SM03

NTSC/PAL/SECAM Video Enhancer

User Manual

Revision 0.1
5th March 2024

Revisions

Date	Revisions	Version
05-03-2024	First draft	0.1

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1. Introduction

SM03 is a video processor and enhancer for standard definition video (PAL, NTSC or SECAM).

SM03 accepts analogue NTSC-M, PAL, SECAM, NTSC-443 or PAL-60 encoded video (Composite or Y/C format) which it decodes to a component serial digital interface (SDI) output. Decoding is performed using a proprietary 3D comb filter to maintain the best detail with the lowest artifacts. The video is then passed through a video noise reducer which reduces noise in the image without trails or contouring effects. The video is then retimed in a full frame synchroniser to provide a stable, low jitter output, even with out-of-specification input signals (e.g. from a video cassette player). The video can be edge sharpened and contrast enhanced before the video is formatted to an SDI output. A processing amplifier allows control of various video parameters, and a test pattern generator allows for setup of downstream components such as a monitor or video encoder. Stereo audio may also be embedded in the SDI output – the audio may be delayed, correcting any lip-sync errors.

SM03 requires 12VDC which is provided via the supplied AC-DC converter.

2. Quick start guide

The connections to the SM03 are shown in Figure 1.

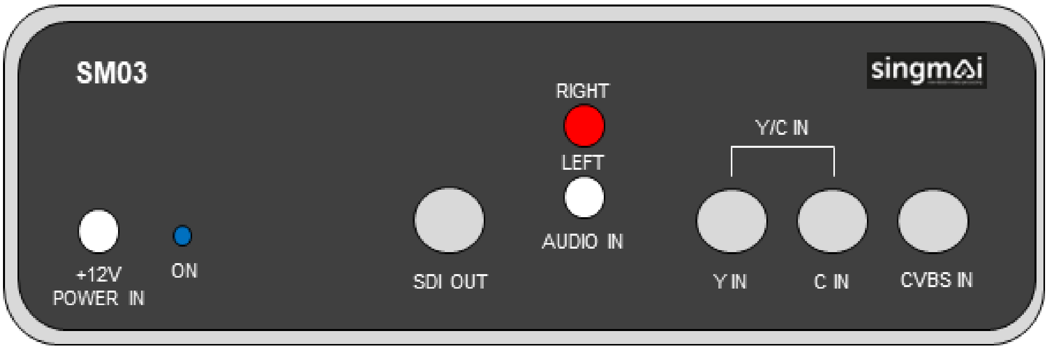

Figure 1 SM03 connections.

The SM03 requires a 12VDC supply which is provided via the supplied AC-DC adaptor. The adaptor accepts AC between 100 and 240VAC – the full specification is provided in Appendix A. The adaptor comes with a number of 'blades': fit the blade that is appropriate to your country (see Figure 2).

Figure 2 AC-DC adaptor.

Connect the 12VDC jack from the adaptor to the +12V 'Power In' socket on the SM03.
To turn on the SM03 push the front panel 'Adjust' control. After a short delay the front panel LCD display should display a logo, followed by a menu (see Figure 6) and the rear panel 'Power' LED should light.

To turn off the SM03, press and hold the 'Adjust' button for more than two seconds.

Connect a composite video input to the 'CVBS' BNC (an RCA/phono to BNC adaptor is supplied if required) or a Y/C input to the 'Y In' and 'C In' BNC inputs (a Y/C to BNC cable is provided with the SM03). The video standard and input format need to be selected using the front panel control (see Chapter 4). If using the Y/C input, the red BNC connects to the 'Y In' input and the white BNC to the 'C In' input.

Figure 3 Y/C cable.

The output of the SM03 is SDI (serial digital interface), which is a SMPTE (Society of Motion Pictures and Television Experts) standard (SMPTE-259M). The video decoder of the SM03 separates the composite video input (e.g. NTSC) into its component parts – the synchronizing signals, the luma (brightness) signal and the colour components (called Cb and Cr in SDI terminology). The luma and chroma signals are 10-bit values (0-1023 in decimal). The SDI interface serialises all this information into a one-bit signal that can be sent across a single coaxial cable. The luma signal is sampled at 13.5MHz and the two colour components sampled at 6.75MHz each. So, to combine these signals we have 13.5MHz + 2 x 6.75MHz = 27MHz data at 10-bits. And to serialise this data from 10-bits to 1-bit we now have a data rate of 10 x 27MHz = 270MHz. The synchronizing signals are embedded in the video data using a special code word (TRS in SDI terminology). During the time when there is no video (the horizontal and vertical blanking) other data can be sent – for example the audio.

SDI is an uncompressed video interface and it is used extensively in the broadcast industry. To view the SDI output it is necessary to have an SDI monitor. If you are encoding the SDI output for archiving then there are a number of converter modules which accept SDI (e.g. see Figure 4).

Figure 4 Magewell SDI to USB adaptor.

HDMI is more usually used in consumer equipment, and you can convert SDI to HDMI using a number of modules available. We use the Blackmagic SDI to HDMI converter (see Figure 5) which is available for approximately $50. (https://www.blackmagicdesign.com/products/microconverters). Connect the SDI output of the SM03 to the SDI input of the module and the SDI lock light should light. Then connect the HDMI output of the module to your TV. No setup is necessary.

Figure 5 Blackmagic SDI to HDMI converter.

The SM03 also accepts stereo audio inputs which are connected to the two phono (RCA) connectors on the rear panel. The audio can be inserted into the SDI video output where it can be encoded with the video for archiving.

3. SM03 Control

The SM03 is controlled via the front panel encoder/switch. At switch-on the top-level menu options are shown (see Figure 6). Rotate the 'Adjust' control to highlight the option you wish to adjust.

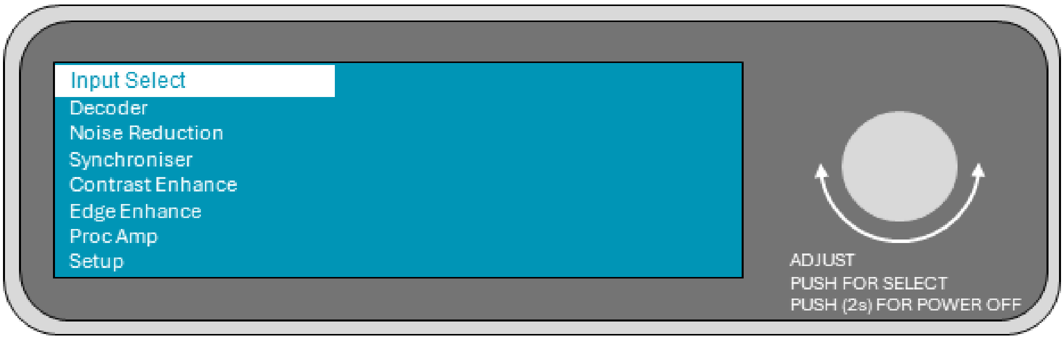

Figure 6 Top Level Menu

To view the sub-menu options briefly push the 'Adjust' control and the sub-menu will appear. If there is more than one option, turning the 'Adjust' control will again highlight the chosen option or parameter. To quit the sub-menu, select the 'Exit' option at the bottom of the sub-menu and press the 'Adjust' control and it will return you to the top-level menu.

Input Select

Selecting Input select allows you choose between CVBS or Y/C inputs. Rotating the 'Adjust' control selects the input. To return to the default menu press the 'Adjust' control.

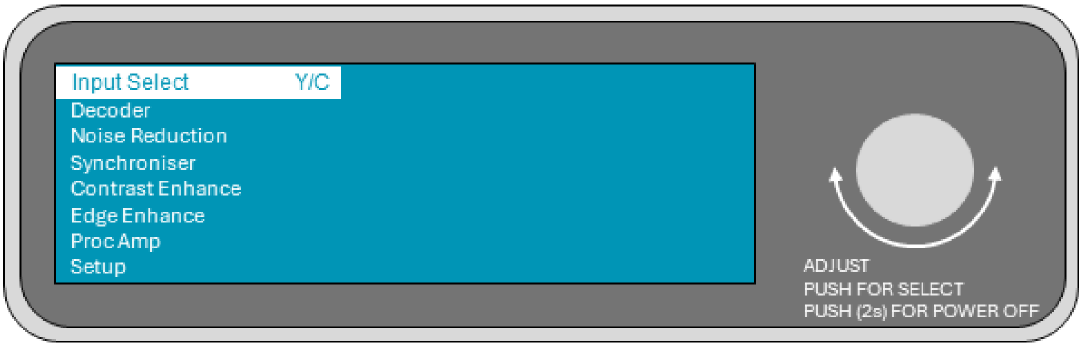

Figure 7 Input select menu.

Decoder

To bring up the Decoder menu, move the highlight bar until it indicates 'Decoder' from the top-level menu and press the 'Adjust' control. The menu shown in Figure 8 will appear. To exit the decoder menu, select 'Exit' and press the 'Adjust' control.

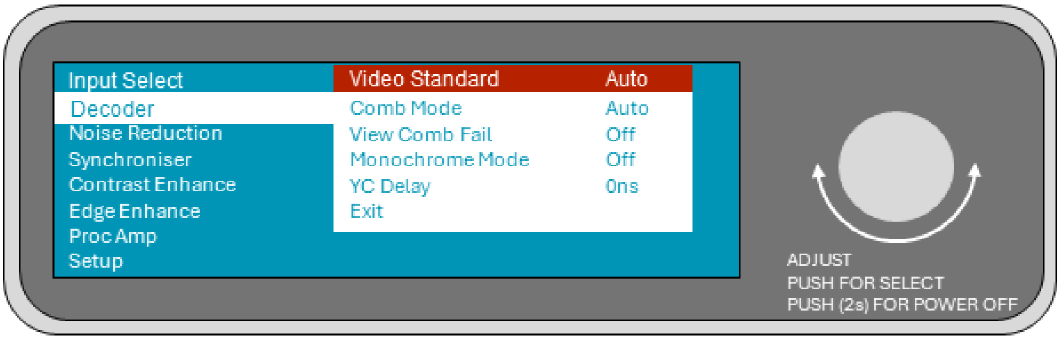

Figure 8 Decoder control menu.

The 'Video_Standard' menu allows you to select a fixed video standard (NTSC, PAL, NTSC443, PAL60 or SECAM) or for the SM03 select automatically between NTSC and PAL (Auto).

Note, if the input video standard does not match the selected standard, the output will not be valid.

Auto PAL/NTSC is the default setting.

The 'Comb Mode' menu allows you to control the SM03 comb filter. The comb filter may be set to a notch filter (a band reject filter centred on the subcarrier frequency), a 3-line comb filter, or a symmetric 3D frame comb. Auto (the default setting) allows the SM03 to select the best mode (based on an evaluation of the resulting image for each mode) on a pixel-by-pixel basis. Auto mode should be selected for all video sources.

The 'View Comb Fail' menu option allows you see what comb mode is being selected. This function can only be selected if the comb mode is set to auto. Rotating the 'Adjust' control will toggle this option on and off. When switched on, the colours in the image show which comb mode has been determined to be the best to use. Three colours indicate one of the three comb modes as shown in Table 1:

Comb mode	Displayed colour
Simple (notch)	Magenta
Line comb	Red
Frame comb	Green

Table 1 Comb failure colour settings.

Figure 9 shows an example of the image with the view comb fail enabled. A more detailed description of the comb filter may be found in Chapter 5.

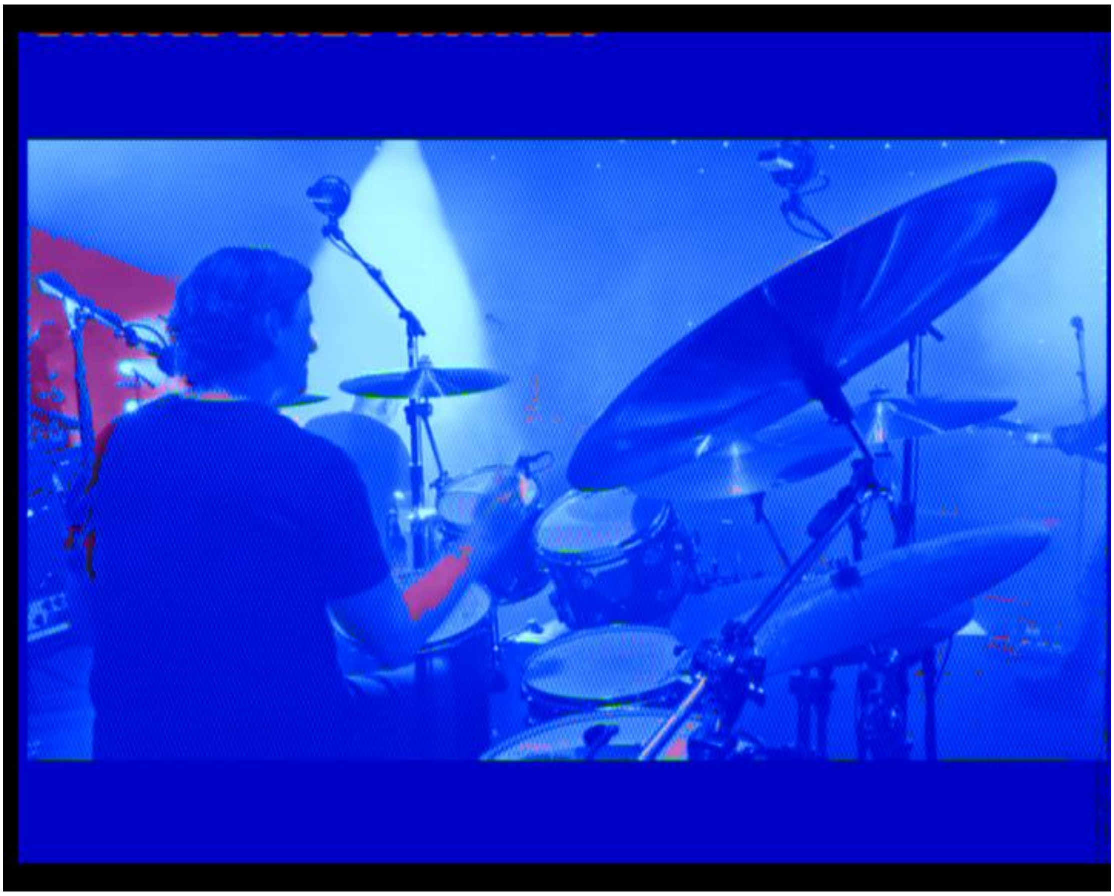

Figure 9 View comb failure mode.

The monochrome off/on option is for monochrome only video inputs (e.g. intensified night-view camera). If Monochrome is selected the colour processing of the video decoder is bypassed and the video input is passed unprocessed to the output. Monochrome On should not be selected if the video input is colour.

For some video sources such as VCRs the luma and chroma signals may not be co-timed, with one lagging the other which leads to very blurred vertical transitions. The YC delay control allows the chroma signal to be adjusted relative to the luma. The adjustment should be made to achieve the best vertical transition. The timing is adjusted in 74ns (one pixel) increments.

Noise Reduction

To select the Noise Reduction menu, select ‘Noise Reduction’ from the top-level menu and press the ‘Adjust’ control. The menu shown in Figure 10 will appear. To exit the noise reduction menu, select ‘Exit’ and press the ‘Adjust’ control.

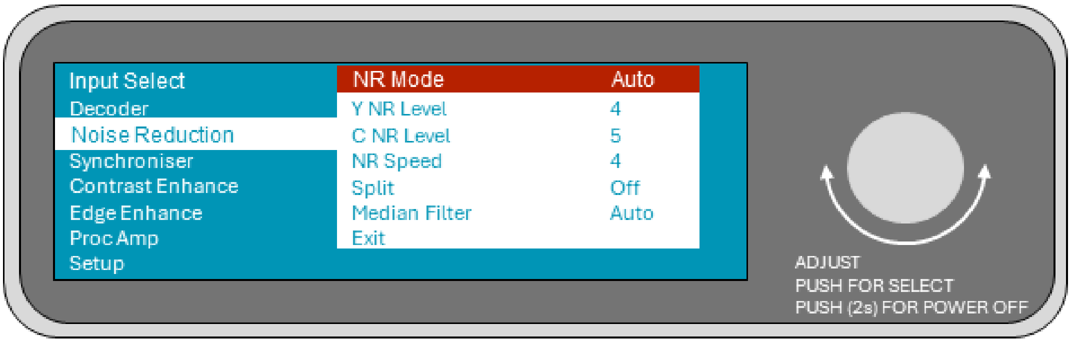

Figure 10 Noise Reduction menu.

NR Mode selects between Auto (motion adaptive) or Manual noise reduction.

The default option is MA (Motion Adaption) where the degree of noise reduction is selected using the Y and C NR Level and NR Speed settings. The Y and C NR Levels can be adjusted between 0 (noise reduction off) and 7 (maximum noise reduction). The NR Speed control affects how fast the motion adaption reacts to detected motion in the motion, affecting any trails left behind moving objects.

In the Manual adjustment, the motion adaption is turned off. In the MA modes, if there is motion in the video, the degree of noise reduction is automatically reduced to lessen blurring of the image and prevent trails being left behind moving objects. However, with video with very high levels of noise, the motion adaption cannot differentiate between noise and motion and will appear to be ineffectual. Under these conditions the Manual mode allows the noise adaption to be turned off. The degree of noise reduction is adjusted between 0 (noise reduction off) and 255 (maximum noise reduction) using the Y and C NR Level controls: the NR Speed control has no effect in manual mode. A fuller description of the recursive noise reduction may be found in Chapter 7.

The Split control divides the screen left and right. On the left is the original image, and on the right is the noise reduced image. This can be useful for adjusting the noise settings.

The median filter menu selects between two fixed median filter kernal sizes, 3x3 pixels or 5x5 pixels, or Auto mode when the median kernal size is automatically adjusted, providing the best noise reduction without corrupting the high frequencies of the video. Chapter 6 has further information on the median filter.

Synchroniser

To select the Synchroniser menu, select ‘Synchroniser’ from the top-level menu and press the ‘Adjust’ control. The menu shown in Figure 11 will appear. To exit the synchroniser menu, select ‘Exit’ and press the ‘Adjust’ control.

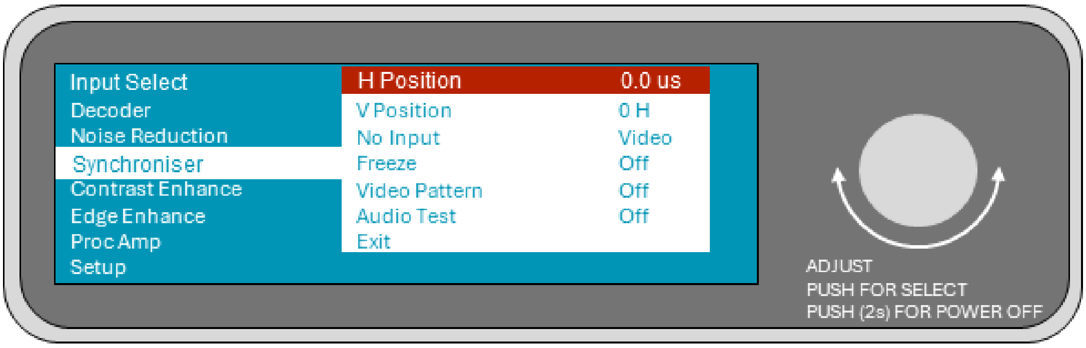

Figure 11 Synchroniser Menu.

The synchroniser is a video frame size memory. Video is written to the memory from the video decoder which is locked to the video input. Video is read from the memory using a standard compliant sync generator, so the output video is always accurate in its timing and has low jitter. This means that any errors in the timing of the input do not affect the output video. It is possible to adjust the horizontal and vertical timing of the output video so the video frame may be moved. This is done using the H Position and V Position controls from the synchroniser menu. The horizontal position is moved in 74ns increments (one pixel) over a range of ±31.5µs (±half a horizontal line). The vertical position may be moved ±100 lines in one-line increments.

The 'No Input' menu selects what happens when the input is lost. The options are 'Pass', where no action is taken and you just see whatever is on the video input: 'Freeze', where the input is frozen and not updated until the input is determined as valid or 'Screen', where a blue screen is shown when the input is invalid or missing.

Pressing the Freeze menu option freezes the video. Pressing it again unfreezes the video.

Video Pattern allows one of three test patterns to be output for the setup of downstream components such as video encoders and monitors. When Off is selected the video is passed. The three patterns are SMPTE Bars (525 line standards only) or Bars and Red (625 line standards), a luma/chroma ramp, N7CMPF (525 line only) or CCIR17 (625 line only) pulse and bar pattern and a zone plate.

Audio test allows an audio test tone to be inserted into the SDI output (if Audio Insert in the Setup menu is selected On). The tones can be 1kHz left channel and 3kHz right channel, or vice versa.

Contrast Enhance

To select the Contrast Enhance menu, select 'Contrast Enhance' from the top-level menu and press the 'Adjust' control. The menu shown in Figure 12 will appear. Rotate the Adjust control to switch contrast enhance on or off. To exit the menu, push the Adjust control.

A fuller description of the contrast enhancement may be found in Chapter 8.

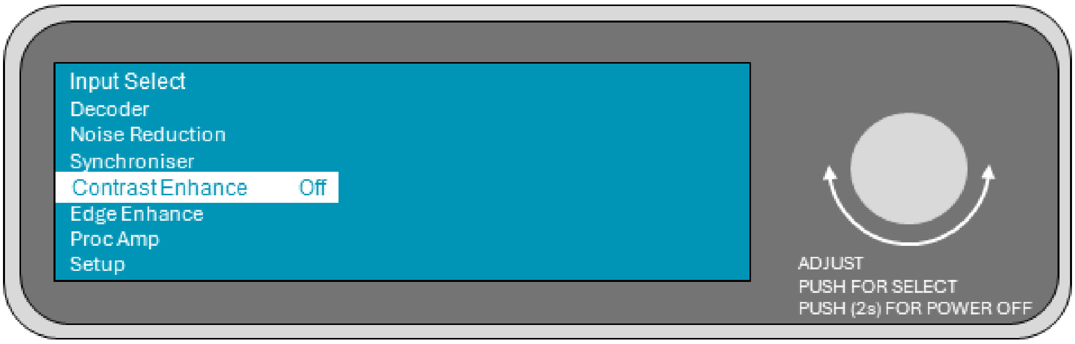

Figure 12 Contrast Enhance menu.

Edge Enhance

For standard definition video the chroma bandwidth (1.3MHz) is much lower than the luma bandwidth (5.5MHz). For sources such as VCRs the chroma bandwidth can be even less. The result of this is that, on a vertical edge, the risetime of the luma is much faster than that of the chroma. This gives a 'soft' edge when viewing. The chroma enhance menu allows the chroma edge to be sharpened (without overshoots) giving a 'crisper' look to the video image.

To select the Edge Enhance menu, select 'Edge Enhance' from the top-level menu and press the 'Adjust' control. The menu shown in Figure 13 will appear. Rotate the Adjust control to adjust the edge enhance between 0 (off) and 7 (maximum edge sharpening). To exit the menu, push the Adjust control.

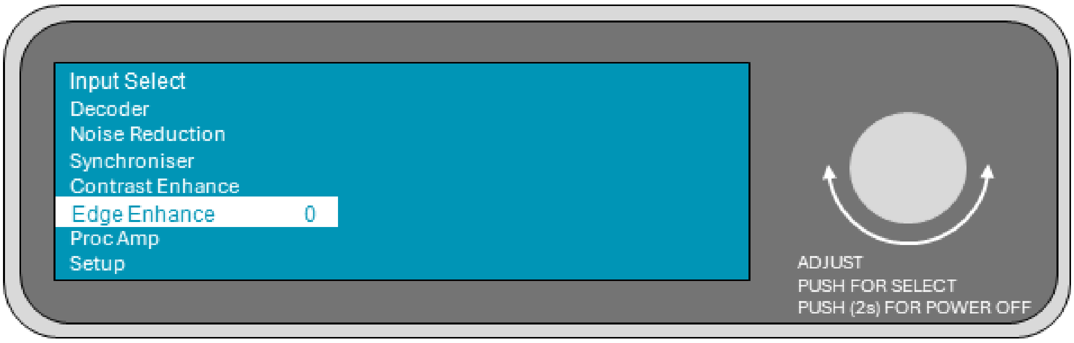

Figure 13 Edge Enhance menu.

ProcAmp

To bring up the Procamp menu, select 'ProcAmp' from the top-level menu and press the 'Adjust' control. The menu shown in Figure 14 will appear. To exit the ProcAmp menu, select 'Exit' and press the 'Adjust' control.

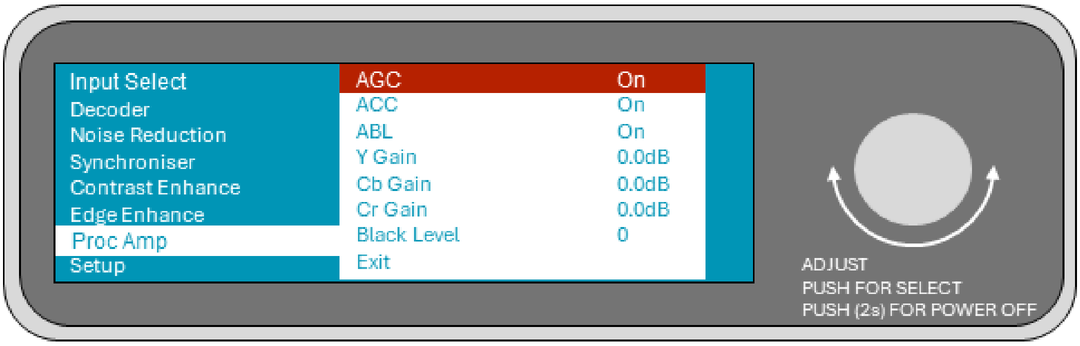

Figure 14 Proc Amp menu.

Procamp is an abbreviated term for Processing Amplifier and the menu allows adjustments to the video gain and colour.

AGC (Automatic Gain Controls) adjusts the input video amplitude to the decoder automatically (when switched 'On') comparing the measured sync amplitude with a reference level. The AGC range is approximately ±6dB. When switched 'Off' the video output will vary depending on the video input level. The Y Gain control still operates with AGC switched on.

ACC (Automatic Colour Control) adjusts the input chroma amplitude to the decoder automatically (when switched 'On') comparing the measured burst amplitude with a reference level. The ACC range is approximately ±6dB. When switched 'Off' the chroma output will vary depending on the video input level. The Cb and Cr Gain controls still operate with ACC switched on.

'ABL' turns off or on the Automatic Black Level of the video decoder. The video decoder continuously measures the black level of the incoming video and subtracts it from output video (effectively this removes the sync pulse from the output video). The Black Level control still operates with ABL switched on.

'Y Gain' allows an approximate ±6dB amplitude adjustment in the Y (luma) gain. Similarly, 'Cb Gain' and 'Cr Gain' allow an approximate ±6dB adjustment of the gain of the Cb (B-Y) and Cr (R-Y) chroma channels respectively. Note, that these latter adjustments will alter the colour hue in the image.

Black Level allows an offset to be added or subtracted to the video output (effectively a brightness control). This can be useful if the video blacks are compressed or are 'below black'.

Setup

To bring up the Setup menu, select 'Setup' from the top-level menu and press the 'Adjust' button. The menu shown in Figure 15 will appear. To exit the Setup menu, select 'Exit' and press the 'Adjust' button.

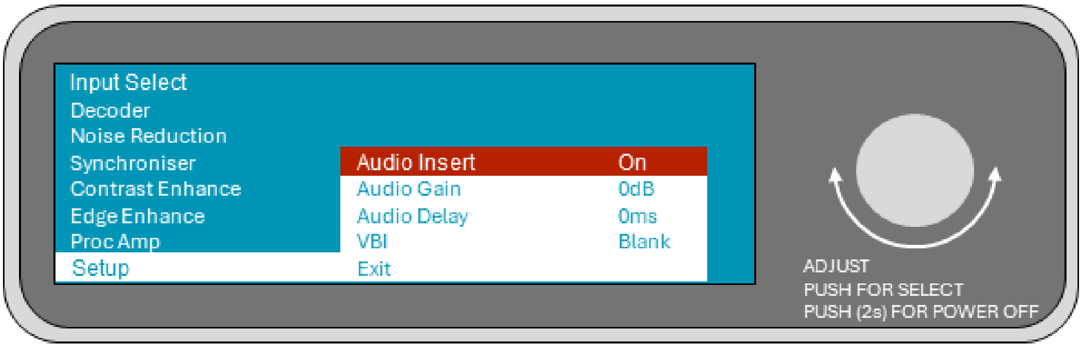

Figure 15 Setup menu.

Audio Insert enables or disables the insertion of audio into the SDI output.

Audio Gain selects a fixed +14dB gain in the audio input amplifier to accommodate low signal inputs.

Audio Delay allows the audio to be delayed with respect to the video (to correct lip sync errors). The audio delay can be adjusted between -60ms (audio preceeds the video by 60ms) and +120ms (audio delayed with respect the video). The increments are 5ms.

The Vertical Blanking Interval (VBI) of the video can be used to convey other information such as video test signals (VITS) or closed caption. Usually this information is blanked but if VBI is set to Pass the vertical blanking lines are passed unprocessed through the SM03 to the SDI output.

4. Technical Overview

The block diagram of the SM03 is shown in Figure 16.

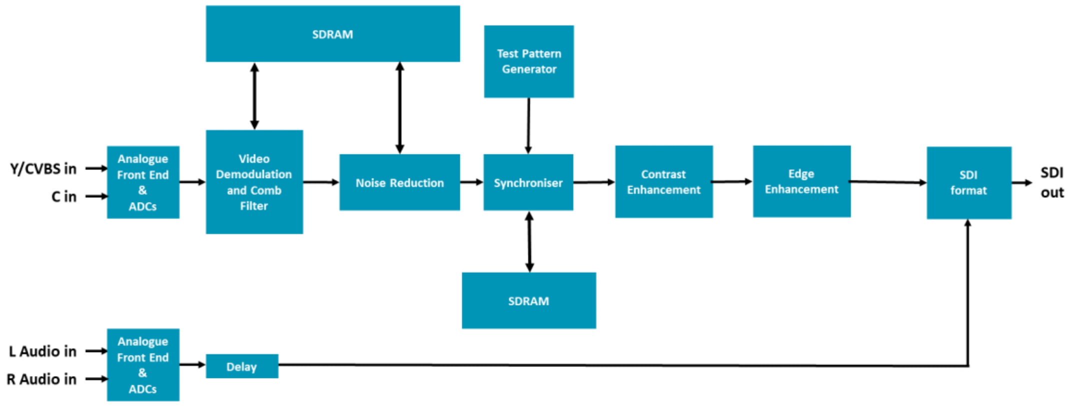

Figure 16 SM03 block diagram.

The CVBS and Y video input is pseudo-differentially received to reduce any hum pickup. The selected input (CVBS or Y/C mode) is then filtered to reduce out of band noise and DC clamped. The Chroma input (Y/C mode only) is also filtered and amplified. The Chroma and CVBS inputs are converted to digital CVBS using a dual 12-bit analog to digital converter running at 27MHz.

All of the video processing is performed in an FPGA.

The CVBS video is demodulated using a complementary architecture. The result is 'simple' U and V chroma (colour difference signals) and a CVBS signal notch filtered at the subcarrier frequency.
The demodulation is run at a fixed sample rate. The chroma and luma video are passed through a sample rate converter. This filter maps the fixed rate samples onto a line locked timebase which is compatible with the SDI output sample requirements.

The chroma is then comb filtered to remove high frequency luma. The combed chroma is then subtracted from the 'simple' chroma to leave high frequency luminance. This high frequency luma signal is then remodulated and added back to the notched CVBS signal to restore the full luma bandwidth. A more detailed description of the comb filter may be found in Chapter 5.

The notched CVBS signal is also sent to a sync pulse generator, which separates the synchronizing signals from the CVBS video and generates all the timing signals required of the SM03. This block also creates the control signal for the sample rate converter.

The combed chroma and luma signal are then modified in a processing amplifier (Proc Amp) where gain and brightness may be adjusted.

The luma output from the video decoder is then passed through an adaptive median filter to reduce impulse type noise. A fuller description of the median filter may be found in Chapter 6.

The video is then passed through a recursive filter to reduce random noise such as tape noise or film grain. A fuller description of the recursive noise reduction may be found in Chapter 7. Both the recursive filter and the comb filter use the same SDRAM to implement the delays.

The filtered video is then resynchronized using a frame synchronizer (sometimes incorrectly called a TBC). The input video may have instability from the video source, especially if it is a mechanically scanned analogue source such as laserdisc or VCR. To remove this the video is written into a full frame memory, which is read asynchronously by a stable sync pulse generator. This ensures the output is always low jitter and correctly formatted. Test patterns may also be inserted into the output to allow testing of downstream components.

The synchronizer allows adjustment of the picture position.

The retimed video can then be contrast and edge enhanced (A fuller description of the contrast enhancement may be found in Chapter 8). It is then formatted into an SDI (Serial Digital Interface) output.

The stereo audio inputs are filtered and amplified before being converted to digital I2S using a 24-bit ADC running at 48kHz. The audio is passed through an adjustable delay (to compensate for lip-sync issues) and inserted into the SDI output.

Control of the SM03 is via an LCD display which is controlled via an 8-bit microprocessor, also within the main FPGA.

5. Comb Filters

At the heart of the SM03 video decoder is a comb filter. This chapter describes the advantages (and disadvantages) of a comb filter.

The analogue television broadcast system (NTSC, PAL or SECAM) was designed as a complete system, from the psycho-visual compromises made at the encoding (camera) end through to the persistence of the phosphor on the cathode ray tube (CRT) in your living room. The advent of large flat screen displays, whilst in many ways being the element that allowed the widespread adoption of high-definition television broadcasting, placed additional demands on the analogue video decoder where conventional sources were viewed, and for a large number of viewers that was still the case; that yellow RCA plug was still in widespread use. Even apparent 'HD' (high definition) content can often be up-converted SD (standard definition).

The most obvious result of viewing analogue video sources on a large display is that any artefacts are, of course, larger and visually more apparent. For larger displays the analogue video decoder actually has a more stringent requirement. This problem is compounded because the flat screen displays require additional processing of the analogue source before it can be properly displayed, namely de-interlacing and scaling. The de-interlacer, in particular, can amplify any artefacts left from the video decoder. This is because the de-interlacer is sensitive to motion in the image and residual artefacts and noise left from the analogue decoder cannot be discriminated from real motion in the image. The result is the de-interlacer may make the wrong mode decision resulting in additional artefacts.

The problem with NTSC and PAL video signals is that, because of the introduction of colour onto a public that had already a large number of monochrome (black and white) TVs, the introduction had to be made without losing compatibility with the old sets. The compromise that was made was to overlay the colour information with the high frequency luma (black and white) information (see Figure 17).

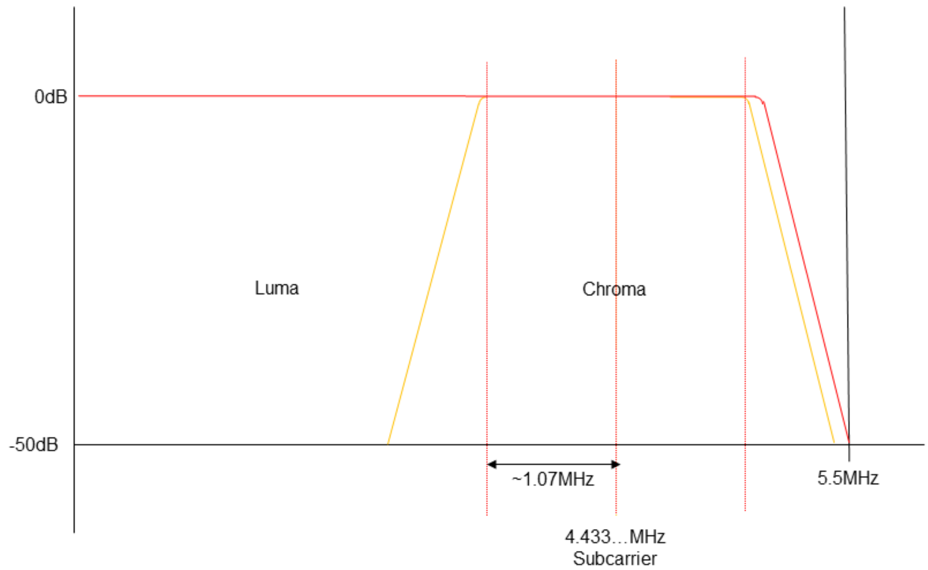

Figure 17 PAL video frequency response.

The simple way to separate the luma and chroma is a low pass filter. All low frequencies (say below 3MHz for PAL) are assumed luma only. All frequencies above 3MHz are assumed to be chroma. The problem with this is we are losing 2.5MHz of luma detail and the video will look 'soft' and lacking in detail, albeit with no artifacts. The problem is worse for NTSC because the chroma subcarrier is lower, at 3.58MHz.

To separate the high frequency luma from the chroma, the majority of the video decoders use a line comb decoder. The separation relies on the repetitive line to line phase relationship of the colour subcarrier used to encode the chrominance component. For example, for NTSC, each line in the field has a 180° phase shift so adding or subtracting the consecutive lines results in cancellation or reinforcement of the chrominance. That statement is only true, of course, if the colours are of exactly the same hue and even if they are we are not acting upon spatially aligned pixels because not only are we looking at pixels a line apart, but two lines apart because there is the interlaced field line that we do not have access to. Effectively we are looking at pixels 2 lines apart and the situation is worse for PAL because of the additional 90° line based subcarrier phase shift: without specialized and complex processing it is necessary to have a 4 line spacing. Because of all of the above it is necessary to detect when the comb filter will not work, because instead of cancelling the chroma from the luma signal (the cross-colour) we can actually reinforce it (see Figure 18).

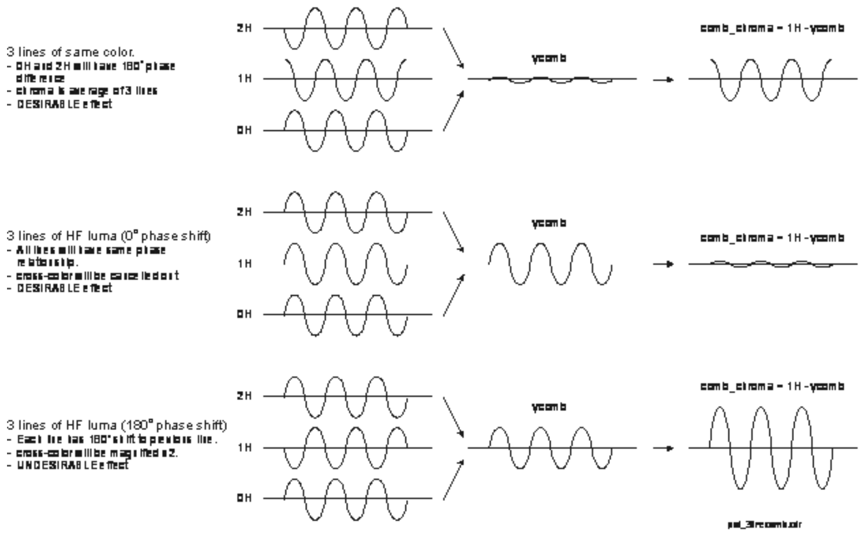

Figure 18 NTSC Comb failures.

It is possible to detect most of the conditions under which a line comb filter based video decoder will fail, and under these circumstances a simple notch filter is usually reverted to, but Figure 19 shows the result of not detecting this condition.

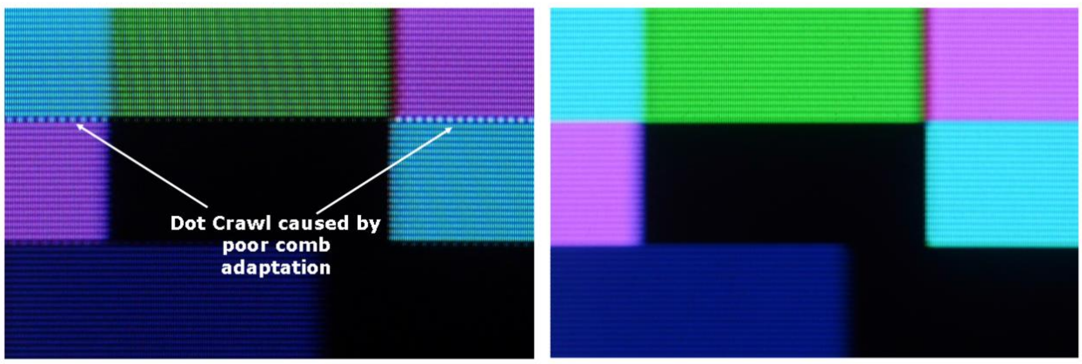

Figure 19 'Dot crawl', left, caused by failing to detect when the comb filter fails.

Although the magenta/cyan boundary seems obvious to the eye, a lot of comb failure detection uses luminance values only to determine if the comb is failing, and in this case whilst the hues are very different the luminance values are similar so the comb failure is not detected. As mentioned, one of the issues with these artifacts is that they are not static and cannot be easily removed with further post processing such as noise reduction and because the artefacts are moving they interfere with the motion adaptation of the television de-interlacer.

A similar issue arises if the output of the video decoder is to be compressed as all MPEG compression methods effectively send only the motion of an image. Unable to discriminate between artefacts, video source noise and 'real' image motion it can be shown that up 20% of satellite and cable digital broadcast bandwidth is utilized to send unnecessary information. This is extremely useful bandwidth that is especially useful given the high compression ratios used by today's broadcasters and is the difference between the viewer seeing the highly visible MPEG artefacts such as blocking, or not.

One large improvement to the video decoder that has been made by some manufacturers is to add a 3D comb filter. The filter utilizes the same phase relationship in the subcarrier to cancel the cross-colour as the line comb filter, but a pixel accurate frame delay ensures the pixels are exactly spatially aligned. Even on the most complex images near perfect, artefact free decoding is the result: (I say near perfect because frame combs are very sensitive to clock jitter and clock jitter as little as 1ns over the frame delay period can result in residual subcarrier. PAL also has an addition subcarrier offset which means perfect cancellation cannot occur even with a frame comb).

Figure 20 shows the artefact free image achievable with a well-designed frame comb.

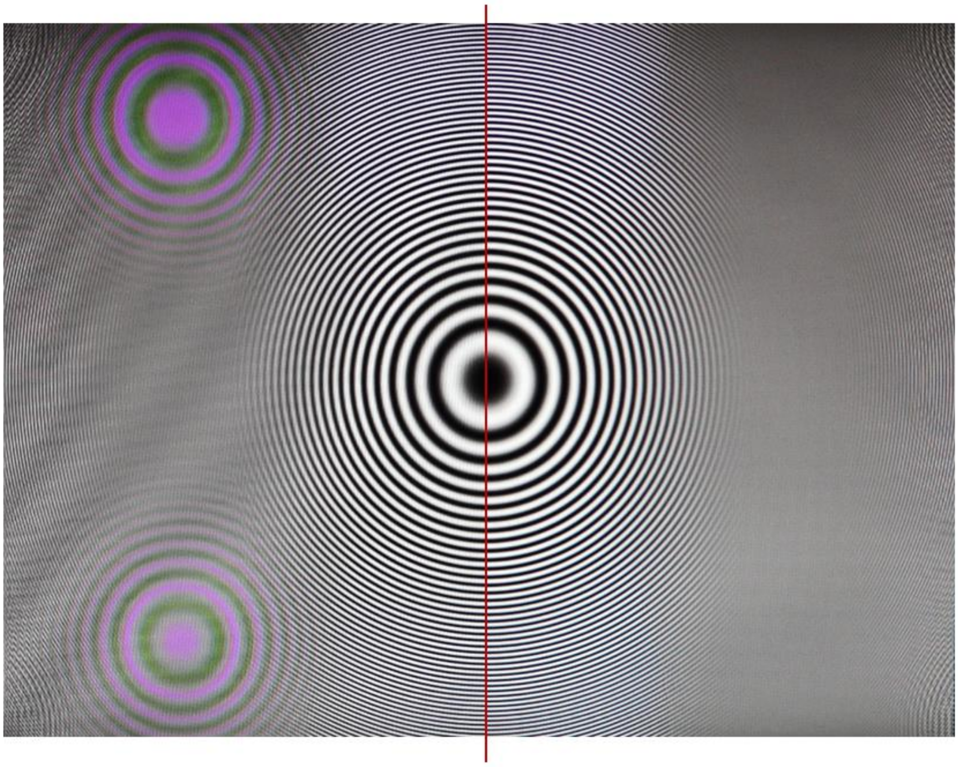

Figure 20 The left image shows a zone plate with a line comb filter. The colours in the image are cross-colour effects caused by the line comb filter not operating correctly. The right side of the image shows the frame comb filter.

The zone plate image in Figure 20 may seem rather esoteric, but you may be more familiar with the shimmering colours created by a newsreader's check shirt, something they seem to have a peculiar penchant for wearing (see Figure 21). Note that because of the fine structure of the check shirt the line comb filter produces, not only artefacts (see the woman's shirt colour) but also a softer image.

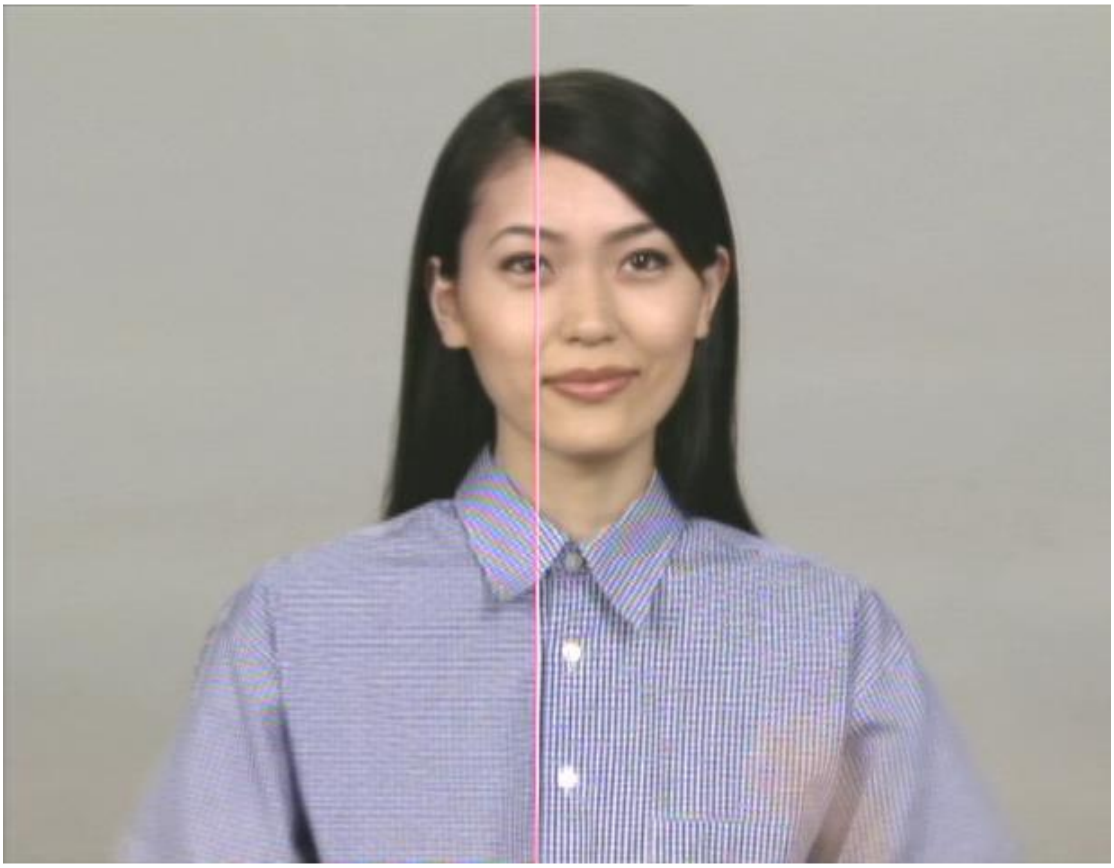

Figure 21 Line comb filter (left): frame comb filter (right).

Another example of the improvement of a frame comb filter over a line comb filter is shown in Figure 22.

Figure 22 Comb filter comparisons.

But of course, the frame comb is not a panacea. We are now looking across comb filter taps of one frame (for NTSC) or 2 frames for PAL, a delay of 80ms in the latter case. Whereas any difference spatially across the 2 or 4 lines caused the line comb filter to fail, now any difference temporally across 33ms or 80ms will cause the frame comb to fail, with similar artefacts being created. The only recourse open to most video decoders is to choose the line comb, or if that is also failing to go to the low pass filter mode, a clean but low bandwidth fall back.

For PAL in particular it can be shown that for a large amount of video material the frame comb cannot be chosen because of image motion; it becomes an expensive luxury, good only for those static demonstration zone plate images. However, we have yet one more, under-utilised comb option and that is the field comb. The field comb has an aperture of 262 lines for NTSC and 312 lines for PAL and is therefore much closer spatially than the line comb and closer temporally than the frame comb (especially for PAL).

Figure 23 shows a fast moving still image from the movie Kung Fu Panda. The image is false coloured to show the various comb modes automatically selected by the SM03. The blue colour is the low pass filter mode, and you can see that for the majority of the image, despite the motion, we are able to comb the image in one the three modes the SM03 has available (frame, field and line combs), thereby ensuring the lowest artefacts with the highest resolution. The SM03 constantly monitors each comb filters performance independently and chooses the one with the best performance on a pixel-by-pixel basis.

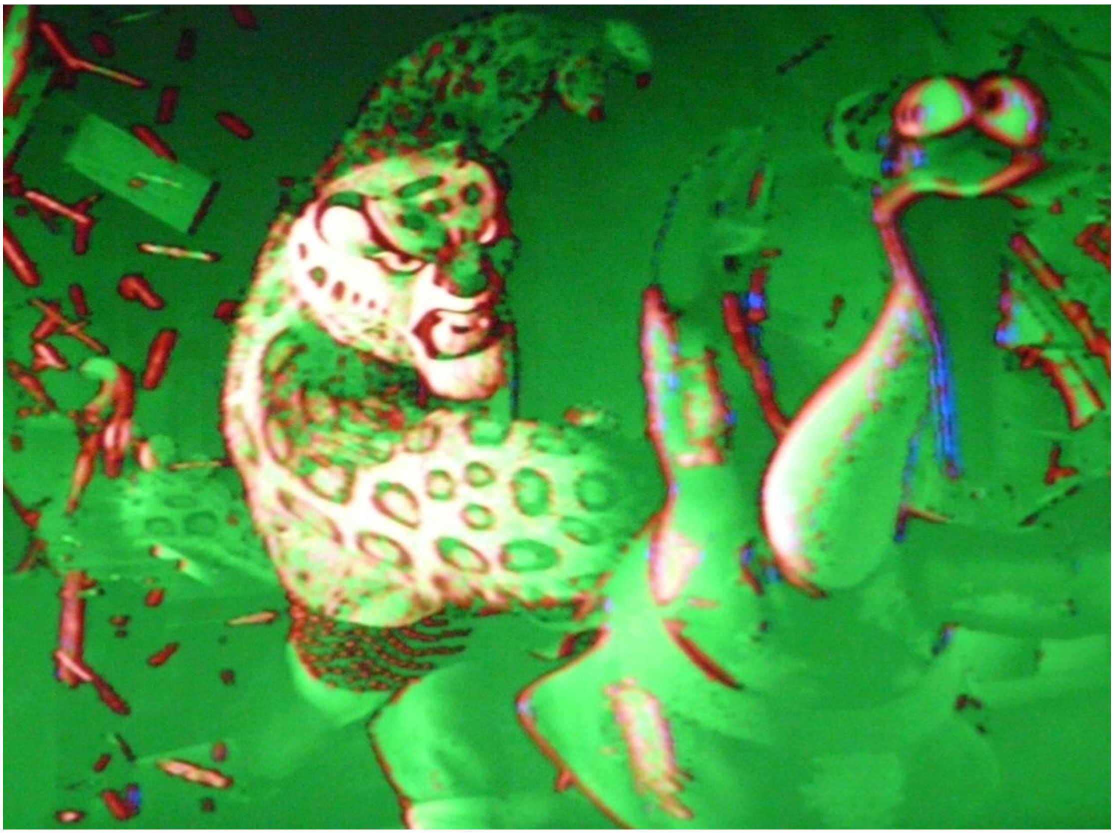

Figure 23 Comb failure detection.

6. Median Filter

The median filter is a non-linear rank order filter. It is ideal for removing impulse type noise, sometimes called salt and pepper noise. As an example, let us look at the image values in Figure 24 below. The pixel we are operating on is the highlighted value, 255. This value is an outlier, a white impulse compared with most of the pixels surrounding it which are around the 100 value. Let us sort all the nine pixels into ascending values. We now replace the central pixel with the median value of the sorted pixels (value 96).

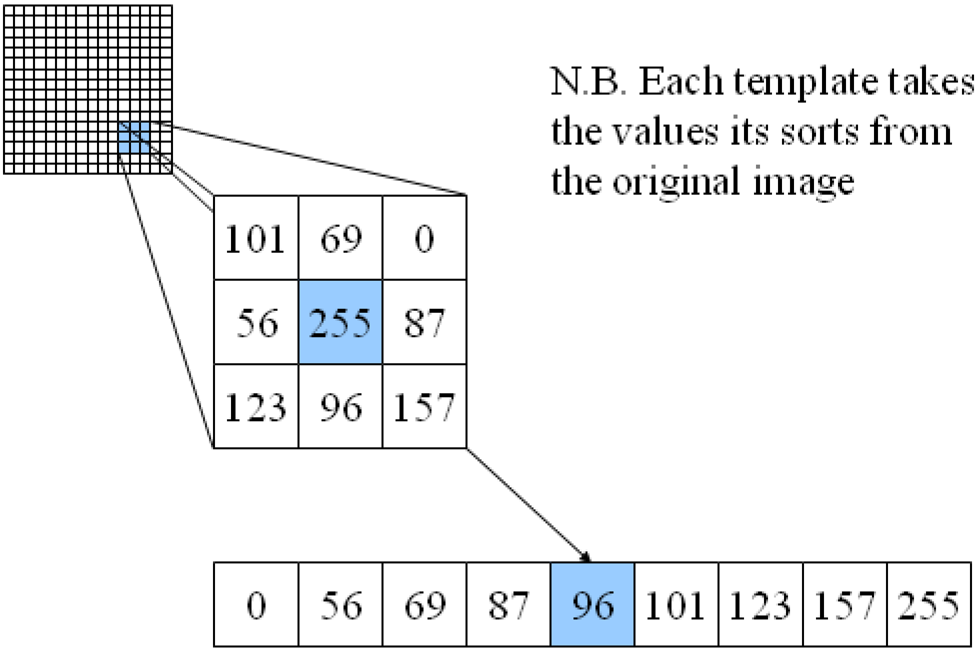

Figure 24 Principles of the median filter.

Let us look at an example of this. Figure 25 shows an image corrupted with a quite high level of impulse noise. Figure 26 shows the same image after processing through a 3x3 pixel median filter similar to the example above: most of the noise has been removed. If we use a larger kernel size of 7x7 pixels (see Figure 27) we can see almost all of the noise has been removed, but we have also lost the high frequency detail and we are left with a very soft image.

The SM03 uses an adaptive median filter to offer the best compromise between preserving detail in the image and reducing noise. Two median filters are run on the image, one a 3x3 pixel kernel, the other a 5x5 pixel kernel. Maximum, minimum and median values are analysed, together with the original pixel value to determine better if the pixel is detail or an impulse. The original pixel is then replaced with either the 3x3 or 5x5 median value or is passed unprocessed.

Figure 25 Median filter: original image.

Figure 26 Median Filter: 3x3 filter kernal size.

Figure 27 Median Filter: 7x7 kernal size.

7. Recursive Noise reduction

A simplified block diagram of the SM03 video noise reducer is shown in Figure 28.

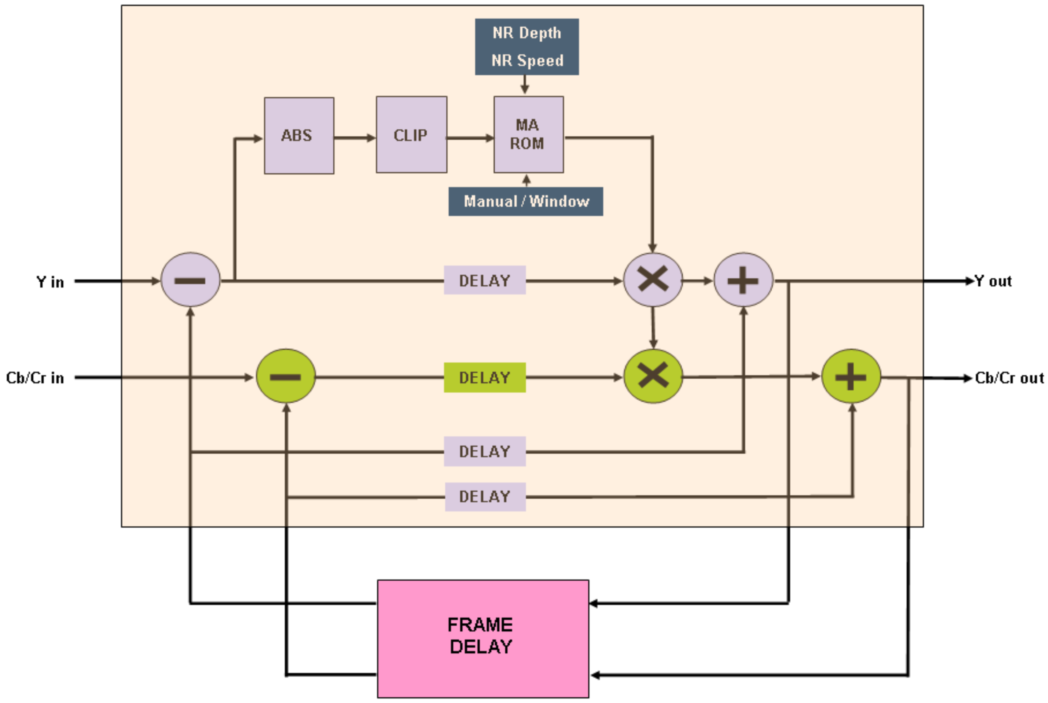

Figure 28 Video noise reducer block diagram.

This noise reducer architecture is a rearrangement of the following equation:

$Y_{out} = k*Y_{in} + (1-k)*Y_{delay}$ where:

Y_{out} is the output luma (or Cb/Cr output)
Y_{in} is the input luma (or Cb/Cr input)
Y_{delay} is the output from the frame delay
k is the feedback factor.

The k factor sets the degree of noise reduction. However temporal noise reduction such as this leaves trails on moving objects. To prevent this the frame difference from the first subtractor (Y channel only) is used to detect motion and reduce the noise reduction where motion occurs.

The absolute value of the difference is calculated and this value is then clipped, (all differences above value 127 are clipped to 127). The clipped differences value is then used to address a lookup table along with two controls, the depth and the speed. These fixed controls (via control register 1) are used to set the degree of noise reduction (NR_Ydepth[1:0] and NR_Cdepth[1:0]) and the speed that the noise reducer responds to motion (NR_speed[2:0] - the level of the difference value that starts a reduction in the noise reduction. Two lookup tables are used, one for the Y value and one for the Cb/Cr values because the chroma trails are less visible to the eye so a higher degree of noise reduction may be applied to them.
The LUT adaptation values are shown graphically in Figures 29 and 30. The degree of noise reduction is shown on the vertical axis (value 1 is no noise reduction) and the horizontal axis if the value of the

luma difference. So, for example, with no motion (difference value = 0) the k value is set to 0.3, 0.5 or 0.7 depending on the depth control register setting. As the difference value increases then. Depending on the NR_speed setting (either value 24, 32, 40, 48, 56, 60, 72 or 80) the k value is then adjusted according to the curves shown in the diagram. An NR_speed setting of '111' (80) is the slowest to adapt to motion and the value '000' (24) is the fastest to adapt to motion.

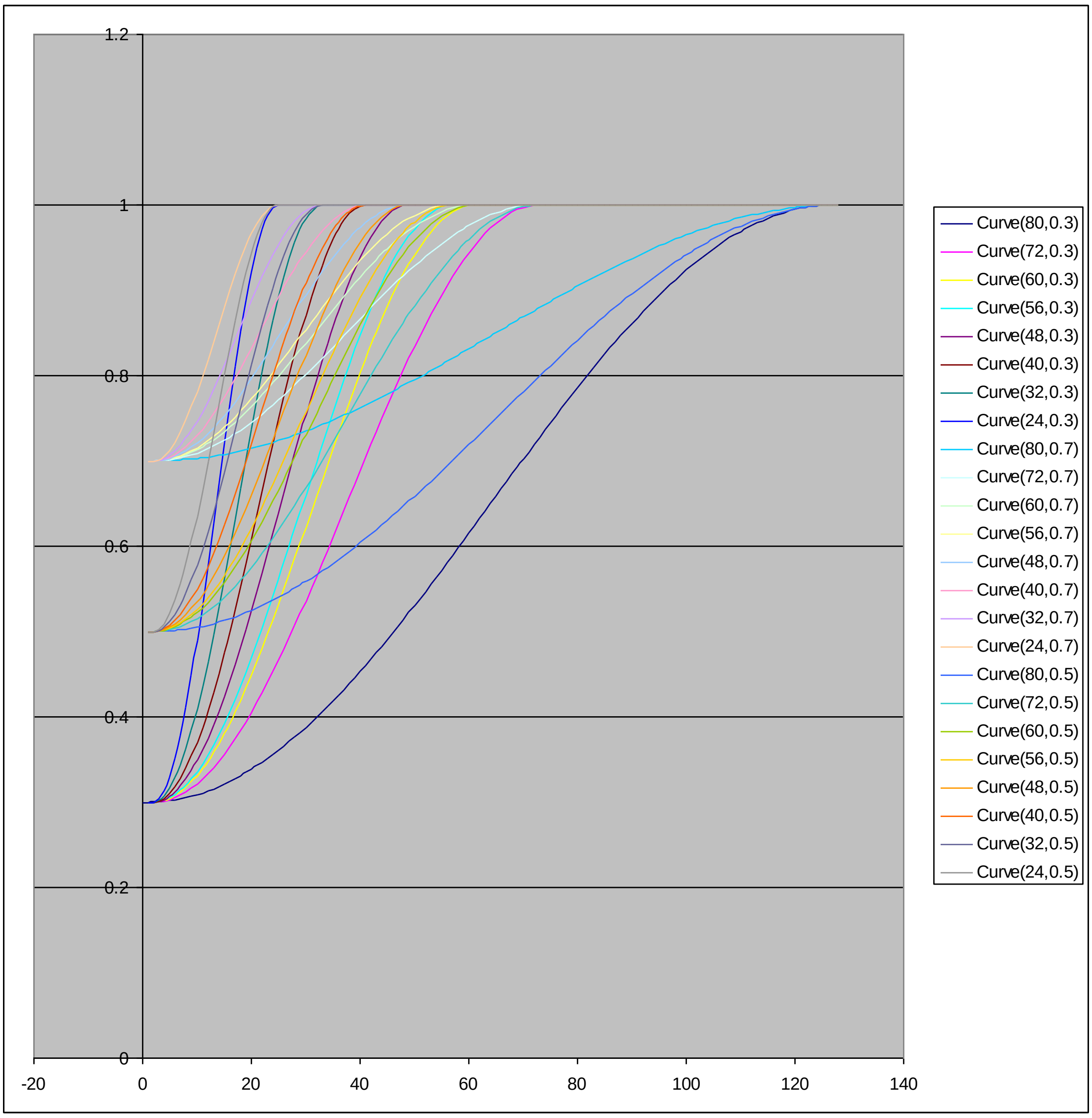

Figure 29 Y (Luma) channel noise reduction adaptation tables

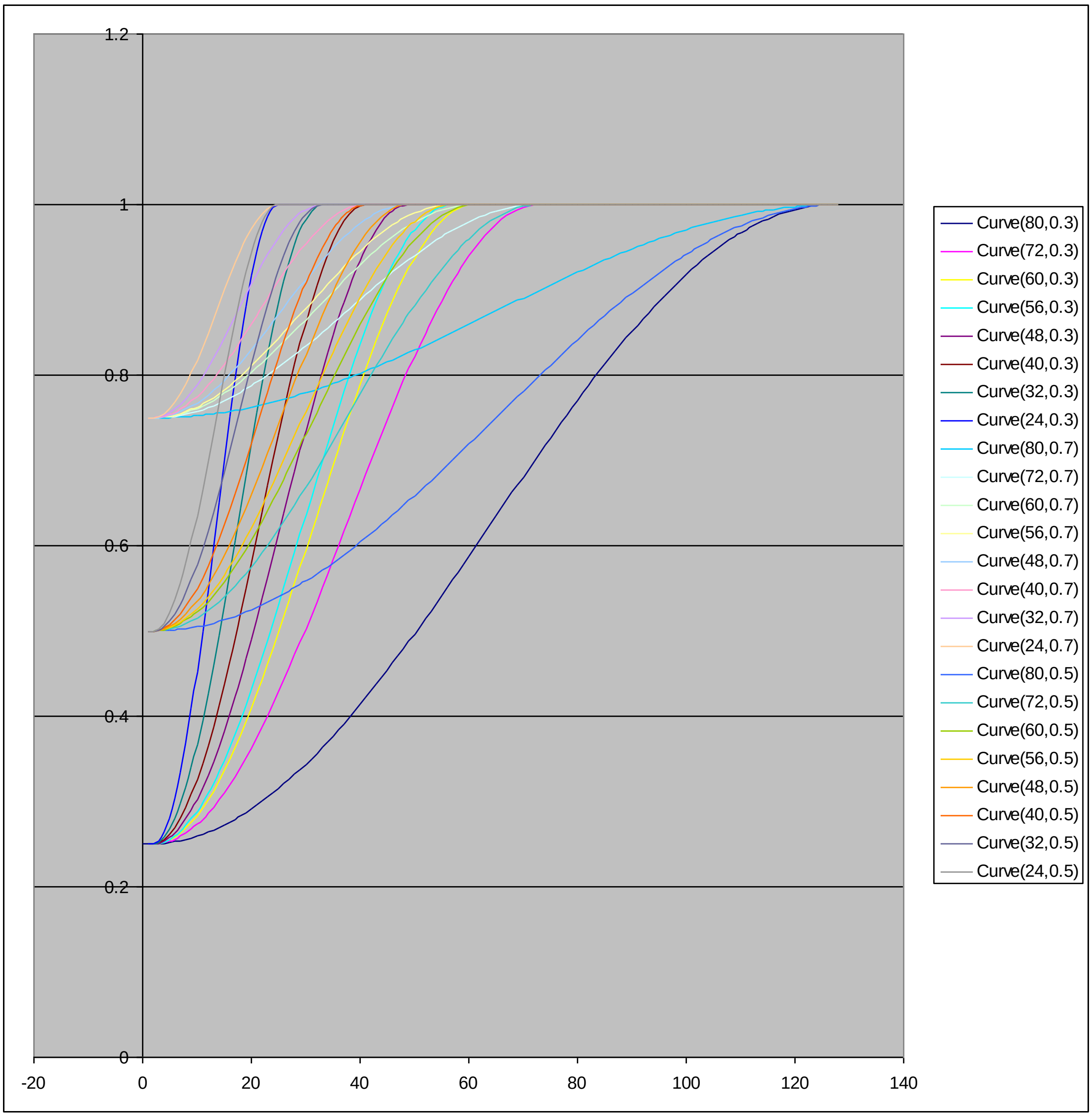

Figure 30 C (Chroma) noise reduction adaptation values.

The expected degree of noise reduction (Gaussian noise) for static objects is 4.8dB (k=0.5), 8.5dB (k-0.25) and 11.8dB (k=0.125).

For conditions where the noise is very high and the motion adaptation is not required a manual k factor may be chosen (see Figure 31, a screen capture of an image-intensified – night vision - camera).

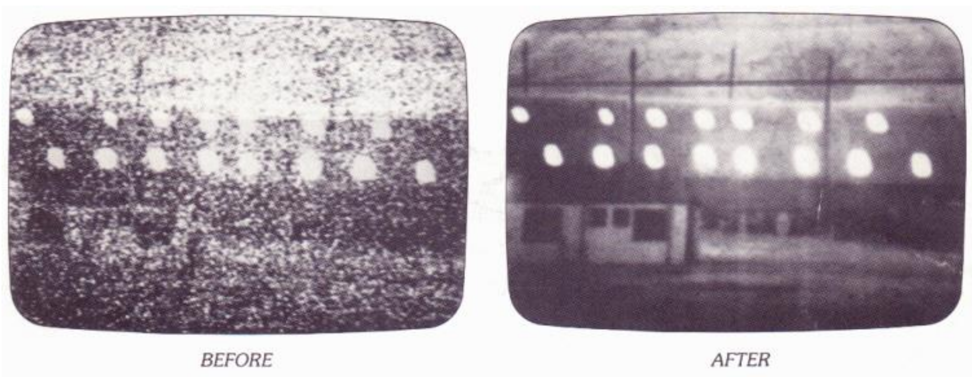

Figure 31 SM03 noise reduction - image intensified camera.

8. Histogram Equalisation

A histogram of an image is a count of how many pixels of each grey level value are present and shows the intensity profile of the image.

Histogram equalization is a method of equalizing that histogram so that intensity is distributed evenly. Figure 32 shows an original image of a girl. If we study the histogram of that image, we can see there are no pixels below about relative value 0.25. Histogram equalization stretches out the histogram so that the image occupies the full range of intensities.

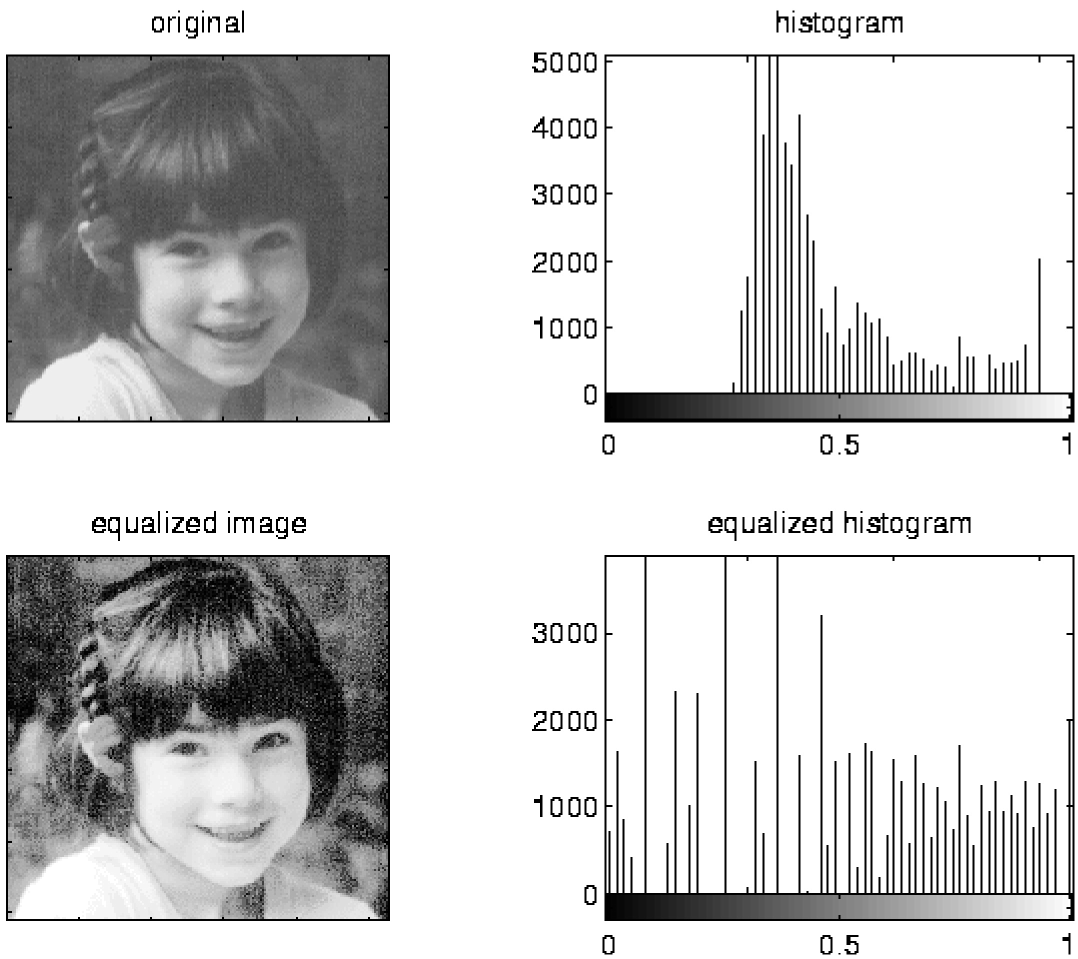

Figure 32 Histogram equalisation.

A simplified block diagram of the histogram equalization (contrast enhancement) module is shown in Figure 33.

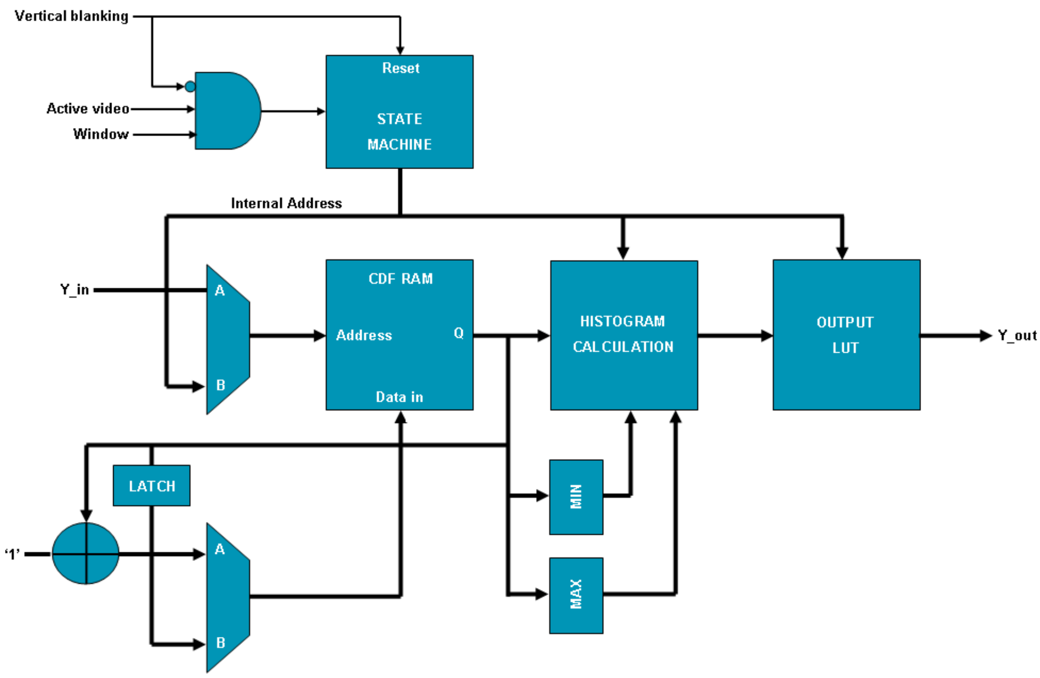

Figure 33 Histogram Equalisation block diagram.

First the histogram is calculated during the active picture area. Then the cumulative distribution function - the accumulated histogram values - is calculated during the blanking interval following that active field. Pixel values that are not present in the image do not contribute to the CDF

To calculate the histogram equalization corrected value (*HE*) from that histogram for pixel value (*p*) we use the following equation:

$$HE(p) = \frac{\mathrm{CDF}(p) - \mathrm{CDF(min)}}{\text{Total number of active pixels} - \mathrm{CDF(min)}} \times (Pixel\ range)$$

A look-up table is used to map the old pixels to the new pixel values.

Figure 34 shows an image of a tunnel where the dark walls are rendered invisible (left side image) by the bright exit to the tunnel. The right side of the image shows the wall details after histogram equalization.

Figure 34 Histogram equalized image.

9. Specification

Power:	+5VDC ± 5% @ ~650mA.
Dimensions:	160mm x 78mm x 27mm.
CVBS/YC input:	NTSC-M / PAL / SECAM / NTSC-443 / PAL-60. 75Ω input impedance.
Luma bandwidth:	5.5MHz ± 0.2dB.
Chroma bandwidth:	1.3MHz - 3dB.
Differential gain/phase:	<1%, <1°.
K-factor:	<1%.
Luma/chroma delay:	< ±10ns.
Signal to noise ratio:	< -55dB unified weighting (Y channel, noise reduction off).
Audio input:	316mV pk-pk (0dB gain setting) into 47k. 24-bit sampling at 48kHz.
Output:	SDI format (SMPTE-259M).
Latency:	40-80ms.
Operating temperature:	0 – 40 degC.

Appendix A: AC-DC adaptor

The specification for the supplied AC-DC adaptor (CUI SMI36-12-V-P6) is shown in Figures 35-39.

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date 06/23/2022
page 1 of 5

SERIES: SMI36 | **DESCRIPTION:** AC-DC POWER SUPPLY

FEATURES
- up to 36 W continuous power
- DoE Level VI, CoC Tier 2 efficiency
- no load power consumption < 0.075 W
- universal input voltage range
- interchangeable Ac blades for global use
- over voltage, over current, and short circuit protections
- UL/cUL, RCM, CCC, and PSE safety approvals
- certified to 60950-1 and 62368-1 standards

MODEL	input voltage	input frequency	output voltage	output current	output power	ripple and noise[1]	efficiency level[2]		no load power consumption
	range (Vac)	range (Hz)	nom (Vdc)	max (A)	max (W)	max (mVp-p)	average[3] (%)	10% (%)	typ (W)
SMI36-5	90 ~ 264	47 ~ 63	5	5.0	25	80	85.2	79.8	0.06
SMI36-9	90 ~ 264	47 ~ 63	9	3.34	30	90	88.2	81.4	0.07
SMI36-12	90 ~ 264	47 ~ 63	12	3.0	36	120	88.7	85.3	0.05
SMI36-15	90 ~ 264	47 ~ 63	15	2.4	36	150	89.1	84.3	0.06
SMI36-24	90 ~ 264	47 ~ 63	24	1.5	36	240	89.4	84.3	0.07
SMI36-48	90 ~ 264	47 ~ 63	48	0.75	36	480	91.2	89.1	0.07

Notes:
1. At full load, nominal input, 20 MHz bandwidth oscilloscope, each output terminated with 0.1 µF multilayer and 47 µF low ESR electrolytic capacitors.
2. CoC Tier 2 compliant
3. Average efficiency is measured at 25%, 50%, 75%, and 100% load.

PART NUMBER KEY

SMI36 - XX - X - XXX - CXX

Base Number

Output Voltage

Blades:
V = North America, Europe, United Kingdom, Australia, and China blade included
N = North America blade included
E = Europe blade included
B = United Kingdom blade included
A = Australia blade included
C = China blade included
K = No blades included

DC Plug Type:
XXX = See output plug options on page 4 for more details

Reserved for Custom Configurations

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Figure 35 Power supply specification – Page 1.

INPUT

parameter	conditions/description	min	typ	max	units
voltage		90		264	Vac
frequency		47		63	Hz
current				1	A
inrush current	at 230 Vac, full load, 25°C, cold start			70	A
leakage current				0.25	mA
no load power consumption	at 115/230 Vac			0.075	W

OUTPUT

parameter	conditions/description	min	typ	max	units
regulation			±5		%
hold-up time	at full load	10			ms

PROTECTIONS

parameter	conditions/description	min	typ	max	units
over voltage protection	output shut down			180	%
over current protection	output shut down, auto recovery			170	%
short circuit protection	output shut down, auto recovery				

SAFETY & COMPLIANCE

parameter	conditions/description	min	typ	max	units
isolation voltage	input to output at 10 mA for 1 minute		3,000		Vac
isolation resistance	input to output at 500 Vdc	10			MΩ
safety approvals	UL/cUL (60950-1, 62368-1), RCM, CCC, PSE, UKCA				
EMI/EMC	FCC Part 15B Class B, CE				
MTBF	as per Telcordia SR-332, 25°C	300,000			hours
RoHS	yes				

ENVIRONMENTAL

parameter	conditions/description	min	typ	max	units
operating temperature		0		40	°C
storage temperature		-20		80	°C
operating humidity	non-condensing	20		80	%
storage humidity	non-condensing	10		90	%

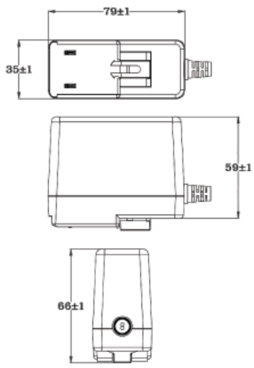
Figure 36 Power supply specification – Page 2.

MECHANICAL

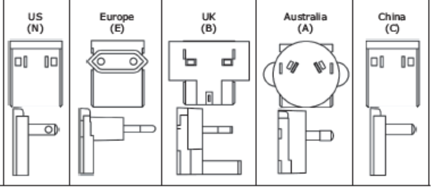
parameter	conditions/description	min	typ	max	units
dimensions	79 x 35 x 66				mm
inlet plug	interchangeable blades (North America, Europe, UK, Australia, China)				
ac blade clip type	pinch clip				
weight	without blades		160		g

MECHANICAL DRAWING

units: mm
tolerance: ±1.0 mm



INTERCHANGEABLE BLADES					
BLADE DESIGNATOR	N	E	B	A	C
REGION	North America	Europe	UK	Australia	China
BLADE ACCESSORY	SMI-US-2	SMI-EU-2	SMI-UK-2	SMI-AU-2	SMI-CN-2
BLADE					



DC CORD

units: mm

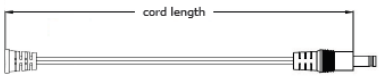


Table 1

MODEL NO.	CABLE	CORD LENGTH
SMI36-5	UL2468, 16 AWG	1,000 mm ±30
SMI36-9	UL2468, 18 AWG	1,500 mm ±30
SMI36-12	UL2468, 16 AWG	1,500 mm ±30
SMI36-15	UL2468, 18 AWG	1,500 mm ±30
SMI36-24	UL2468, 20 AWG	1,500 mm ±30
SMI36-48	UL2468, 22 AWG	1,500 mm ±30

Figure 37 Power supply specification – Page 3.

CUI Inc | SERIES: SMI36 | DESCRIPTION: AC-DC POWER SUPPLY   date 06/23/2022 | page 4 of 5

DC PLUG TYPE PART NUMBER KEY

X X X

Plug Polarity:
P = Center Positive
N = Center Negative

Plug Code:
X = Choose a code from the options below

Plug Angle:
"blank" = Straight
R = Right Angle

Plug Polarity		Code		Dimensions (mm)			Plug Angle	
Center Pos.	Center Neg.	Option	Type	A	B	C	Straight	Right
•	•	5	Standard	5.5	2.1	9.5	•	•
•	•	6	Standard	5.5	2.5	9.5	•	•
•	•	7	Standard	3.5	1.35	9.5	•	•
•	•	8	Standard	3.8	1.35	9.5	•	•
•	•	9	Standard	3.8	1.05	9.5	•	•
•	•	10	Locking[2]	5.5	2.1	9.5	•	N/A
•	•	11	Locking[2]	5.5	2.5	9.5	•	N/A
•	•	12	EIAJ-1	2.35	0.7	9.5	•	•
•	•	13	EIAJ-2	4.0	1.7	9.5	•	•
•	•	14	EIAJ-3	4.75	1.7	9.5	•	•
N/A	N/A	ST	Stripped & Tinned				N/A	N/A

Note: 1. Contact CUI for additional plug options
2. Maximum insertion depth is 10mm

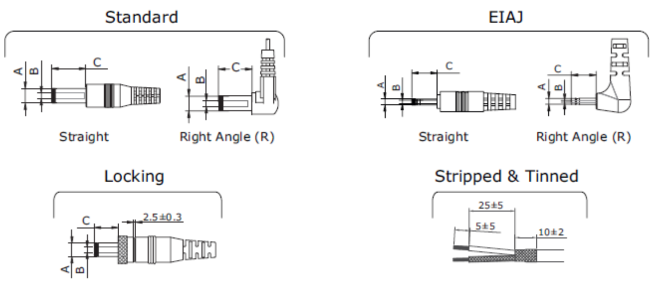


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Figure 38 Power supply specification – Page 4.

REVISION HISTORY

rev.	description	date
1.0	initial release	08/07/2015
1.01	updated datasheet	11/04/2015
1.02	housing width changed to 35.3 mm	01/27/2016
1.03	changed wire gauge on 12 Vdc models, updated datasheet	09/15/2016
1.04	added 62368-1 standard	08/31/2018
1.05	cable drawing update	12/05/2019
1.06	company logo updated	09/30/2020
1.07	model table updated	11/27/2020
1.08	UKCA added to specification	08/11/2021
1.09	plug polarity symbols updated	09/16/2021
1.10	case dimensions updated	03/23/2022
1.11	dc plugs updated	04/29/2022
1.12	ac blade clip type added	06/23/2022

The revision history provided is for informational purposes only and is believed to be accurate.

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Figure 39 Power supply specification – Page 5.