different sampling phase conventions for the generated Feature Connector video signal. There was no VESA standard for this (although sampling at the rising phase seems to be most common), and it looks like the correct sampling phase may substantially drift even between different video modes on the same VGA adapter, especially on the older ISA video adapters.

Jumper J2 is used to enable a simple automatic configuration of the sampling phase settings. In this mode, CRT Terminator will continuously analyze which sampling phase it should use for each signal line. It is recommended that this option is enabled (J2 set to 1-2) first to see if this simple automatic scheme will work. The other options are available in case this automatic configuration does not work as expected for a particular VGA adapter.

An incorrect video sampling phase setting typically manifests as a video signal that geometrically drifts or jitters, or continuously loses video sync.



Jumpers settings J3-6 enable manually configuring the appropriate video signal sampling phases to use. In order for these jumpers to take effect, jumper J2 must first be set to state 2-3.

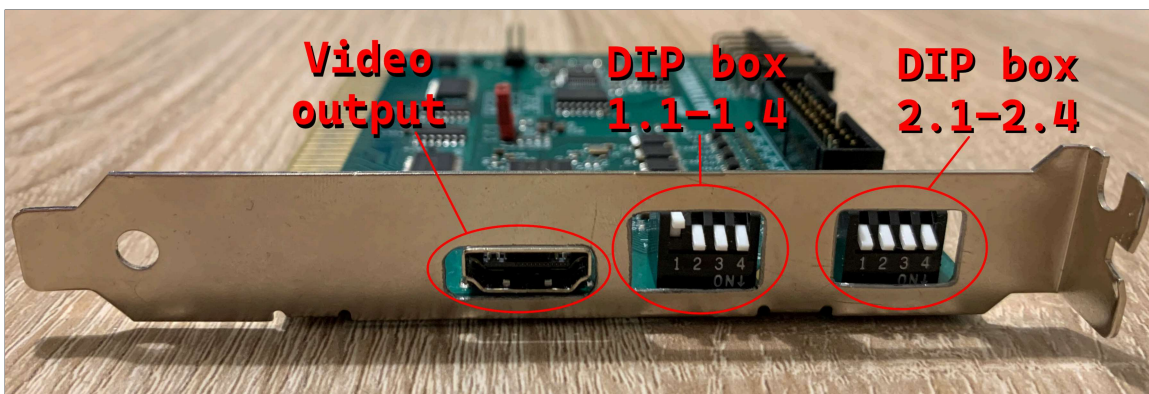
Jumper setting J7 unlocks the display output frequency pixel clock limit. The maximum rated output provided by the FPGA board that CRT Terminator uses is a 118.8 MHz pixel clock. If J7 is set to state 1-2: OFF, then CRT Terminator will adhere to this specification, and will always generate a display signal that does not exceed this limit.

If J7 is set to 2-3: ON, then CRT Terminator will ignore this specification, and always attempt to generate the best ideal output clock speed for the display. There is no guarantee that this will produce a stable output video signal however.

Note that enabling overclocking will **not** void the warranty of CRT Terminator. Feel free to play around. The maximum rated pixel clock speed for DVI-D cables is 165 MHz, which gives a theoretical ceiling as to how fast pixel frequencies might be able to work.

DIP Switches

The back of CRT Terminator looks like follows:



A total of eight DIP switches, organized in two DIP boxes are present.

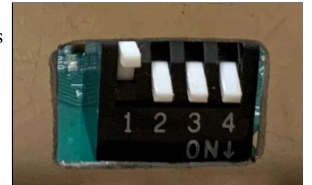
The first DIP box next to the video output connector contains four switches named 1.1, 1.2, 1.3 and 1.4. The values of these four switches are interpreted as a 4-bit binary number, and this number selects the output video mode.

DIP switches 1.1-1.4		Resolution
Decimal	Binary	
0	0000b	Passthrough
1	1000b	640x480
2	0100b	800x600
3	1100b	960x720
4	0010b	1280x720
5	1010b	1024x768
6	0110b	1200x900
7	1110b	1280x960
8	0001b	1280x1024
9	1001b	1364x1024
10	0101b	1400x1050
11	1101b	1680x1050
12	0011b	1440x1080
13	1011b	1920x1080
14	0111b	1600x1200
15	1111b	1920x1200

In the DIP switch box, a switch that is flipped down (as indicated by the text **ON↓** on the box) denotes a binary **1**, and a switch that is flipped away (↑) denotes a **0**.

The bits are concatenated into the above table from DIP 1.1 to 1.4, left to right.

For example, the image on the right corresponds to a state 0111b, or decimal 14, or an output video mode of 1600x1200.



The value 0000b selects **Passthrough** mode. In this mode, CRT Terminator bypasses its video upscaling subsystem (except to normalize scandoubled VGA from e.g. 320x400 to 640x400 and to crop the VGA border) and outputs the input video signal unscalled to the display.

Passthrough mode is useful for enabling the lowest possible latency output from CRT Terminator. Some flat panel displays support the oddball video timings generated by CGA/EGA/VGA video modes better than others, so there is a bit of YMMV at play when using it.

If any other value than Passthrough is selected, then a given Resolution in the above table is chosen. The exact meaning of this selected resolution depends on the state of DIP2.1 switch, see the next table.

DIP switches 2.1-2.4		Description
DIP 2.1		OFF: Output Fixed Resolution ON: Output Multimode
DIP2.2=OFF	DIP2.3=OFF	StutterStop level 0: Disabled. Output fixed 60Hz
DIP2.2=ON	DIP2.3=OFF	StutterStop level 1: Sync pixel clocks
DIP2.2=OFF	DIP2.3=ON	StutterStop level 2: Level 1 + sync vertical porch
DIP2.2=ON	DIP2.3=ON	StutterStop level 3: Level 2 + sync horizontal porch
DIP 2.4		OFF: Disable Developer UI ON: Show Developer UI

In Passthrough mode, the values of DIP switches 2.1, 2.2 and 2.3 have no effect. That is, Multimode and StutterStop do not apply in Passthrough mode.

Fixed Resolution Output:

If DIP 2.1 is **OFF**, then the resolution selected by DIP 1.1 - 1.4 denote a **fixed** output resolution. In this mode, CRT Terminator will always output this specific chosen resolution, using point sampled upscaling.

Use this mode to maximize compatibility of CRT Terminator with picky monitors or video capture cards.

Multimode Output:

If DIP 2.1 is **ON** (and not running in Passthrough mode), then the resolution selected by DIP 1.1 - 1.4 denote a **maximum** upscaled output resolution. In this mode, CRT Terminator will dynamically adjust the output resolution based on the current resolution of the input.

This way, for example when playing a Pinball game that uses a custom video mode, the video output will look crisp and well upscaled both in-game and in menus, without needing to manually re-adjust any video output parameters when navigating the game menus.

StutterStop Level

When not operating in Passthrough mode, DIP switches 2.2 and 2.3 select a two bit binary number that activates the StutterStop feature of CRT Terminator.

The StutterStop feature tunes the output refresh rate of CRT Terminator so it best matches the input video rate, even when processed through the video upscaling circuitry.

If both DIPs are OFF (value of 00b), StutterStop is disabled, and CRT Terminator always outputs 60Hz video, even if the input video was e.g. 70 Hz like in DOS VGA video.

If StutterStop is set to any other value, Level 1-3, then StutterStop is enabled. The StutterStop "level" indicates the fine-grainedness or aggressiveness of the video rate matching. Level 3 is most preferable, and we find that many modern displays are compatible with it. (such as ASUS ProArt PA248QV and Philips Brilliance 252B9/00 that we recommend)

However, if the video display is unable to sync e.g. StutterStop Level 3 mode, you can try to run in Level 2 or Level 1 instead, to achieve at least some level of video frame rate matching.

VGA Palette Snoop

In order to enable support for CGA, EGA and VGA video modes (as they are *palettized*), CRT Terminator *snoops* the ISA I/O bus to observe the palette write commands as they arrive to the VGA adapter. The term snooping here means that CRT Terminator listens to the communication that takes place on the ISA bus between hardware peripherals, and it recognizes all palette color writes to the hardcoded VGA adapter palette I/O port addresses 3C8h and 3C9h from the PC CPU. With that information, CRT Terminator is then able to recreate the needed palette color entries to convert palettized video into 24-bit RGB.

In particular, this means that the I/O bus configuration on the PC must support this kind of "palette snooping" from the ISA bus, or otherwise palette information will not be observed and colors will come out incorrect.

If you are running a PC setup with a VGA adapter residing on the 8-bit or 16-bit ISA bus, then palette snooping will always be enabled and no further configuration is needed. This is because electronically, the ISA bus is an unswitched I/O hub: all peripherals physically observe all communication on this bus.

If you have an **ISA VLB** or a **PCI** video adapter, then the situation is a little bit more complicated. Both of these peripheral buses are switched, and disconnected from the ISA bus, so an explicit solution is required for CRT Terminator to be able to snoop the palette writes. There are four options:

PCI Standard VGA Palette Snoop:

If your VGA adapter is PCI-based, there exists a register bit in the PCI standard to enable PCI palette snoop on the VGA card. This register bit needs to be flipped once at system startup, e.g. in AUTOEXEC.BAT. The SNOOP.EXE configuration utility ([\[GitHub\]](#) [\[Download ZIP\]](#)) can do this.

On one rare VGA card, the Diamond Speedstar 64 CL-GD5434, we observe a quirky VGA firmware bug that the card resets the PCI palette snoop setting on each video mode change. For this specific VGA adapter and others that possibly behave like this, we provide a TSR utility PCITSR.EXE ([\[GitHub\]](#) [\[Download ZIP\]](#)) that keeps the PCI palette snoop register latched to be force-enabled.

BIOS VGA Palette Snoop:

If the motherboard supports a "**ISA VGA Palette Snoop**" option in the BIOS, then that feature can be used to solve the issue. With this option enabled, the motherboard will post all palette writes to the PCI bus also onto the ISA bus, which allows CRT Terminator to follow all modifications to the VGA palette.

VGA Card Specific Palette Snoop:

Reading the datasheets of some PCI and ISA VLB graphics chips, they provide a built-in programmable option to enable *passing through* the palette writes from the adapter. The idea with this option is to program the PCI/ISA VLB VGA adapter to stop acknowledging VGA palette write commands back to the CPU. This will cause the CPU to continue propagating these palette write I/O operations onwards to, first in the PCI hub, and then finally reaching the ISA hub as a final destination, where CRT Terminator will then be able to snoop the writes. This requires a hardware configuration support in the VGA adapter, and a software driver that programs the VGA adapter to enable this passthrough.

Software TSR Palette Snoop:

Finally, if there is no configuration option available either in BIOS or with the VGA adapter itself, the last resort may be to revert to utilizing a software polling approach. CRT Terminator provides a DOS software TSR program, which periodically polls the VGA palette, and then mirrors the palette over to CRT Terminator I/O address space. This software TSR will not be able to provide perfectly synchronized VGA palette uploads, and will cause a small performance penalty, but on fast PCI based systems the performance impact may be unnoticeable.

Note: On PCI and ISA VLB adapters, enabling palette snoop has a small but measurable performance impact on overall graphics performance on some games, e.g. -~4% score measured in Doom timedemo.

Software Configuration

In addition to the jumpers and DIP switches, some aspects of CRT Terminator are configured via software. These settings include:

- Enable/disable vsync: By default CRT Terminator runs triple-buffered. Disable vsync to lower input latency to perform video upscaling that does not synchronize to vertical refresh rate.
- Enable/disable VGA border crop: By default CRT Terminator removes the VGA border area to enable pixel-perfect video upscaling in modes like 320x200, 320x240 and 800x600. Disable the VGA border crop if you'd like to see the borders, at the expense of forfeiting pixel perfect upscaling.

Our software repository to configure CRT Terminator, and other utilities, can be found on the GitHub repository [juj/crt_terminator](#).

Supported Input Video Modes

The following input video modes are supported:

Standard	Mode Number	Resolution	Refresh Rate	Colors
CGA	0h	40x25	70hz*	B/W
CGA	1h	40x25	70hz*	16c
CGA	2h	80x25	70hz*	gray
CGA	3h	80x25	70hz*	16c

Standard	Mode Number	Resolution	Refresh Rate	Colors
CGA	4h	320x200	70hz*	4c
CGA	5h	320x200	70hz*	4c
CGA	6h	640x200	70hz*	B/W
MDA	7h	80x25	70hz*	B/W
EGA	Dh	320x200	70hz*	16c
EGA	Eh	640x200	70hz*	16c
EGA	Fh	640x350	70hz*	B/W
EGA	10h	640x350	70hz*	16c
VGA	11h	640x480	60hz	B/W
VGA	12h	640x480	60hz	16c
VGA	13h	320x200	70hz	256c
VGA	Mode X	320x240	60hz	256c
SVGA	58h,5Ch	800x600	56hz	256c
Nonstandard**	N/A	≤ 800x600	≤ 70hz	≤ 256c

*On the original CGA and EGA adapters these were 60hz, but on VGA adapters these run as 70hz.

CRT Terminator is **very widely compatible with many custom video modes that programs from the DOS era utilized. We have tested hundreds of different known programs, games and demoscene demos with CRT Terminator to ensure as broad support as possible.

The maximum supported input video clock is 37.5 MHz. This is generally good for ~800x600@56 Hz, though some input video modes, like 800x600@60 Hz or 1024x768@60i Hz may also work, if you are lucky.

1024x768@60Hz progressive will not work, that is unfortunately beyond the possible speed of the Feature Connector bus (1024x768@60Hz is ~65 MHz pixel clock).

Additionally, CRT Terminator can be used to experiment with some 15bpp, 16bpp and 24bpp input video modes on some specific video adapters.

Recommended Displays

For best results, a display that supports Coordinated Video Timings - Reduced Blanking V2 standard (CVT-RBv2) is recommended. Further, a display that supports even tighter nonstandard video timings as well as arbitrary video resolutions is recommended in order to enable the use of CRT Terminator Multimode and StutterStop features.

Whichever monitor you are using, the output from DOS programs are almost always intended to be viewed in 4:3 aspect ratio. So using a display that supports a **Force 4:3 aspect ratio** scaling mode is highly recommended.

In the absence of such scaling mode, some monitors support a **1:1 aspect ratio** mode. This aspect ratio mode, while not necessarily perfect in all cases, can be a decent fallback for many scenarios.

For best viewing results of content that uses 320x200 or 320x240 resolutions, we recommend acquiring a display with a 1920x1200 resolution that supports up to 75 Hz video and 4:3 aspect ratio control. This will enable frame rate precise crisp pixel perfect and aspect ratio preserved upscaling of input video.

Pixel peeping users who are seeking the best upscaling results for 640x480 resolution content specifically might want to entertain 1280x1024 sized displays with 4:3 or 1:1 aspect ratio control, for a 2x 640x480 → 1280x960 upscaling path, providing thin letterboxes at top and bottom.

Video Upscaling with CRT Terminator

This section describes the video upscaling strategy employed by CRT Terminator.

First note that CRT Terminator supports a **Passthrough mode** for use cases where upscaling is not desired. In Passthrough mode, minimal on-the-fly video normalization is performed without the use of a framebuffer (i.e. no added latency), to generate a video signal that many modern displays will hopefully be able to synchronize to.

However, Passthrough mode may have some drawbacks:

- If the modern display does not have a Force 4:3 Aspect ratio option, the video aspect ratio will not be faithful to original CRT 4:3, since old DOS CRTs displayed non-square pixels.
- A low DOS video resolution (320x200, 640x350, 720x400, etc.) may be something that a modern display might not understand to sync to.
- The *bilinear*-ish video upscaling algorithm used by a modern display might result in a soft/blurry image.

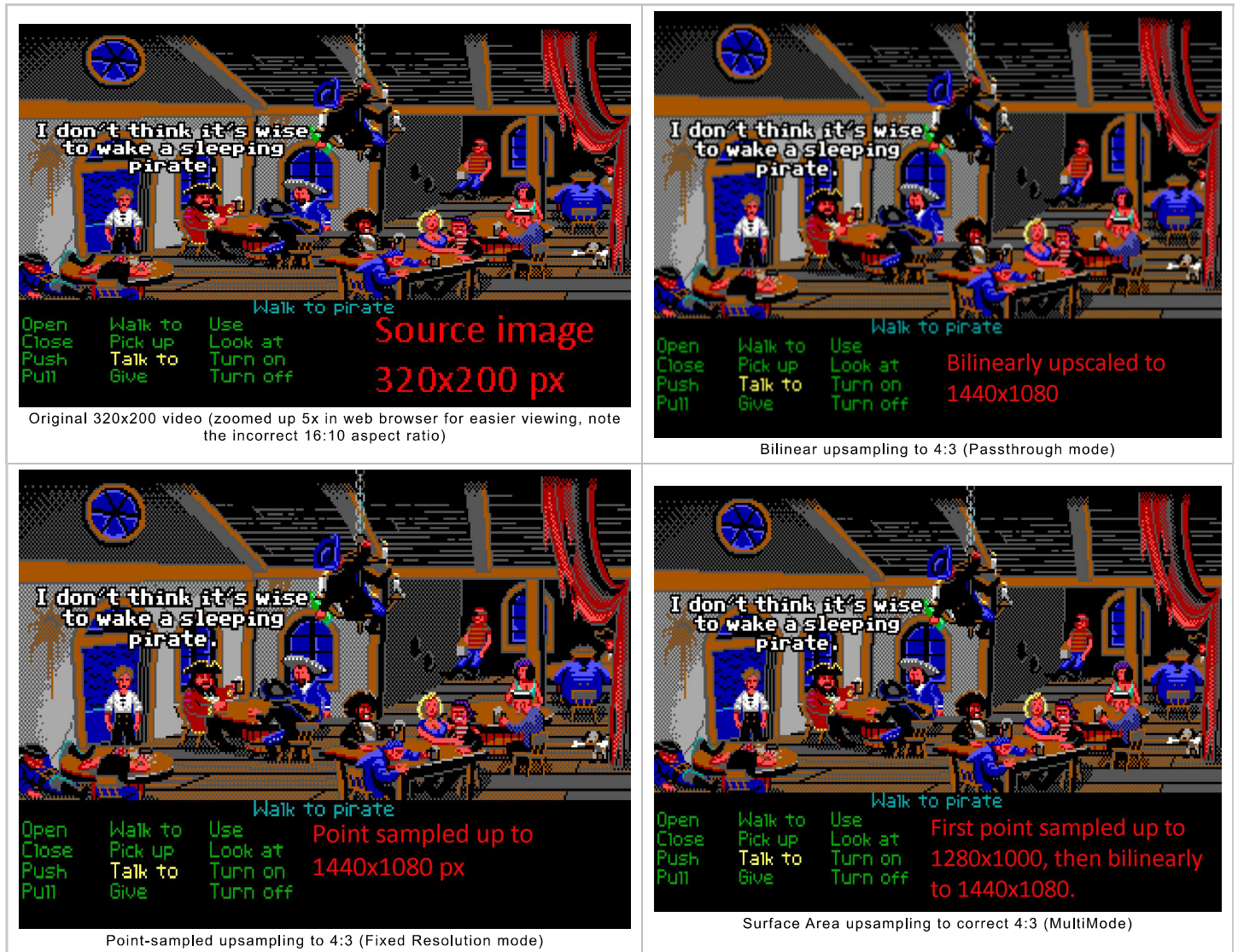
To help resolve these problems, CRT Terminator provides a video upscaling circuitry that uses a video framebuffer to upscale the input video.

The video upscaling circuitry in CRT Terminator can be utilized in two different modes: **Fixed Resolution** or **MultiMode**.

In Fixed Resolution mode, CRT Terminator upsamples the given input video signal to the given fixed output resolution using *Point Sampling*. The output resolution does not change depending on the input video resolution. This mode is useful for crispest video output, and for e.g. buggy USB video capture cards that get confused on video mode changes.

In MultiMode operation mode, CRT Terminator will upscale the input video by a multiple of an integer factor in both width and height. When viewed with a modern flat panel display's Force 4:3 Aspect ratio option, this produces an end result that is sometimes called "*Surface-Area Sampling*". This upsampling mode is generally superior to Point Sampling and Bilinear Filtering on low-resolution pixelated source content.

The effect of these different upsampling modes can be observed in practice below on a 320x200 input video signal, which is upscaled to 1440x1080 resolution to be viewed in 4:3 aspect ratio on a 1920x1080 display.



Click on the above thumbnails to pixel peep into the full images in 100% size.

When the effects of CRT Terminator video upsampling and flat panel display upsampling are combined, the different CRT Terminator operation modes produce different final results:

- **Passthrough:** Bilinear filtering
- **Fixed Resolution:** Point sampling
- **MultiMode:** Surface Area upsampling

In general we recommend using MultiMode for best picture quality, and falling back to other modes for compatibility, subject to taste.

Sidenote: If you are using a 1600x1200 or a 1920x1200 display, then in particular for the above DOS 320x200 scenario, CRT Terminator can upscale the 320x200 video up to 1600x1200 to produce the pixel perfect video output without any bilinear filtering applied.

Compatible Graphics Adapters

A major challenge in developing CRT Terminator is that there are hundreds of different (S)VGA adapters that are clones of the original IBM VGA adapter, and the original IBM VGA was not based on a published specification or a hardware design standard.

This means that we do not have a single target to develop CRT Terminator against, but rather, need to test every display adapter one by one for compatibility.

The following table presents the results of many display adapters we have tested CRT Terminator with. It should hopefully guide some expectations, but note that the information provided in the following table is still not an affirmation or a guarantee of support.

That is, even if you have the same graphics adapter with the same graphics chip, there could be qualitative variances that can affect your results.

Legend:

- ☑: CRT Terminator works.
- ⚠: Works, with some caveat.
- ✘: Does not work with CRT Terminator.

IBM

Name	Bus	Year	FC	CRT Terminator Support Notes
IBM VGA 75X9017XM	ISA	1988	IBM	✓

Acumos ⇒ Cirrus Logic

Name	Bus	Year	FC	CRT Terminator Support Notes
Everex Viewpoint EV-628 (Acumos AVGA1. "CL-GD5401")	ISA	1991	IBM	✓
Acumos AVGA 2 ("CL-GD5402")	ISA	1992	VESA	✓
Hightech Information System Ltd VGA Card (CL-GD5422)	ISA	1993	VESA	✓
Cirrus Logic GD-542x Eval Board (CL-GD5428)	ISA	1994	VESA	✓
Cirrus Logic GD-5430	PCI	1994	VESA	✓
Diamond SpeedStar 64 (CL-GD5434)	PCI	1994	VESA	⚠ VGA BIOS bug requires PCITSR.EXE
Cirrus Logic GD-5440	PCI	1995	VESA	✗ Unstable FC video signal
Creative CT6330 Graphics Blaster MA200 CL-GD5446	PCI	1996	VESA	✓
Jaton Corporation Cirrus Logic CL-GD5446	PCI	1998	VESA	✓

Trident

Name	Bus	Year	FC	CRT Terminator Support Notes
Trident TVGA8816CSC2 (TVGA 8800CS)	ISA	1989	IBM	✓
ASKA ZyMOS POACH 51 (TVGA 8800CS)	ISA	1990	IBM	✓
Trident TVGA8900C MQTD023/9218	ISA	1992	IBM	✓
Trident TVGA8900C EQB144001/9220	ISA	1992	IBM	✓
Trident TVGA8900D	ISA	1994	VESA	✓
Trident TGUI9440	PCI	1995	VESA	✓
Trident TVGA 9000i-3	PCI	1996	VESA	✓

Tseng Labs

Name	Bus	Year	FC	CRT Terminator Support Notes
Tseng Labs ET3000AX	ISA	1991	IBM	⚠ Card hangs after BIOS POST on test 486 PC, boots OK on another PC, where superficially tested OK with CRT Terminator.
Diamond SpeedSTAR 24 (Tseng Labs ET4000AX)	ISA	1992	VESA	✓
Tseng Labs ET4000/W32p	PCI	1995	VESA	✓
Jazz Multimedia G-Force 128 (Tseng ET6000)	PCI	1996	VESA	✓

Paradise ⇒ Western Digital

Name	Bus	Year	FC	CRT Terminator Support Notes
Paradise PVGA1A-JK	ISA	1990	IBM	✓
WDC WD90C30-LR	ISA	1992	VESA	✓
WDC WD90C31A-LR	ISA	1993	IBM	✓

Avance Logic ⇒ Realtek

Name	Bus	Year	FC	CRT Terminator Support Notes
Realtek RTG3106	ISA	1991	IBM	✓
Avance Logic ALG2302	PCI	1995	VESA	✓

S3

Name	Bus	Year	FC	CRT Terminator Support Notes
S3 Powergraph X-24 (S3 86C801)	ISA	1993	VESA	⚠ Works with CRT Terminator, but hangs in SNOOP.EXE scan.
S3 Vision864	PCI	1994	VESA	✓
Diamond Stealth 64 Video 3200 (S3 Vision 968)	PCI	1995	VESA	✗ Faulty card? Does not POST.
S3 VIRGE ST-325A	PCI	1996	16-bit S3 Local Peripheral Bus (LPB), 26 + 6(8) + 16 = 50 pins	⚠ S3 BIOS quirk: Feature Connector is not enabled at boot, but requires S3 utility (or SNOOP.EXE) to enable.
S3 Trio64V+	PCI	Mfg. 1997	VESA	⚠ Works with CRT Terminator, but hangs in SNOOP.EXE scan.
S3 Trio64V2/DX	PCI	1996	8-bit S3 Local Peripheral Bus (LPB), 26 + 6(8) = 34 pins	✓

ATI

Name	Bus	Year	FC	CRT Terminator Support Notes
ATI 28800-5	ISA	1991	IBM	⚠ Works with CRT Terminator, but card does not implement 1:2 Dot Clock option.
ATI 28800-6	ISA	1992	IBM	⚠ Works with CRT Terminator, but card does not implement 1:2 Dot Clock option.
ATI Mach64 VT2	PCI	1996	ATI Multimedia Channel (AMC)	✓
ATI 3D Rage II	PCI	1997	ATI Multimedia Channel (AMC)	✓

Others

Name	Bus	Year	FC	CRT Terminator Support Notes
Oak 037C	ISA	1990	IBM	⚠ Works with CRT Terminator, but card does not implement 1:2 Dot Clock option.
Genoa SuperVGA 6200	ISA	1991	IBM	✓
Video Seven VGA 1024i (Headland HT208)	ISA	1991	IBM	✓
Wang Labs Chips & Technologies F82C452	ISA	1991	IBM	✓
Ahead V5000B	ISA	1992	IBM	✓
Hercules Stingray Pro (ARK1000PV)	PCI	1995	VESA	✓
MiroVideo 12PD v1.02 (Alliance Semiconductor ProMotion 3210)	PCI	1995	VESA	✗ Bad color signal on Feature Connector.
MiroVideo 12PD v2.00 (Alliance Semiconductor ProMotion 6410)	PCI	1995	VESA	✗ Bad color signal on Feature Connector.
Matrox Millennium 2064W	PCI	1997	VESA	✓
SiS 6326	PCI	1998	VESA	✗ No output from Feature Connector

Hardware Random Number Generation

When IBM released the VGA adapter, they dropped support for the CGA and EGA light pen feature. However, the hardware registers relating to light pen support still remained in a crippled form, and one of those registers would contain a free-running counter.

In a [Headland V7 VGA adapter technical manual](#) from June 1988, the authors noted this quirk, and offered that maybe the feature could be used to generate random numbers:

	I/O Port 375 Index 10	CRTC Light Pen Register High	LPENH																																													
msb	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 5%;">Bit #</th> <th style="width: 75%;">Description</th> <th style="width: 10%;">375 Access</th> <th style="width: 5%;">Reset By</th> <th style="width: 5%;">Reset State</th> </tr> </thead> <tbody> <tr><td>7</td><td>Light Pen Address Bit-15</td><td>R</td><td></td><td></td></tr> <tr><td>6</td><td>Light Pen Address Bit-14</td><td>R</td><td></td><td></td></tr> <tr><td>5</td><td>Light Pen Address Bit-13</td><td>R</td><td></td><td></td></tr> <tr><td>4</td><td>Light Pen Address Bit-12</td><td>R</td><td></td><td></td></tr> <tr><td>3</td><td>Light Pen Address Bit-11</td><td>R</td><td></td><td></td></tr> <tr><td>2</td><td>Light Pen Address Bit-10</td><td>R</td><td></td><td></td></tr> <tr><td>1</td><td>Light Pen Address Bit-9</td><td>R</td><td></td><td></td></tr> <tr><td>0</td><td>Light Pen Address Bit-8</td><td>R</td><td></td><td></td></tr> </tbody> </table>	Bit #	Description	375 Access	Reset By	Reset State	7	Light Pen Address Bit-15	R			6	Light Pen Address Bit-14	R			5	Light Pen Address Bit-13	R			4	Light Pen Address Bit-12	R			3	Light Pen Address Bit-11	R			2	Light Pen Address Bit-10	R			1	Light Pen Address Bit-9	R			0	Light Pen Address Bit-8	R				
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1	Light Pen Address Bit-9	R																																														
0	Light Pen Address Bit-8	R																																														
lsb																																																

In the EGA, the Light Pen High register contains the 8 high-order bits of the CRTC memory address counter at the time the light pen flip flop is set. The low order 8 bits are stored in the Light Pen Low register (LPENL at CRTC index 11).

In the VGA, the light pen 'register' is held in a transparent state, such that reading from LPENH at CRTC index 10 returns the 8 high-order bits of the free-running memory address counter at the time of the read. There is no way to latch the value read to make sure that the high and low readings match, or even to be sure that the memory address counter isn't in the process of changing during a read and hence temporarily invalid. This may not sound very useful, except for generating random numbers, but it emulates the IBM VGA exactly.

CRTC registers CR10-11 and LPENH/L are at conflicting locations in the EGA. The VGA provides software control (CR3 bit-7) of whether CR10-11 or LPENH/L are readable at CRTC indices 10-11.

See page 3-47 in the PDF. In the [Vogons thread: "Can your VGA card provide a hardware source for random numbers?"](#) the community got a bit excited to try out various clone VGA adapters, to see whether this behavior was still present in each, and if it could indeed be used to produce random numbers. And for some of them, it

totally did!

As a homage to this fun behavior, and observing that vintage PCs really do not have a good fast source to hardware RNGs, we decided to add a proper hardware random number generator to CRT Terminator, in a way that is accessible as fast as possible on a vintage PC.

The hardware I/O port **0125h** is dedicated to provide a new random number each time it is read. This random number generator was tested to pass the [NIST 800-22 Rev 1a](#) specification for random number generators.

See the Hardware Programming Reference section for details on how to use the RNG.

Hardware Programming Reference

This section provides example code to interact with CRT Terminator from your real mode DOS programs.

I/O Address Space

CRT Terminator uses the ISA I/O bus port range **120h-12Fh** for communicating with the ISA card.

The following I/O address ports are provided.

Port Number	Name	Direction	Description
120h	CRT Terminator ID Port	Read Only	Reading this port cycles to return ASCII values 'C', 'R', 'T' and 'T'. Use this port to identify CRT Terminator with minimal intrusion to the I/O device space.
121h	Index Port	Read/Write	Selects the current indexed sub-register to access, or returns the current sub-register index.
122h	Data Port	Read/Write	Reads or writes the given 8-bit sub-register selected by the index port.
123h	8bpp Palette Index Port	Write Only	Selects the active palette index to write, 0-255.
124h	8bpp Palette Data Port	Write Only	Consecutively write 3 bytes to program a 24-bit color for active palette index. The index is then autoincremented to receive the color for the next palette index (wrapping around to zero after 255).
125h	RNG Port	Read Only	Every read from this port returns a new 8-bit random number from a fast high quality hardware random number generator source that passes the NIST 800-22 Rev 1a specification.
126h	Frame Counter Port	Read Only	Reading this port returns the lowest 8 bits value of the currently displayed frame number counter.
127h	Scanline Counter Port	Read Only	Reading this port returns the number of scanlines remaining until the start of next vertical blank. If the adapter is currently in vblank, this port returns 0. If more than 254 scanlines remain until vblank, this port returns 255.
128h	High Precision Wallclock Port 0 (LSB bits 7-0)	Read Only with Side Effect	Reading this port latches the 32-bit high precision wallclock time counter and returns the lowest 8 bits of its value. This wallclock timer has the frequency of 27,000,000 Hz ± 1350 Hz. (Accuracy of 50ppm)
129h	High Precision Wallclock Port 1 (bits 15-8)	Read Only	Reading this port returns bits 15-8 of the latched 32-bit high precision wallclock time counter value.
12Ah	High Precision Wallclock Port 2 (bits 23-16)	Read Only	Reading this port returns bits 23-16 of the latched 32-bit high precision wallclock time counter value.
12Bh	High Precision Wallclock Port 3 (MSB bits 31-24)	Read Only	Reading this port returns bits 31-24 of the latched 32-bit high precision wallclock time counter value.

Note that the I/O address space used by CRT Terminator is currently fixed and not configurable. This is because CRT Terminator provides several highly performance sensitive I/O ports, so to enable sequences of minimal assembly instructions to interact with CRT Terminator, fixed port assignment is used.

Consulting known I/O address mapping lists, such as

- [Stanislavs PORTS Common I/O Port Addresses](#)
- [OSDev Wiki I/O Ports](#)
- [Wim Osterholt XT, AT and PS/2 I/O port addresses](#)

this range of ports is expected to be free from conflicts.

If however such conflicts should arise, a dynamic I/O port mapping assignment may be employed in the future.

Detecting CRT Terminator

The following code may be used to detect the presence of CRT Terminator in a real-mode DOS system.

```
#include <dos.h>
#include <stdio.h>

// CRT Terminator ID port: this is a read-only port that cycles to return
// values 'C', 'R', 'T', 'T' on subsequent reads.
#define CRTT_ID_PORT 0x120

int crt_t_detect()
{
    static int crt_t_found = 0;
    if (!crt_t_found)
    {
```

```

disable();
crtt_found = -1;
for(int i = 4; i--;) // one of 4 consecutive reads must be 'C'
{
    char id = inportb(CRTT_ID_PORT);
    if (id != 'R' && id != 'T') break; // On anything else than C, R or T, not CRT Terminator.
    if (id == 'C')
    {
        if (inportb(CRTT_ID_PORT) != 'R') break; // and 'RTT' must follow
        if (inportb(CRTT_ID_PORT) != 'T') break;
        if (inportb(CRTT_ID_PORT) != 'T') break;
        crt_t_found = 1; // Found CRT Terminator
        break;
    }
}
enable();
}
return crt_t_found == 1;
}

int main()
{
    printf("CRT Terminator detected: %s\n", crt_t_detect() ? "true" : "false");
    return crt_t_detect();
}

```

Listing 1. Recommended C code to detect CRT Terminator in Borland C++, Turbo C or Turbo C++.

Indexed Registers

In addition to the direct registers presented in the previous table, there are several indexed registers that are provided.

These registers are accessed through the CRT Terminator Index+Data Port pair. First write the index of the desired register to access into the CRT Terminator Index Port (121h), and then the selected register can be accessed via the CRT Terminator Data Port (122h).

Indexed Port Number	Name	Direction	Description
00h-01h	CRT Terminator Product ID	Read Only	CRT Terminator Product ID. (16 bits, Little Endian)
02h	CRT Terminator Product Revision ID	Read Only	CRT Terminator Product Revision ID.
03h	Firmware Revision Year	Read Only	Version identifier for the firmware.
04h	Firmware Revision Month	Read Only	Version identifier for the firmware.
05h	Firmware Revision Day	Read Only	Version identifier for the firmware.
06h-09h	Feature Connector Pixel Clock	Read Only	Pixel clock of the currently received video signal through Feature Connector, in Hz. (32 bits, Little Endian)
0Ah-0Dh	Feature Connector Hsync Rate	Read Only	Horizontal Refresh Rate of the currently received video signal through Feature Connector. (32 bits, Little Endian)
0Eh-11h	Feature Connector Vsync Rate	Read Only	Vertical Refresh Rate of the currently received video signal through Feature Connector. (32 bits, Little Endian)
12h	Feature Connector Video Properties	Read Only	Returns parameters of the Feature Connector video signal: Bit 0 - Hsync Polarity Bit 1 - Vsync Polarity Bit 2 - Video Signal Present Bit 3 - Video is Scandoubled Bit 4 - Video is interlaced?
13h	Feature Connector Video Bit Depth	Read Only	Bits 0-1: 00h: ≤ 8bpp 01h: 15bpp 10h: 16bpp 11h: 24bpp
14h		Read Only	If Video Bit Depth is 00h (≤ 8bpp), this field denotes the number of distinct colors in Feature Connector video signal.
15h		Read Only	If Video Bit Depth is 00h (≤ 8bpp), this field denotes the highest palette ID present in the Feature Connector video signal.
16h-17h		Read Only	FC Horizontal Front Porch length.
18h-19h		Read Only	FC Horizontal Sync length.
1Ah-1Bh		Read Only	FC Horizontal Back Porch length.
1Ch-1Eh		Read Only	FC Horizontal Visible Screen Width in clocks (not necessarily equal to screen pixel width).
1Eh-1Fh		Read Only	FC Horizontal Total Line length in clocks.
20h-21h		Read Only	FC Vertical Front Porch length, in lines.
22h-23h		Read Only	FC Vertical Sync length, in lines.
24h-25h		Read Only	FC Vertical Back Porch length, in lines.
26h-27h		Read Only	FC Vertical Visible Screen Height in lines.
28h-29h		Read Only	FC Vertical Total Lines.
2Ah-2Bh		Read Only	FC Screen Width in pixels.
2Ch-2Eh		Read Only	FC Screen Height in pixels.
2Eh-2Fh		Read Only	FC Left Edge VGA Border Crop.
30h-31h		Read Only	FC Top Edge VGA Border Crop.

Indexed Port Number	Name	Direction	Description
32h-33h		Read Only	FC Right Edge VGA Border Crop.
34h-35h		Read Only	FC Bottom Edge VGA Border Crop.
36h-37h		Read Only	FC Leftmost visible pixel x coordinate.
38h-39h		Read Only	FC Topmost visible pixel y coordinate.
3Ah-3Bh		Read Only	FC Rightmost visible pixel x coordinate.
3Ch-3Eh		Read Only	FC Bottommost visible pixel y coordinate.
3Eh-3Fh		Read Only	Currently selected values of the DIP switches at the back of the card.
40h		Read-Write	Configures currently active features: Bit 0 - Enable 8bpp colors (disable 6bpp palette) Bit 1 - Enable Vsync. If set to 1, video is upscaled triple-buffered. If set to 0, video is upscaled without vertical synchronization, and can tear. Bit 2 - Enable border crop. If set to 1, the video border is cropped away from output image. If set to 0, video border is preserved. Bits 3-7 - Reserved. Please preserve these bits when writing to this register.
44h-47h	ISA Bus Speed	Read Only	Measured ISA bus clock speed, in Hz.
48h		Read Only	Most Recently Written Palette Index.
49h-4Bh		Read Only	Most Recently Written Palette RGB color.
Other Indices	Reserved	Read Only	(Reads will return FFh, but do not assume this)

Hardware RNG

To generate a random byte, issue a 8-bit read from the port **0125h**. This can be quickly tested in DOS via the **debug** command:

```
C:\>debug
-i 125
47
-i 125
67
-i 125
0F
-i 125
0D
-i 125
CB
-q
C:\>
```

16-bit reads to this port will not generate a 16-bit random number, because CRT Terminator is only an 8-bit card. So stick to 8-bit reads only.

The following C++ program prints out ten random numbers.

```
#include <dos.h>
#include <stdio.h>

int main()
{
    for(int i = 0; i < 10; ++i)
    {
        unsigned char rng = inp(0x125);
        printf("%d\n", (int)rng);
    }
    return 0;
}
```

Listing 2. Borland Turbo C++ 3.0 example to generate random numbers from CRT Terminator hardware RNG source.

If the above code is run on a system that does not have CRT Terminator installed, the program will likely output the same byte value ten times. Refer to listing 1 to detect the presence of CRT Terminator before using the above code.

Likewise, random numbers may be generated from within x86 assembly code.

```
#include <stdio.h>

int main()
{
    for(int i = 0; i < 10; ++i)
    {
        unsigned char rng;
        asm mov dx, 0x125
        asm in al, dx
```

```

asm mov rng, a1
printf("%d\n", (int)rng);
}
return 0;
}

```

Listing 3. Borland Turbo C++ 3.0 inline x86 assembly example to generate random numbers from CRT Terminator hardware RNG source.

for the relevant bits to be adapted into an existing x86 assembly program.

Frequently Asked Questions

Does CRT Terminator support sending audio through the digital video cable?

No. Audio output over the video cable is not supported. Please use e.g. the 3.5mm Line-In connector of your PC when capturing video+audio for recording and streaming purposes, and an external 3.5mm audio in jack on your display, or a pair of external speakers when playing audio out locally.

Troubleshooting

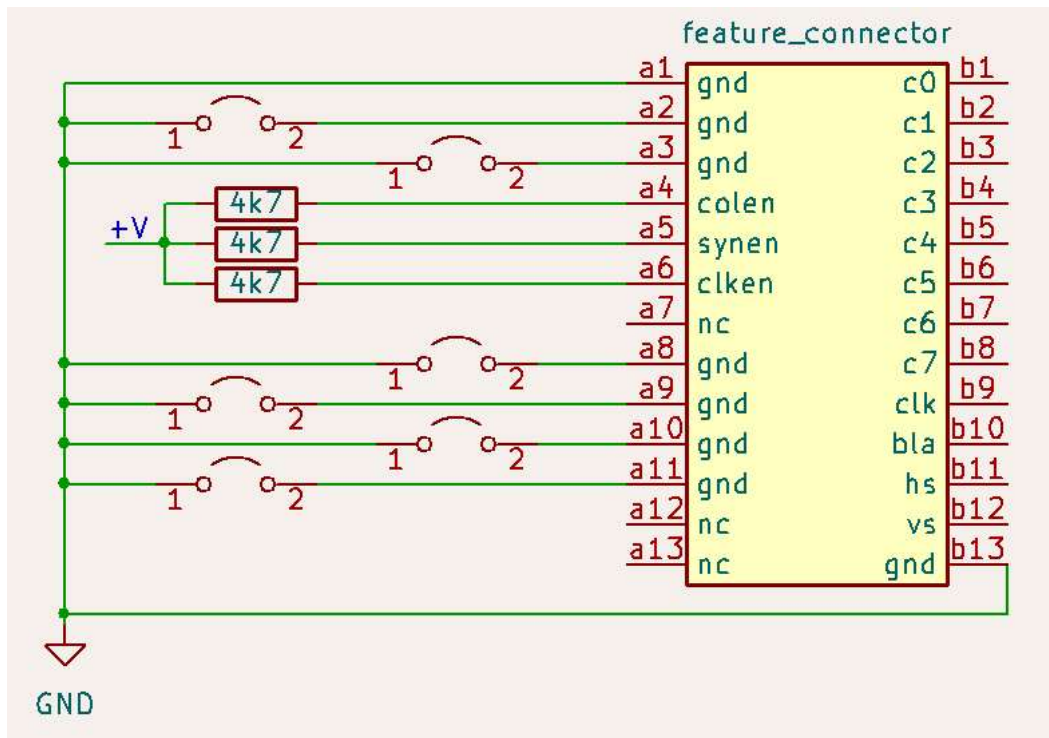
Hardware and software bugs are collected at the public GitHub issue tracker at https://github.com/juj/crt_terminator/issues.

Contact us directly at oummgr@gmail.com.

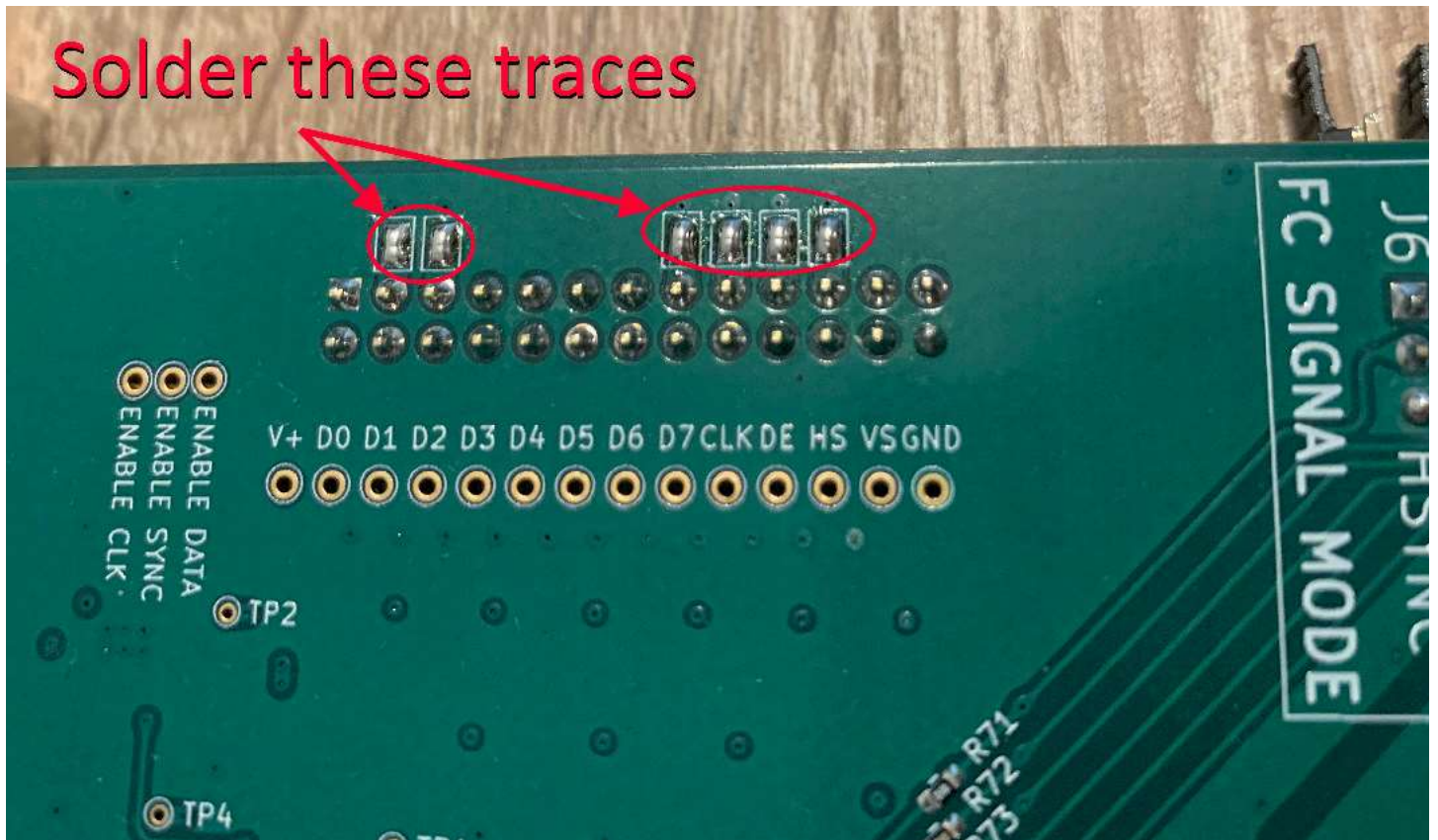
Improving Feature Connector Video Signal

The Feature Connector bus contains multiple ground pins. The reason for this is that it allows the connector to provide a cleaner ground signal to each individual high speed video pin.

However, to help mitigate accidental short circuits from an incorrect 180 degrees reversed installation of the Feature Connector cable, CRT Terminator by default does not wire some of these ground pins on the connector.



If your VGA adapter has a really glitchy video signal or you are attempting to make higher input video resolutions work, there are six unsoldered ground traces on the CRT Terminator board, on ground pins a2, a3, a8 through a11. You can attempt to solder these traces together in order to improve the individual ground lines, like so:



There is a small chance that this could improve a glitchy video signal quality. In our testing however, in DOS 320x200, 640x480, 720x400 and 800x600 video modes, these ground lines did not prove to have noticeable effect, so for abundance of caution, these have been left unconnected by default.

If you do decide to try this mod out, be aware that incorrectly connecting the Feature Connector cable rotated 180 degrees in wrong orientation will then result in a catastrophic short to ground. Warranty does not cover this modification.

Appendix A: IBM VGA Feature Connector

Apparently the IBM Feature Connector first appeared in the following manuals:

- [Personal System 2 Hardware Interface Technical Reference May88.pdf](#)
- [IBM VGA Technical Reference Manual.pdf](#)

However there are some discrepancies, since the above documents both describe a 20-pin connector, whereas the Feature Connector present on the first IBM PS/2 ISA VGA adapter is a 2x13-pin edge connector.

📁 **Lost Documents:** If IBM ever released any technical documentation related to IBM ISA PS/2 Display Adapter (VGA) 75X9017XM and you might have it, please **please** share it with us or scan it to archive.org!

Appendix B: VESA Standard VGA Pass-Through Connector

In August 1989, VESA took IBM's existing Feature Connector functionality and standardized it as [VESA Standard VS890803: VESA Standard VGA Pass-Through Connector](#).

📁 **Lost Documents:** Unfortunately this standard may to have lost in time, and not even VESA themselves seem to have this specification. If you would happen to have a copy, please **please** share it with us or scan it to archive.org!

VESA has released to the public the following documents related to their later VESA Advanced Feature Connector (VAFC):

- [VAFC_HW.pdf](#)
- [VAFC_SW.pdf](#)

Appendix C: DVI-D Standard

CRT Terminator outputs a TMDS+LVDS encoded video signal over a single-link DVI-D standard.

- [DVI-1.0.pdf](#)

Appendix D: CRT Terminator Supported Output Resolutions

CRT Terminator is able to output video modes that are shown in the following table. When CRT Terminator is operated in fixed output resolution mode (i.e. MultiMode and StutterStop features are disabled), standard resolutions shown in DIP switch values 0-15 can be configured. These video modes provide support for compatible operation for displays that are not able to sync to historical low resolution DOS or upscaled video modes.

DIP switches 1.1-1.4 and JP7			Resolution	Standard	Mode Rates			Horizontal Timings (clocks)			Vertical Timings (lines)		
Decimal	Binary	JP7 (OC)			Vertical Rate	Horizontal Rate	Pixel Clock	Front Porch	Sync	Back Porch	Front Porch	Sync	Back Porch
0	0000b	*	Passthrough	Nonstandard	.1	.1	.1	.1	.1	.1	.1	.1	.1
1	1000b	*	640x480	DMT	60.000 Hz	31.5 kHz	25.200 MHz	8	96	40	2	2	25
2	0100b	*	800x600	DMT	60.256 Hz	37.841 kHz	39.960 MHz	40	128	88	1	4	23
3	1100b	*	960x720	CVT	59.775 Hz	44.711 kHz	55.800 MHz	48	96	144	3	4	21
4	0010b	*	1280x720	DMT	60.001 Hz	45.000 kHz	74.250 MHz	110	40	220	5	5	20
5	1010b	*	1024x768	DMT	60.004 Hz	48.363 kHz	65.000 MHz	24	136	160	3	6	29
6	0110b	*	1200x900	CVT	59.617 Hz	55.682 kHz	88.200 MHz	72	120	192	3	4	27
7	1110b	*	1280x960	CVT	59.673 Hz	59.434 kHz	100.800 MHz	80	128	208	3	4	29
8	0001b	*	1280x1024	CVT-RBv2	60.275 Hz	63.529 kHz	86.400 MHz	8	32	40	16	8	6
9	1001b	*	1364x1024	CVT	60.000 Hz	63.240 kHz	91.065 MHz	8	32	40	16	18	6
10	0101b	*	1400x1050	CVT-RBv2	59.685 Hz	64.459 kHz	95.400 MHz	8	32	40	16	8	6
11	1101b	*	1680x1050	CVT-RBv2	59.659 Hz	64.432 kHz	113.400 MHz	8	32	40	16	8	6
12	0011b	*	1440x1080	CVT-RBv2	59.690 Hz	66.316 kHz	100.800 MHz	8	32	40	17	8	6
13	1011b	OFF	1920x1080	CVT-RBv2	53.610 Hz	59.400 kHz	118.800 MHz	8	32	40	14	8	6
13	1011b	ON	1920x1080	CVT-RBv2	59.541 Hz	66.150 kHz	132.300 MHz ³	8	32	40	17	8	6
14	0111b	OFF	1600x1200	CVT-RBv2	57.351 Hz	70.714 kHz	118.800 MHz	8	32	40	19	8	6
14	0111b	ON	1600x1200	CVT-RBv2	59.861 Hz	73.929 kHz	124.200 MHz ³	8	32	40	21	8	6
15	1111b	OFF	1920x1200	CVT-RBv2	48.371 Hz	59.400 kHz	118.800 MHz	8	32	40	14	8	6
15	1111b	ON	1920x1200	CVT-RBv2	60.121 Hz	74.250 kHz	148.500 MHz ³	8	32	40	21	8	6
-	-	OFF	MultiMode or StutterStop	Nonstandard ²	≤ 75.000 Hz	.2	≤ 118.800 MHz	.2	.2	.2	.2	.2	.2
-	-	ON	MultiMode or StutterStop	Nonstandard ²	≤ 75.000 Hz	.2	≤ 199.800 MHz ³	.2	.2	.2	.2	.2	.2

1: Varies. Passes through input video signal, with small corrections.

2: Relaxed from CVT-RBv2 timings.

3: Overclocked, support not guaranteed. Single link DVI-D cable can reach a pixel clock up to 165 MHz.