AURORA
DESIGN

Standards Converter with RF Modulator

# Model's SCRF

User and Technical Manual

Introduction

This manual covers the operation and technical aspects of the Single-Standard Converter with RF Modulator. The Converter is designed to accept an NTSC or PAL/SECAM video signal and convert to one of several different output standards depending on the model. The converted video is sent to the built-in RF Modulator, along with the audio, and to a composite video output connector.

Features

- Compact, low power, surface mount design
- Front panel tri-color Status LED
- Flexible built-in RF Modulator:
  - Up to 30 selectable carrier frequencies
  - Programmable between 30-880MHz (actual channels vary by model)
  - Supports positive/negative video and AM/FM audio modulation schemes
- Converter bypass mode for use as stand alone RF Modulator
- Up to 16 user selectable options control
- Extremely stable output: +/- 3% levels, +/- 50ppm timing
- Output clock line locked to input clock for perfect conversions
- 10 bit video D/A for greater than 54dB dynamic range
- 4Mb FLASH Image Memory for storing a custom image
- 100K gate equivalent FieldProgrammableGateArray (250K on SCRF405A-NTSC)
- EEPROM memory for FPGA firmware, field upgradeable
- Extremely accurate algorithms used for conversions:
  - Three line interpolation on all standards
  - All internal calculations done to a minimum 12 bit precision
- Unique partial-field memory for stable output syncs
- Externally adjustable RF channel and audio modulation depth control
- Automatic Sleep Mode for low power standby operation
- Versatile I/O:
  - Composite Video Input (NTSC/PAL, 1Vpp, 75 ohm)
  - Composite Video Output (various standards depending on model, 1Vpp, 75 ohm)
  - Stereo Audio Inputs (-10dBV nominal, 0.2Vpp-5Vpp, 20k ohm)
  - RF Output (76dBµV, 75 ohm, approx. 6mV)
  - DC power (7-14Vdc, 250ma)

Front Panel
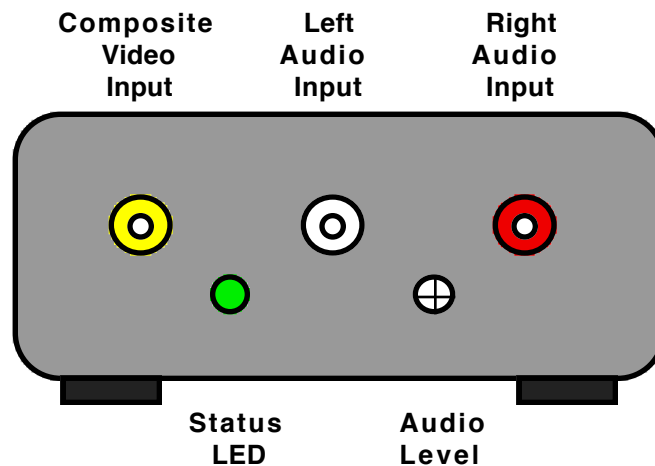
Composite Video Input:

   The Composite video input signal required depends on the operating mode and model of the converter. If the converter is enabled (not bypassed), then a video source conforming to the NTSC or PAL/SECAM video standards must be supplied to the Composite (RCA or BNC) input connector. An NTSC source must be used with 30 fps models and a PAL/SECAM source must be used with 25fps models. The converter will use this video signal to convert to the model's output standard. For example, the SCRF405A converter with convert a PAL/SECAM source to 405/25i video. Connecting a video signal not conforming to the NTSC or PAL video standards will result in erratic operation in this mode.
   If the converter is set to bypassed, then the video signal on this connector is sent to the modulator with no signal processing, other than an audio trap filter. Any video signal can be supplied in this mode, although it is the users responsibility to verify this video signal to obtain the desired result from the modulator.

Audio Inputs:

   Two RCA connectors are provided for audio input. The two connectors are summed internally into a mono signal that is fed to the RF modulator. If only a mono source is available, it can be connected to either of the audio input connectors, or both through a "Y" cable if higher input gain is required. The inputs can accept a wide range of audio input levels, but are designed to work optimally with standard, consumer level -10dBV audio signals. Due to the variance of audio output levels from many devices an audio input gain control is provided which allows the user to set the modulation depth of the audio RF carrier to suite the source level. Please refer to *Specifications* sections found later in this manual.

Status LED:

The tri-color status LED conveys the current operating state of the converter.

Solid Red: No video input signal detected. Default image will be output.

Solid Green: Converter locked to video input. Normal operation.

Flashing: Options setting mode.

Pulsating Red: Converter in low power Sleep mode.

Fast Flashing: Converter storing default image to internal FLASH
Green:

Audio Level:

The Audio Level control is used to set the modulation depth of the audio RF carrier. This control is required to handle the variations in the audio output levels from different devices. This control should be set to the maximum possible without causing distortion of the audio in the RF signal. The potentiometer is adjusted by inserting a small flat blade or phillips screw driver into the hole, and turning it until it engages the rotor of the potentiometer. Maximum drive is obtained by turning the potentiometer clockwise.

Rear Panel
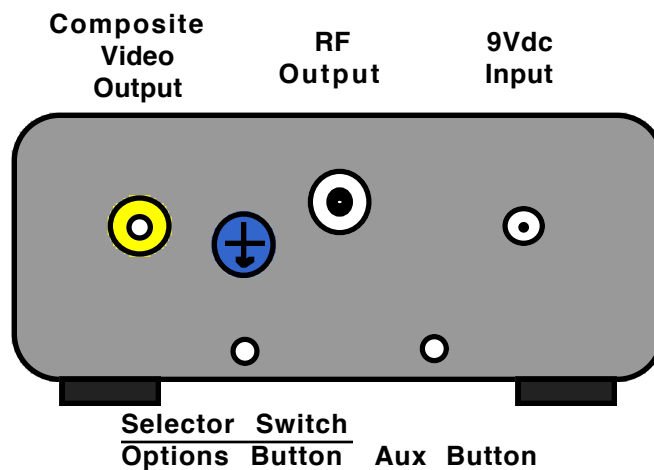
Composite Video Output:

This RCA or BNC connector provides the video output from the converter. This output should terminate into a 75 ohm load. This output is only valid when the converter is not set to bypass mode. If the converter is set to bypass mode, no signal will be present at this output. For complete information about the characteristics of this output, please refer to the *Specifications* section found later in this manual.

Selector Switch:

The dual purpose Selector Switch used to select the output frequency, or channel of the RF output in normal operation and to select the user option during options programing.

During normal operation, the Selector Switch selects the channel of the RF output. The specific frequency or channel for each position is unique to the model of converter, and can be found on the bottom label of the converter, and in the *Supported RF Systems* section found later in this manual. When the switch is set to '0', the RF modulator is disabled and put into a low power state. In this mode, the unit will still output a converted video signal on the composite output connector. This control is adjusted by inserting a small flat blade or phillips screw driver into the hole, and engaging the slots in the switch.

If the Option Button is pressed (see below), the current RF channel is frozen, and the Selector Switch is used to select the desired user programable option.

Options Button:

This pushbutton is used to enter the Options Setting Mode and to change the state of the User Options. The button can be depressed by inserting a paper clip, or other small tool into the hole in the back of the unit. When the Option Button is depressed for 1 second, the unit enters the Option Setting Mode and freezes the currently selected RF channel. By using the Selector Switch, you can choose the desired option position. The front panel Status LED will blink green if the option is enabled, red if the option is disabled, and yellow if the option is not supported. When the desired User Option is chosen using the Selector Switch, the Option Button is pressed momentarily to toggle the option between enabled and disabled. Each option can be programmed in this manner. When finished, the Option Button is once again depressed for 1 second to exit the Option Setting Mode. Also if no changes of the Selector Switch or Option Button are detected for 1 minute, the unit will automatically exit the Options Setting Mode and return to normal operation.

When the unit returns the normal operation, the Selector Switch may need to be returned to the desired RF Channel.

RF Output:

This F connector provides the RF output from the modulator. This output should terminate into a 75 ohm load. It should only be used to connect directly to the antenna terminals of a television set, and never be used for broadcast purposes. For complete information about the characteristics of this output, please refer to the *Specifications* section found later in this manual.

Auxiliary Button:

The Auxiliary Button is used to store a default image into the internal FLASH memory. On the SCRF525M-SC, it is additionally used to control the color phasing of the output, rotating by one field each time the button is pushed momentarily.

To store a default image, the converter must be in it's normal operating mode, with a valid video input connected, and a Solid green Status LED. If a valid video input is not connected, the button will have no effect. With a stable, stationary video input applied, the Auxiliary Button may be pressed and held for 4 seconds by inserting a paper clip, or other small tool into the hole in the back of the unit. The Status LED will begin to flash green quickly, indicating storing of the image FLASH is taking place. This process can take up to 15 seconds, and the video signal must not be disturbed during this process. Once the image is stored, the Status LED will return to solid green.

Once an image is stored, whenever there is no video input connected to the unit, the default image stored in the FLASH will be outputted.

Caution! Because of the nature of the partial-field memory contained in this unit, the default image is stored in bands of several lines at a time. If the connected video is not stationary during the storing process, the resulting image will be distorted. The best way to provide a stationary image for storing is to use the output from a computer video card, or a DVD/PVR player in pause. A typical VCR without a TBC in pause is not suitable for this use.

Power:

The converter requires a power source of between 7.0 and 14 volts DC at 250 mA. A 9 volt DC power supply is recommended to reduce power consumption. Voltages over 16 volts will damage the unit. The unit has a reverse polarity diode in series with the input, so it will not be damaged by reversal of polarity. The unit uses a standard 2.1mm X 5.5mm, center positive, coaxial power connector as found on most consumer electronic equipment.

User Options

As previously outlined, using a small tool such as a paper clip, carefully press the Options Button for 1 second. This will place the unit into the Options Setting Mode. Next choose the desired option using the Selector Switch. The front panel Status LED will blink green if the option is enabled, red if it is disabled, and yellow if not supported. To change the state of the option, momentarily depress the Options Button to toggle between enabled and disabled. When all desired options are set, again depress the Option Button for 1 second to exit the Options Setting Mode. Also the unit will automatically return to normal operation if the Selector Switch and Option Button are not changed for 1 minute.

Note: Be sure to return the Selector Switch to the desired RF Channel setting after changing the User Options.

Position 0 - Converter Enable: (All models)

This option is used to enable/bypass the internal Standards Converter, and use the unit as a stand alone RF Modulator. When Enabled the converter and modulator operate normally. When Disabled the converter is bypassed, and the video signal on the composite input connector is sent directly to the modulator.

Position 1 - Sleep: (All models)

This option is used to disable the automatic Sleep Mode. When Enabled the Sleep Mode will operate normally as discussed in the next section. When Disabled the unit will not go to sleep. This can be useful when using the unit as a test pattern generator and no video input signal is connected.

Position 2 - Audio Tone: (All models)

This switch is used to disable the Audio Tone in the default mode. When this switch is OFF the Audio Tone will output when no valid video source is connected to the converter. When this switch is ON, the Audio Tone will be disabled. This can be useful if other audio is connected to the converter and the Audio Tone is not desired.

Position 3 - RGB/RBG Select: (Model SCRF525M-SC Only)

This option is used to select the color sequence of the output. When Disabled, the color fields in the output will be in a Red-Green-Blue sequence. When Enabled, the color fields in the output will be in a Red-Blue-Green sequence. This option should be set to match the order of the filters in the color wheel.

Position 3 - Equalization Pulses: (SCRF405, SCRF343 only)

This option is used to control the equalization pulses in the vertical (frame) sync for the 405/25i and 343/30i models. This option is nit supported on all other models.

When these formats were first created, they did not include equalization pulses in the vertical (frame) sync. Because of this, poor interlacing of the image can result due to difficulty of the vertical (frame) oscillator in the television properly locking to the signal. Equalization pulses are added before and after the serration (broad) pulses to improve the vertical (frame) oscillator's ability to lock to the sync signal. All modern analog video formats utilize equalization pulses in the sync.

When this option is Enabled, equalization pulses will be added to the listed formats for better synchronization. While this does create a better interlaced image, it is not historically accurate, and does not represent the formats as they would have originally appeared.

When this option is Disabled the equalization pulses will not be added, resulting in the formats as they would have been. This may result in a poorly interlaced image on the television, exactly as it would have been when originally broadcast. This mode can be used to better convey what these formats would have looked like originally.

Position 4 - Color Select: (SCRF525M-SC & SCRF405A-NTSC)

This option is used to select the output mode of the converter between color and monochrome. When Enabled, the converter will output a color signal. When Disabled, the converter will output a monochrome signal.

Position 5 - Chroma Gain: (Model SCRF525M-SC Only)

This option is used to control the Chroma Gain of the converter. When Disabled, the gain is set to standard CCIR levels resulting in the output matching the input's chroma levels. When Enabled, the gain is increased by +33% resulting in the output levels being higher than the input levels. For instance, in this position, standard SMPTE 75% color bars will appear as fully saturated 100% color bars on the output.

Position 5 - Cross Color Filter: (Model SCRF405A-NTSC Only)

This option is used to control the Cross Color Filter. When Disabled, the luminance channel is not modified. When Enabled, a -12dB filter at the chroma subcarrier frequency is added. This filter may help reduce dot crawl effects in the composite output. The filter characteristics match those of the original BBC specification.

Operating Modes

Normal Full Operating Mode:

When valid video is present and an RF Channel is selected, the Status LED will show a Solid Green light, and the unit will output converted video on the composite output connector and on the RF connector. This is the most common operating mode.

Converter Only Mode:

This mode is similar to the Normal Full Operating Mode except the RF Channel Selector Switch is set to 0 disabling the RF modulator. In this mode the converted video output will only be present on the composite video output connector. This mode is useful when connecting to a video monitor that has a composite video input.

RF Modulator Only Mode (Converter Bypass):

In this mode the standards converter is bypassed and placed into a low power mode. The video on the composite input connector is only processed by an audio trap filter before being sent to the modulator along with the audio that is present on the audio input connectors. This mode is useful when only an RF Modulator is required as with the use of custom or nonstandard video signals, or for experimentation. Since the video is sent unprocessed to the modulator, it is the responsibility of the user to verify the suitability of this signal. Also the Sleep and Audio Tone features are not available when operating in this mode, and will be disabled regardless of the settings in the Option Switch.

Default Mode:

When the unit is in the Normal or Converter Only modes, and no valid video is connected to the composite input, the unit will output the image stored in the image FLASH on it's outputs and an audio tone will be injected into the audio path (if enabled). This can be used to verify operation of the unit, or aid in setup of the television. The unit is shipped with an appropriate test pattern stored in the image FLASH, but this can be over written at any time as previously explained.

Options Setting Mode:

When the unit is in the Options Setting Mode, various options can be set by the

user to control the behavior of the unit. These settings will be saved to an internal FLASH memory and are retained even if power is lost.

Sleep Mode:

Since no power switch is supplied on this unit, an automatic Sleep Mode will be entered whenever the video input is not present for more than 1 hour. This feature is available when operating in the Normal or Converter Only modes. It is not available in the RF Modulator Only mode. With this feature, the RF Modulator is shut down, along with the standards converter, image FLASH, and the video output. Only the video decoder is left active to signal when a valid video input is again supplied to the unit to wake it up. This Mode can be disabled using one of the internal option switches, This is useful when the unit is used as a test pattern generator and no video input is connected.

Typical Connections

In normal usage, the desired RF Channel is chosen on the RF Channel Select switch as previously described. The power adapter is connected to the converter and to the AC power source. A valid NTSC or PAL/SECAM video source should then be connected to the video input. The video source can be anything from a VCR to a DVD to an off-air broadcast. For the best quality, a DVD or PVR is recommended. The video output can then be connected to the input of a video monitor, or the RF output can be connected to the antenna terminals of a television. A balance transformer may be needed to convert the 75 ohm output of the unit to the appropriate signal type for the television.

Caution! The RF output from the internal modulator uses a double side band modulation technique, and is not suitable for broadcast without filtering. Also, due to the method of frequency division provided in the RF modulator IC's, their outputs are rich in harmonics. It is intended to only be connected directly to a television's antenna input. At no time should the RF output from this unit be connected to an antenna for the purpose of broadcasting the signal. While no damage will result to the unit, it is against the law in most countries to use a modulator in such a manor.

The audio from the source device (VCR, DVD, etc.) should be routed to the converters audio inputs. Two inputs are provided with low cross talk so a stereo audio signal can be fed to the unit. The two channels are combined into a mono signal. If only a mono audio source is available, it can be fed to either input. For additional audio gain, a "Y" cable can be used with a mono source to feed both inputs.

The use of high quality video cables is recommended for best results. Cables conforming to 75 ohm impedance should be used on the video inputs and outputs. Cables of lesser quality can be used for the audio channels.

There should now be a solid green status light on the front panel indicating a locked video signal as described previously, and a stable image on the television.

To help aid in setup, when no video input is presented to the converter, it will output a default image. This can be useful in making final adjustments to the television.

The audio level control can be adjusted to set the audio RF modulation depth for the connected source. This control should be set to the maximum setting without causing distortion of the audio. If the audio is distorted, this control should be lowered slightly. If the audio is low in volume or noisy, this control should be raised. It can be adjusted my inserting a small flat blade screw driver in the hole in the front panel. A clockwise turn will increase the level, while the opposite will decrease the level.

An additional benefit of the converter can be found in it's video processing path. Since most early television sets did not have Vertical Blanking Interval Suppression, or Chroma Traps, retrace lines and moire patterns can be visible when using modern video signals. The converter will suppress the VBI signals eliminating retrace lines, and contains a 4 line adaptive comb filter to remove the chroma signal.

Theory of Operation

In order to convert between different video standards of the same frame rate, only spatial correction is required. Spatial correction involves changing the resolution, size and aspect ratio of the incoming video to the output video format. This can be easily achieved through standard digital methods utilizing scalers and FIR filters. This will be discussed in detail.

It was decided that no off the shelf components existed that would provide the desired functionality, so a FieldProgrammableGateArray, or FPGA, was chosen to provide all the digital functionality. By adding input/output circuitry, memory, and ancillary circuitry to the FPGA, the entire system could be realized. The basic building blocks to the design are; FPGA, video decoder (ADC), video DAC, RF modulators, image FLASH memory, audio amplifier, and multiple power supplies. A brief description of each part follows:

FPGA: Xilinx XC3S100E-4VQ100 (XC3S250E-4VQ100)
                                100K gate equivalent (250K gate equivalent)
                                72Kb Block RAM (216K Block RAM)
                                1.2V Core / 2.5V Aux / 3.3V I/O
                                (number is parenthesis are for SCRF405A-NTSC only)

Video Decoder: TI TVP5150A
                                9bit ADC's, 2X Over-Sampled
                                Line Locked Clock
                                4 Line Adaptive Comb Filter
                                Multiplexed 8bit YCrCb output bus

Video DAC: Proprietary Design
                  10bit effective DAC
                  35 MSPS maximum conversion rate
                  56 dB SNR

RF Modulators: Freescale MC44BS373CA
                  (One for video and FM audio, one for AM audio)
                  30-880MHz Frequency Range
                  Automatic Black Level Clamping
                  76dBµV Output Level

Image Memory: Atmel AT49BV040B-VI
                  512K X 8 FLASH ROM

Topology

A block diagram of the circuitry is shown below:
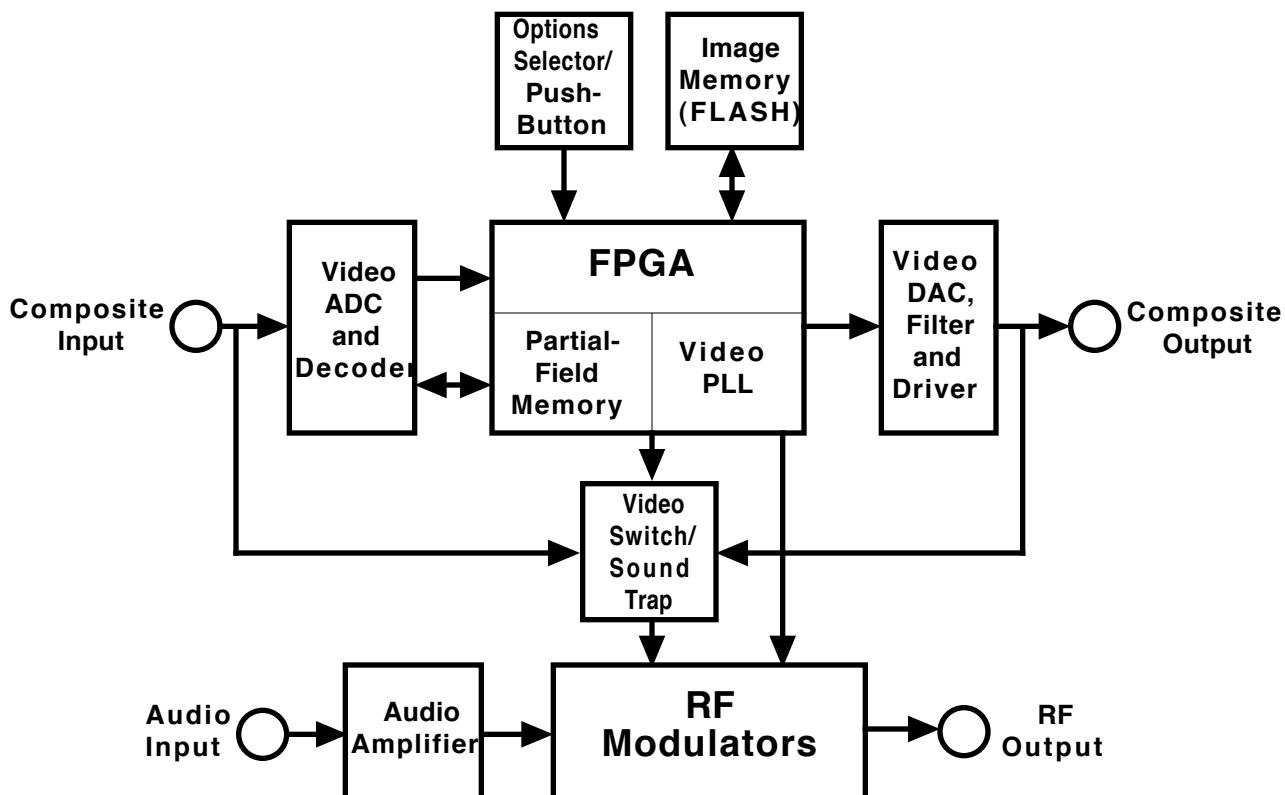
The incoming video is digitized and processed by the TVP5150A using a 14.318MHz reference crystal to the ITU-601 (formerly known as CCIR601) specification. All internal timing is generated using this crystal. The video is quantized, processed for brightness, contrast, chroma gain and hue, among others, and output at the ITU rate of 27MHz on an 8 bit, time multiplexed bus, with alternating luma and chroma samples. No other signals are required from this circuit as the ITU specification describes a method for encrypting the horizontal and vertical timing information directly into the digital data using timing reference makers, or TRS codes. A brief description of the ITU-601/656 specification is as follows:

Fundamental quantization frequency: 13.5MHz
Pixel Resolution: 720 H x 486 V NTSC / 720 H x 576 PAL
Image Aspect Ratio: 4:3
Pixel Aspect Ratio: 1.1 NTSC / 0.9 PAL
Horizontal Frequency: 15,734 Hz NTSC / 15,625 Hz PAL
Vertical Frequency: 29.97 Hz NTSC / 25 Hz PAL
Clocks per Line: 1716 NTSC / 1728 PAL (27MHz clock)
Clocks per Frame: 900900 NTSC / 1080000 PAL (27 MHz clock)

Note that the vertical frequency is 29.97Hz for NTSC, not 30Hz as expected. This is due to the NTSC color system that was first ratified in 1953. All monochrome television transmissions prior to this standard used exactly 30Hz, or 30 frames per second, so as to be in sync with the AC line frequency. This is done to reduce distortions in the image due to induced AC fields or "hum" from the power supplies of these early sets. In order to devise a "compatible" color system that would show a monochrome signal on existing sets, RCA proposed a method of modulating the color components of the video signal onto a subcarrier in the video. For reasons beyond the scope of this manual, a frequency needed to be chosen so that no standing patterns in the color signal would result. This required lowering the vertical frequency from 30Hz to 29.97Hz. While this change caused no adverse side effects on televisions, it has created a legacy of problems for modern video equipment. Instead of being able to use integer numbers like 24, 25 and 30, we now have to include 29.97 which makes many calculations and conversion extremely difficult. For digital processing, the ratio 1000/1001 has been established as the conversion between 30 and 29.97 video.

The digital video data is then routed to the FPGA where it is further processed. The data is sent to the internal partial-field memory in round robin fashion. The partial-field memory is large enough to hold many lines of video, so there is always enough data to keep an uninterrupted flow to the output.

All the above processing is done synchronous to the ITU clock, so no additional clocks are necessary at this point. Before any further processing can be done, a new clock, synchronous to the output standard but integrally related to the ITU clock must be generated. The internal DCM's are used for this purpose. By carefully choosing the ratio's, and cascading two DCM's together, the exact frequency for the output standard can be generated in the FPGA. This clock needs to run at least three

times the actual pixel clock desired for reasons that are shown below, but it is actually run at six to twelve times to provide for oversampling, and running the proprietary DAC.

With this new output synchronous clock, a video timing generator, or flywheel is created in the FPGA to generate all timing signals for the model's output standard. All horizontal, vertical, pixel count and line count generation is done in this process. Additional, frame timing signals in the form of equalization and serration pulses can be generated. This is the main "heartbeat" process for the entire design.

Using these timing signals, the video data that was stored in the partial-field memory synchronous to the incoming ITU video clock can now be clocked out synchronous to the new output clock. The data only needs to be downscaled vertically before being output to the video DAC. This is done by reading three pixels out of adjacent lines, and interpolating the desired output pixel. Since three pixels need to be read out of the memories for each pixel sent to the DAC, this is why a three times clock is required.

With all the above timing now generated, the output video can be created. The signals from the flywheel are routed to the video output DAC at the appropriate times in the signal, while the processed video from the partial-field memory is routed to the video DAC during the active portions of the video signal. The DAC is run at a two to four times over sampled rate to reduce filtering requirements and increase SNR.

The video is then filtered and buffered before being sent to the composite output connector and to the RF Modulator section. In the RF Modulator, the video is sent through a sound trap filter to remove any video frequencies that would interfere with the audio RF carrier. Also in this section, a video switch is provided ahead of the sound trap filter that allows the video input to the RF Modulator to come from the output of the DAC, or directly from the composite video input connector as used in the bypass mode.

Audio from the audio input connectors is combined, filtered and amplified before being sent to the RF Modulator. An externally adjustable potentiometer sets the gain of the audio amplifier, thereby setting the modulation depth of the audio RF carrier. An internal potentiometer sets the initial audio RF carrier level for AM modulation schemes. FM modulation schemes are handled internally to the RF Modulator IC's.

Detailed Analysis

Generating an output clock:

As shown in the previous section, a clock, synchronous to the output standard, but related to the incoming video clock must be generated. This is done using the DCMs built into the FPGA. First we need to decide what output clock frequency we need. Taking the example of 625 input with 405 output, it will be shown that the active video time per line is essentially the ratio between the two formats. For 625 the active line time is 51.95μs while the 405 active line period is 80.30μs. 405/625 is 0.65 while 51.95/80.30 is 0.65. This means we can use the same number of pixels per line in the

405 format as there are in the 625. If this were not the case, we would need to take into account the difference in pixel counts into the final ratio. The final ratio for this example only needs to account for the difference in the number of lines, therefore the base ratio we need is 405/625 which can be reduced to 81/125. If we multiplied the ITU 27MHz clock by this number, we would get a clock that has two counts per pixel in the output, since there are two clocks per pixel in the ITU clock. As stated earlier, we need a clock that has at least 3 clocks per pixel in order to achieve the minimal three line interpolation necessary for good image quality. Also, we actually want a clock two to four times higher than this so the output can be over sampled, easing the filter requirements, and yielding a higher SNR.

   This means the output clock needs to use the base ratio times 3/2 (to get to the 3 clocks per pixel), and then again by 4. So the final ratio required is 81/125 * 3/2 * 4 or 486/250. Taking this ratio and multiplying by the 27MHz ITU clock, the output clock becomes 104.98MHz.

   Using this new output clock, all processing of the output pixels can be accomplished while still maintaining a lock to the input clock. If this were not done, and the output clock was unrelated to the input clock, as is the case with using a separate oscillator, the output image will have duplicate, dropped, or torn frames.

Spatial Correction:

   With an output clock now available, the image can be processed. In order to convert between different video standards, the video image must first be spatially converted. Many aspects need to be taken into account such as image aspect ratio, and the number of active lines. The distinction of image aspect ratio is made here to differentiate it from pixel aspect ratio which only has to do with how the analog data is quantized.

   Since this converter is limited to the type of input and output video handled, no spatial correction needs to take place in the horizontal direction. This means that all 720 input pixels will be included in the output line, but at the output clock rate. Only spatial correction in the vertical direction needs to take place.

   On first inspection, it would appear that this correction can easily be achieved by simple adding or dropping lines to get the desired result. For example, if you have 576 lines in the input, and need 384 lines in the output, dropping every third line would appear to be adequate. This is known as decimation. Unfortunately, one third of the original information is lost, not being included in the output in any way, and since the input lines were spaced differently than the output lines, aliasing of the image will occur. This is most noticeable as stair stepping or jagged edges around objects. To avoid this situation, all lines in the input need to be used to generate the output.

   A simple solution for the above case would be to use the first line of the input as the first line in the output, and then average the next two lines of the input to create the second line in the output. This is known as two line interpolation. While it provides a vastly superior image to straight decimation, it has several draw backs. First, the output lines will have different frequency content because one line in the

output is the same as a line of the input with all vertical frequencies intact, while the next line in the output is the average of two lines of the input, with the frequencies filtered down. Also, since this is just a simple averaging filter, aliasing can occur, introducing image data that does not actually exist.

Then consider the case where the output is not a clear division of the input. In the example there were exactly 2/3 the number of lines in the output as there were in the input. Now take the case of 625 input to 441 output. This requires scaling 576 input lines to 406 output lines or a 406/576 ratio, which can be reduced to 203/288. Not an easy ratio to handle with a simple two line interpolator.

By taking more lines into account, a much more accurate representation of the desired ratio can be achieved. By comparing the desired spatial position of the output line to the input lines, and taking a weighted average of several lines around this point, a high quality filter, or interpolator is realized. Through actual tests, it has been shown that carefully chosen weighting coefficients used with four lines gives the best results. It has also been shown that no perceptible loss of image quality occurs when only three adjacent lines are used. Since this converter processes all pixels within the FPGA itself, it can easily handle three or four line interpolation. Because of the higher clock frequency, and therefore higher power consumption required for four line interpolation, and because of the imperceptible difference in quality, a three line interpolator is implemented in this converter.

Outputting Pixels:

Once the output pixels are generated, they are up-sampled by a factor of two to four by creating pixel values in-between the actual ones. These are then sent on to the DAC converter, in this case a proprietary converter that uses a combination of R2R ladder and PWM techniques. This creates an effective higher sampling frequency which allows for lower order filters with less group delay distortion.

RF Modulator:

Due to limitations in the currently available RF Modulator IC's, two IC's are used with their outputs combined before being sent out the RF connector. This arrangement allows for positive and negative video modulation coupled with AM and FM audio modulation. Further, in the case of AM audio, any carrier separation between the audio and video can be achieved. The FM audio carrier is limited to +/- 4.5, 5.5, 6.0 and 6.5MHz from the video carrier.

The reference clock for both modulators is derived from a process in the FPGA. This way no external crystals are required, and both modulators are locked to the same frequency. This reference clock is used by the modulators for an internal PLL with an external loop filter. High quality film capacitors are used in the loop filter to minimize microphonics as is the case with any ceramic capacitor.

The FPGA programs the modulators as to frequency, modulation type, etc. The

video modulator receives it's input from a switch that allows the FPGA to route video from the converter output, or from the video input connector. The video signal goes through a sound trap filter to eliminate any frequencies that could interfere with the audio carrier. The video modulator contains a DC restorer circuit that sets the correct carrier levels.

Audio from the two audio connectors is combined and amplified by an op-amp before being sent to both modulators. For FM audio, the same modulator that is used for the video is enabled, and the carrier spacing set. Initial carrier level is set by the FPGA and depth is set by a gain control provided in the op-amp circuitry. For AM audio, the audio section in the video modulator IC is shut down, and the audio is fed to the video input of the second modulator IC. Feeding the output of the op-amp directly into the video input of the second modulator overrides the internal DC restorer. This allows full control over the AM audio, including initial level and depth.

To set the initial carrier level, a DC offset control is provided in the op-amp circuitry that allows the setting of the input bias. Modulation depth is set by the same gain control.

The outputs of the two modulators are then combined through a balanced network that maintains a 75 ohm impedance and sent to the RF connector.

Hardware Setup and Test Mode

There is a hidden mode of operation that is used during initial setup and test of the converter that may be useful to those users with a technical understanding of the operation of a standards converter. No harm can be done to the unit by simply entering this mode, but care should be taken if the following alignment procedure is attempted.

To enter the *Setup and Test Mode*, remove the power cable from the unit, While depressing the Auxiliary Button on the rear panel, reconnect the power supply to the unit. The Auxiliary Button must remain depressed until the front panel Status LED starts blinking. At this point the pushbutton may be released. The Status LED will repeat a pattern of two fast yellow flashes to indicate the unit is in the *Setup and Test Mode*. There are five different behaviors that can be selected. You can scroll through these by depressing the auxiliary pushbutton to increment to the next test in a round robin fashion.

Note, a valid RF channel should be selected on the Selector Switch when running the *Setup and Test Mode*.

Mode 1:   In this mode, a frequency equal to the audio trap filter center frequency will be output by the video D/A converter. By viewing the RF output on a spectrum analyzer, or by placing an oscilloscope on C52, the Sound Trap Filter Trimmer, the signal can be adjusted for minimum signal.

Mode 2: This mode is used to examine the unmodulated audio and video carrier levels. (no audio signal should be connected to the unit during this test) Additionally the AM audio carrier level can be set in this Test Mode. To set the AM Audio carrier level, connect a spectrum analyzer to the RF output and set so that both the audio and video carriers are visible. Momentarily short the Test Point TP1 inside the converter (must remove case lid) with a screw driver or similar tool. The Status LED will show two fast red flashes to indicate AM Audio Carrier Level Setting Mode. Using the Options and Auxiliary Buttons, the level can be adjusted up or down relative to the Video carrier level. Once the desired level is obtained, momentarily short TP1 again to save the result in FLASH memory and return to the normal Test Mode. To exit the AM Audio Carrier Level Setting Mode without saving the value, remove power from the unit.

Mode 3: In this mode, a video test pattern consisting of a PLUGE followed by a linear ramp will be output from the unit on both the composite output and RF output. This test is used to validate the output section of the converter.

Mode 4: In this mode, a video test pattern consisting of a multi-burst will be output from the unit on both the composite output and RF output. This test can be used to align a television set for frequency response. There are 7 bands of ascending frequency, each ratiometrically derived from the Interpolator clock frequency listed in the Support Conversions section. The seven ratios are as follows: 1/48, 1/36, 1/24, 1/18, 1/12, 1/9 and 1/6,

Mode 5: This mode selects normal operation. This can be used to verify adjustments made in the prior modes on actual input video and audio without having to leave the *Setup and Test Mode*.

Updating Firmware

If it ever becomes necessary to update the firmware in the unit, this can be accomplished through the internal programming port. The connector is a standard 8 pin, double row, 2mm connector. A custom cable with the appropriate mating connector is used in conjunction with an Asix Presto or similar programmer. A full description of the hardware, software, and procedure to FLASH the unit can be found in the supplemental programming guide for the converter.

Specifications

Video Input:

Supported Standards: NTSC 29.97fps / PAL 25fps / SECAM 25fps

Video Quantization: 9bit A/D, 8 bit data

Video Input: Composite - 1Vpp, 75 ohm impedance

Video Output:

Video Output: Composite - 1Vpp into 75 ohms

Video Quantization: 10 bit Effective D/A

Video Levels: +/- 3% of output standard

Video Timing: +/- 50 ppm, Line/PLL locked, < 2ns jitter typical

Video SNR: 56dB typical

Audio Input:

Audio Input: Unbalanced, 20K impedance
-10dBV nominal input level
0.2Vpp to 5Vpp maximum

Audio Response: 50Hz to 15kHz, +/- 2dB

RF Output:

RF Output: 76dBµV (6.3mV) typical into 75 ohms
Crystal/PLL frequency generation

Video SNR: 56dB typical

Modulation Depth: 99% maximum

Audio SNR: 54dB typical

General:

Dimensions: 2.60" X 2.60" X 1.00" (66mm X 66mm X 25mm)

Weight: 2.5oz (70g)

Power Requirements: 9Vdc typical, 7-14Vdc maximum
2.0 watts typical (Full Operation)
1.0 watt typical (Sleep Mode)

Humidity: 20% - 80% non-condensing

Temperature: 10C - 45C ambient (50F - 110F)

Supported Conversions

NTSC to 525/30i Sequential Color:

Image / Pixel Aspect Ratios:	4:3 / 1.13 [0.88]
Interpolator Clock / Oversample:	40.5 MHz / 2X
Active Pixels / Lines :	720 / 480
Horizontal / Vertical Frequency:	15,735 Hz / 29.97 Hz
Video Characteristics:	6.7 MHz [5.3 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

NTSC to 441/30i:

Image / Pixel Aspect Ratios:	4:3 / 1.35 [1.04]
Interpolator Clock / Oversample:	34.0 MHz / 3X
Active Pixels / Lines:	720 / 406
Horizontal / Vertical Frequency:	13,217 Hz / 29.97 Hz
Video Characteristics:	5.7 MHz [4.4 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

NTSC to 343/30i:

Image / Pixel Aspect Ratios:	4:3 / 1.70 [1.37]
Interpolator Clock / Oversample:	26.5 MHz / 4X
Active Pixels / Lines :	720 / 316
Horizontal / Vertical Frequency:	10,280 Hz / 29.97 Hz
Video Characteristics:	4.4 MHz [3.5 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

PAL/SECAM to 819/25i: (France)

Image / Pixel Aspect Ratios:	4:3 / 0.73 [0.59]
Interpolator Clock / Oversample:	53.2 MHz / 2X
Active Pixels / Lines:	720 / 738
Horizontal / Vertical Frequency:	20,475 Hz / 25.0 Hz
Video Characteristics:	8.9 MHz [6.9MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

PAL/SECAM to 819/25i: (Belgium)

Image / Pixel Aspect Ratios:	4:3 / 0.73 [0.59]
Interpolator Clock / Oversample:	53.2 MHz / 2X
Active Pixels / Lines:	720 / 760
Horizontal / Vertical Frequency:	20,475 Hz / 25.0 Hz
Video Characteristics:	8.9 MHz [6.9MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

PAL/SECAM to 441/25i:

Image / Pixel Aspect Ratios:	6:5 / 1.29 [1.03]
Interpolator Clock / Oversample:	24.4 MHz / 4X
Active Pixels / Lines:	648 / 418
Horizontal / Vertical Frequency:	11,025 Hz / 25.0 Hz
Video Characteristics:	4.1 MHz [3.2 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

PAL/SECAM to 405/25i:

Image / Pixel Aspect Ratios:	4:3 / 1.43 [1.14]
Interpolator Clock / Oversample:	26.3 MHz / 4X
Active Pixels / Lines:	720 / 378
Horizontal / Vertical Frequency:	10,125 Hz / 25.0 Hz
Video Characteristics:	4.4 MHz [3.4 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio

PAL/SECAM to 405/25i NTSC Color:

Image / Pixel Aspect Ratios:	4:3 / 1.43 [1.14]
Interpolator Clock / Oversample:	26.6 MHz / 4X
Active Pixels / Lines:	720 / 378
Horizontal / Vertical Frequency:	10,125 Hz / 25.0 Hz
Video Characteristics:	4.4 MHz [3.4 MHz], 1Vpp into 75 ohms, composite sync, 70/30 video/sync ratio
Chroma Subcarrier Frequency:	2,657,812.5 Hz

Note: numbers in brackets [] are effective parameters.

Supported RF Systems

System A:

Positive video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	45.00 MHz	41.5 MHz
2	2	51.75 MHz	48.25 MHz
3	3	56.75 MHz	53.25 MHz
4	4	61.75 MHz	58.25 MHz
5	5	66.75 MHz	63.25 MHz
6	6	179.75 MHz	176.25 MHz
7	7	184.75 MHz	181.25 MHz
8	8	189.75 MHz	186.25 MHz
9	9	194.75 MHz	191.25 MHz
A	10	199.75 MHz	196.25 MHz
B	11	204.75 MHz	201.25 MHz
C	12	209.75 MHz	206.25 MHz
D	13	214.75 MHz	211.25 MHz
E	14	219.75 MHz	216.25 MHz
F	Disabled		

System E:

Positive video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	46.00 MHz	42.00 MHz
2	2	52.40 MHz	41.25 MHz
3	4	65.55 MHz	54.40 MHz
4	5	164.00 MHz	175.15 MHz
5	6	173.40 MHz	162.25 MHz
6	7	177.15 MHz	188.30 MHz
7	8A	185.25 MHz	174.10 MHz
8	8	186.55 MHz	175.40 MHz
9	9	190.30 MHz	201.45 MHz
A	10	199.70 MHz	188.55 MHz
B	11	203.45 MHz	214.60 MHz
C	12	212.85 MHz	201.70 MHz
D	Disabled		
E	Disabled		
F	Disabled		

Note: Channel 1 is for the original channel from the Paris Eiffel Tower transmitter.

System F:

Positive video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	41.25 MHz	46.75 MHz
2	1A	42.25 MHz	47.75 MHz
3	2	48.25 MHz	53.75 MHz
4	2A	49.75 MHz	55.25 MHz
5	3	55.25 MHz	60.75 MHz
6	4	62.25 MHz	67.75 MHz
7	4A	82.25 MHz	87.75 MHz
8	5	175.25 MHz	180.75 MHz
9	6	182.25 MHz	187.75 MHz
A	7	189.25 MHz	194.75 MHz
B	8	196.25 MHz	201.75 MHz
C	9	203.25 MHz	208.75 MHz
D	10	210.25 MHz	215.75 MHz
E	11	217.25 MHz	222.75 MHz
F	12	224.25 MHz	229.75 MHz

System M (1946 - AM or FM Audio):

Negative video modulation, AM or FM audio modulation depending on model, AM audio carrier level -6dB, FM audio carrier level -12dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	45.25 MHz	49.75 MHz
2	2	55.25 MHz	59.75 MHz
3	3	61.25 MHz	65.75 MHz
4	4	67.25 MHz	71.75 MHz
5	5	77.25 MHz	81.75 MHz
6	6	83.25 MHz	87.75 MHz
7	7	175.25 MHz	179.75 MHz
8	8	181.25 MHz	185.75 MHz
9	9	187.25 MHz	191.75 MHz
A	10	193.25 MHz	197.75 MHz
B	11	199.25 MHz	203.75 MHz
C	12	205.25 MHz	209.75 MHz
D	13	211.25 MHz	215.75 MHz
E	14	471.25 MHz	475.75 MHz
F	15	477.25 MHz	481.75 MHz

System M (1940):

Negative video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	51.25 MHz	55.75 MHz
2	2	61.25 MHz	75.75 MHz
3	3	67.25 MHz	71.75 MHz
4	4	79.25 MHz	83.75 MHz
5	5	85.25 MHz	89.75 MHz
6	6	97.25 MHz	101.75 MHz
7	7	103.25 MHz	107.75 MHz
8	8	163.25 MHz	167.75 MHz
9	9	181.25 MHz	185.75 MHz
A	10	187.25 MHz	191.75 MHz
B	11	205.25 MHz	209.75 MHz
C	12	211.25 MHz	215.75 MHz
D	13	231.25 MHz	255.75 MHz
E	14	237.25 MHz	241.75 MHz
F	15	259.25 MHz	263.75 MHz

System M (1937):

Negative video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	45.25 MHz	49.75 MHz
2	2	51.25 MHz	55.75 MHz
3	3	67.25 MHz	71.75 MHz
4	4	79.25 MHz	83.75 MHz
5	5	85.25 MHz	89.75 MHz
6	6	97.25 MHz	101.75 MHz
7	7	103.25 MHz	107.75 MHz
8	8	157.25 MHz	161.75 MHz
9	9	163.25 MHz	167.75 MHz
A	10	181.25 MHz	185.75 MHz
B	11	187.25 MHz	191.75 MHz
C	12	205.25 MHz	209.75 MHz
D	13	211.25 MHz	215.75 MHz
E	14	235.25 MHz	239.75 MHz
F	15	241.25 MHz	245.75 MHz

System X1 (1934):

Negative video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	1	44.75 MHz	47.00 MHz
2	2	49.75 MHz	52.00 MHz
3	3	54.75 MHz	57.00 MHz
4	4	62.75 MHz	65.00 MHz
5	5	67.75 MHz	70.00 MHz
6	6	72.75 MHz	75.00 MHz
7	7	77.75 MHz	80.00 MHz
8	8	82.75 MHz	85.00 MHz
9	9	112.75 MHz	115.00 MHz
A	10	117.75 MHz	120.00 MHz
B	11	122.75 MHz	125.00 MHz
C	12	127.75 MHz	130.00 MHz
D	13	132.75 MHz	135.00 MHz
E	14	137.75 MHz	140.00 MHz
F	15	142.75 MHz	145.00 MHz

Note: There were no official channel assignments at this time, only the bands of 42-56MHz, 60-86MHz and above 110MHz were allocated to television.

System X2 (1936):

Positive video modulation, AM audio modulation, audio carrier level -6dB

Selector Switch Position	Channel Assignment	Video Frequency	Audio Frequency
0	Disabled		
1	P1	46.00 MHz	42.00 MHz
2	B1	47.80 MHz	45.00 MHz
3	B2	52.80 MHz	50.00 MHz
4	Disabled		
5	Disabled		
6	Disabled		
7	Disabled		
8	Disabled		
9	Disabled		
A	Disabled		
B	Disabled		
C	Disabled		
D	Disabled		
E	Disabled		
F	Disabled		

Note: Channel P1 was the original channel from the Paris Eiffel Tower transmitter. Channels B1/B2 were the original channels from the Berlin transmitter.

Available Models

Model No. SCRF-343X
> NTSC to 343/30i with all System X1 (1934) channels

Model No. SCRF-343A
> NTSC to 343/30i with all System A channels [1]

Model No. SCRF-441M
> NTSC to 441/30i with all System M (1937) channels

Model No. SCRF-525M-SC
> NTSC to 525/30i sequential color with all System M (FM audio) channels

Model No. SCRF-405A-NTSC
> PAL/SECAM to 405/25i NTSC Color with all System A channels

Model No. SCRF-405A
> PAL/SECAM to 405/25i with all System A channels

Model No. SCRF-441X
> PAL/SECAM to 441/25i with System X2 channels P1 and B1/B2

Model No. SCRF-819E
> PAL/SECAM to 819/25i with all System E channels

Model No. SCRF-819F
> PAL/SECAM to 819/25i with all System F channels

Notes

(1) This unit is useful for operating 405/25i televisions in parts of the world that use NTSC video and 60Hz AC power. By adjusting the vertical (frame) oscillator in the television, NTSC video can be used to operate these televisions.

Firmware Revision History

Revision 3.3, November 15, 2011:

    1) Updated documents for correct terminology on Converter Enable/Bypass mode.

    2) Added Paris Eiffel Tower transmiter frequency to System X2.

Revision 3.2, May 28, 2010:

    1) Changed default audio tone generation to accommodate any frequency. Changed tone to 440Hz for all early standards and left at 1kHz for all later standards.

Revision 3.1, February 10, 2010:

    1) Corrected error with Equalization Pulses option were it was Enabled when the Status LED was Red, and Disabled when the LED was Green. It now operates correctly as stated in the User Options section of this manual.

Revision 3.0, September 21, 2009:

    1) New hardware revision now incorporates FLASH based Options Settings.

Revision 2.1, February 21, 2007:

    1) Updated to support revision "B" image FLASH memories.

Revision 2.0, January 16, 2007:

    1) Updated for revision 2.0 hardware.
    2) Added externally adjustable RF channel select switch.
    3) Added audio test tone in default mode.

Revision 1.8, August 26, 2006:

    1) Updated 441/25i standard to match German specifications.
    2) Added channels B1 and B2 to System E for Berlin transmitter.

Revision 1.7, June 18, 2006:

    1) Increased internal fpga clock frequency to ease filter design.

Revision 1.6, June 12, 2006:

    1) Added Sleep Disable feature to Option switch position 7.
    2) Modified SCRF-819F and SCRF819L units for dual RF system capability.

Revision 1.5, May 18, 2006:

    1) Increased accuracy of sine wave generator for internal test modes.
    2) Added functionality to Test Mode 2 to measure SNR of D/A.

Revision 1.4, May 8, 2006:

    1) Improved the high frequency video response of the unit.

Revision 1.3, May 3, 2006:

    1) Improved timing to image FLASH.
    2) Added a sixth test mode to aid in modulation depth measurements.

Revision 1.0, April 6, 2006:

    1) Initial release.

Note: Hardware/Firmware revision level can be found on bottom label of unit.