

Application Note

Matrox Corona and Meteor-II/Multi-Channel

Optimizing Video Digitization

Background

Optimizing a video signal for digitization depends on several factors such as the frame grabber's design and the characteristics of the video signal itself (i.e., total peak-to-peak voltage). By amplifying the signal and adjusting the reference levels¹ of the analog-to-digital (A/D) converter, one can make optimal use of the digitizer's dynamic range.

This application note provides an in-depth description of how to control the variable gain amplifier and digitizer references of the Matrox Corona and Meteor-II/Multi-Channel frame grabbers, and complements the reference level basics covered in *MIL/MIL-Lite Command Reference*, *User Guide*, and *Board Specific Notes* manuals. The topics discussed in this document apply to Matrox Corona revision 2 through 6 and Meteor-II/Multi-channel frame grabber revision 1 and 2². For the remainder of this document the term frame grabber will designate either the Matrox Corona or Meteor-II/Multi-channel.

Input Gain

Once the characteristics of the input video signal and optimal input voltage for the frame grabber³ have been determined, the first step is to maximize the incoming signal's amplitude. This is done using the variable gain amplifier. The DC component of the signal is first removed in order to set the incoming video signal's average voltage to a fixed level which is zero (known as AC-coupling). This also allows the variable gain amplifier to amplify only the AC component (video and sync.) based on a user-specified gain factor. For a list of available gain factors, consult the *Board-Specific Notes* manual for your frame grabber.

The selected gain setting should be one that produces a signal amplitude as close as possible to, but not exceeding 2.0V when multiplied by the active portion of the incoming video signal, but excluding the synchronization pulse (see Figure 1). In the digitizer configuration format (dcf) file, the gain value is set to a default value depending on the video format template used (e.g. ntsc.dcf, rs170.dcf, etc.). To change the default values in Matrox Intellicam, de-select "Use default voltage swing..." in the Video Signal menu tab and specify the active video's amplitude in mV (see Figure 2). Matrox Intellicam will then set an appropriate gain factor based on this amplitude. To override the gain factor set in the dcf, use the MIL function `MdigControl(..., M_GRAB_INPUT_GAIN, M_GAINx)`⁴ to specify a gain setting, where x is an identifier of the gain factor. For more details on the GRAB_INPUT_GAIN parameter, refer to the Board-Specific Notes manual for the appropriate frame grabber.

Application Note

Matrox Corona and Meteor-II/Multi-Channel

Optimizing Video Digitization

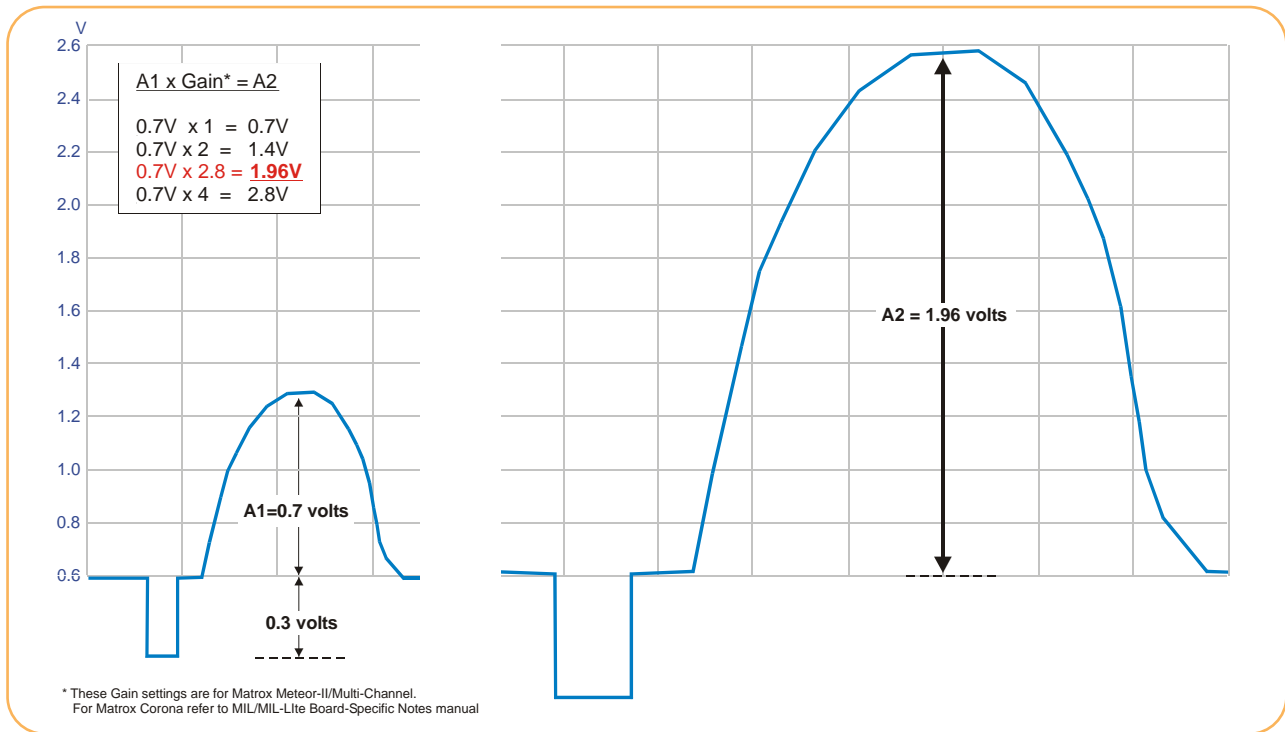


Figure 1. In our example, we want to use the default gain setting (2.8) since it will provide the largest amplification (A2) without exceeding the 2.0V range of the frame grabber.

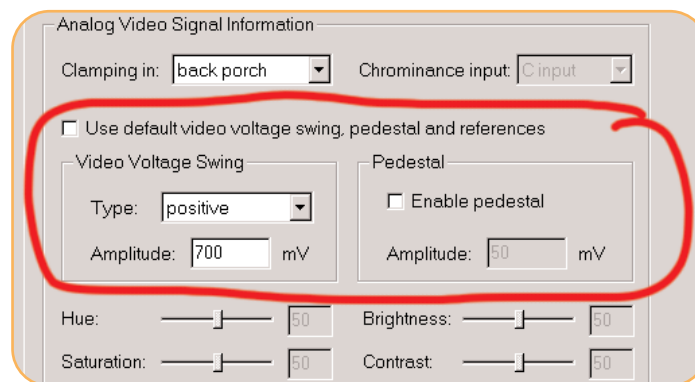


Figure 2. Setting the signal's voltage amplitude in the dcf's Video Signal menu tab.

Application Note

Optimizing Video Digitization

Digitizer References

Following the variable gain amplifier stage, the DC component of the video signal is restored by the DC restoration circuitry. The clamping stage sets the video's blanking level to a stable and known level thereby ensuring proper digitization. The signal continues from the clamping stage to the A/D converter, which digitizes each voltage level to a corresponding integer value between 0 and 255 in the case of 8-bit A/Ds. To provide a relative position for the signal within the input voltage range, the A/D converter has two references, a top reference for white and bottom reference for black. Any voltage at and above the white reference level is converted to a white pixel value (ideally 255) and any voltage at and below the black reference level is converted to a black pixel value (0). Since the frame grabber allows fine-tuning of the reference values, understanding both the software (MIL) model and the hardware (digitizer) design of the frame grabber is essential to achieve optimal use of the digitizer's dynamic range.

In the MIL model⁵, one basically calls a function to set the appropriate reference level using a specified integer value. This integer value is written to a D/A converter, which in turn, translates it into a voltage value, which is then fed to the A/D converter's reference control input. Using `MdigReference(..., M_BLACK_REF 'or' M_WHITE_REF, ReferenceLevel)`⁶, the parameter 'ReferenceLevel' can be set to an integer between 0 and 255. The range for the black or white minimum-to-maximum reference level⁷ is a delta of 1V (see Figure 3). The minimum and maximum black levels correspond to 0.6 and 1.6V while minimum and maximum white levels correspond to 1.6 and 2.6V. The 'ReferenceLevel' parameter can be set to a default level or set to a calculated value (using `MdigReference` equation) based on the required voltage. For details on how to calculate a voltage using the `MdigReference` equation, refer to the *MIL Command Reference* manual.

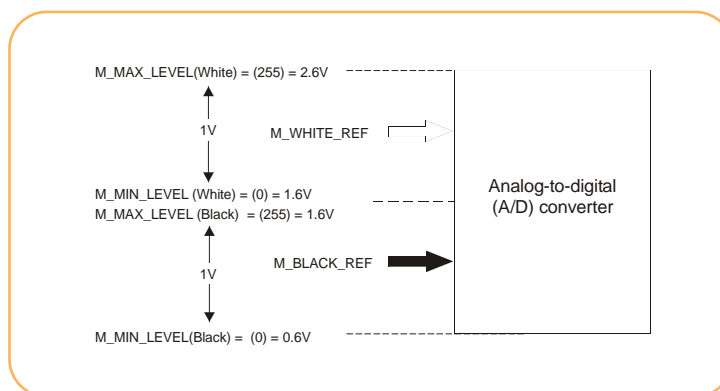


Figure 3. MIL/ActiveMIL method for adjusting digitizer references

Application Note

Optimizing Video Digitization

Digitizer References (cont.)

In the actual hardware, the reference levels are handled somewhat differently since the A/D converter operates with one fixed reference (top) and one adjustable reference (bottom). With a top reference fixed to 2.6V, the clamping level is adjustable in order to provide control for the white reference. When changing the white reference level through MIL, one is actually adjusting the clamping level (blanking level) on the hardware. By adjusting the clamping level, the whole video signal is shifted vertically in one direction or the other, and consequently, the bottom reference is also changed so as to compress or decompress the dynamic range (see Figure 4). Conversely, adjusting the black reference level in MIL (see Figure 5) affects only the bottom reference on the hardware. For additional details refer to Reference Level Equation (see Table 1) and the accompanying hardware diagram in the Appendix.

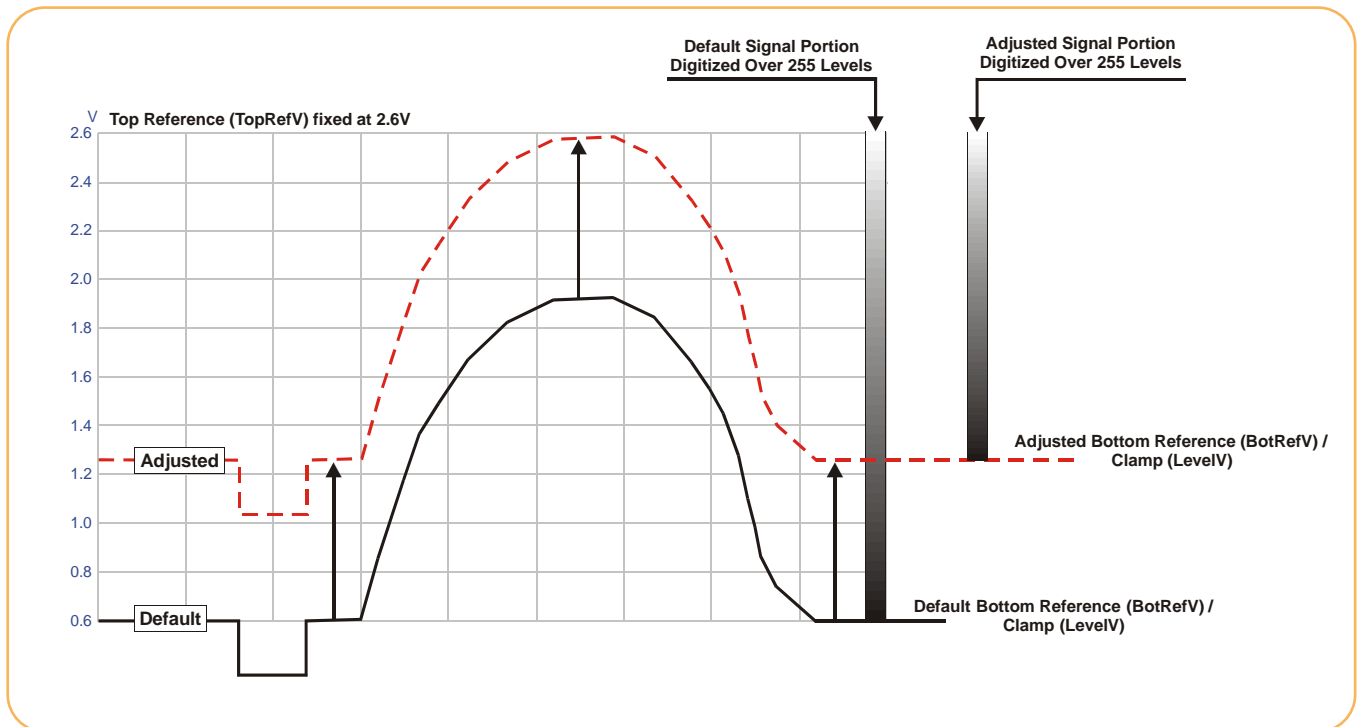


Figure 4. Since the top reference (TopRefV) of the digitizer is fixed, adjusting the White reference level in MIL actually adjusts the clamp level (LevelV) as well as the bottom reference. In this example we lowered the white reference value in MIL, which consequently raises the clamp (LevelV) and compresses the digitizer's dynamic range.

Application Note

Matrox Corona and Meteor-II/Multi-Channel

Optimizing Video Digitization

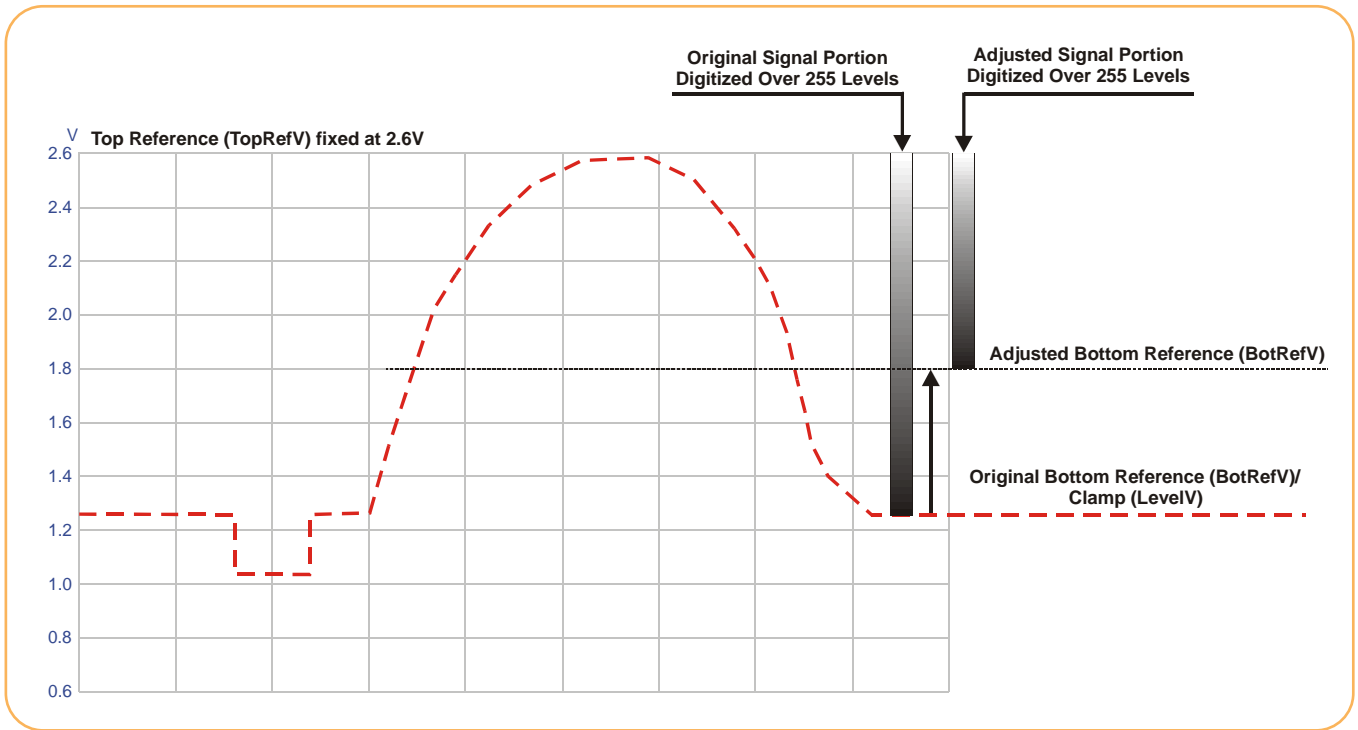


Figure 5. When adjusting the Black reference level in MIL, the bottom reference level (BotRefV) is changed. In this example, by raising the Black reference level, we will only digitize the top portion of the video signal over 255 levels.

Table 1: Reference Level Equations (see also Appendix diagram)	
Equation	Description
<u>White Reference Level (Clamping Level)</u>	
$\text{LevelRegVal} = \left(128 - \frac{\text{WhiteRef}^*}{2} \right) \times \frac{196}{255} + 59$	LevelRegVal equation is based on the WhiteRef* value from MIL and used to calculate the value written to the D/A converter.
$\text{LevelV} = \text{LevelRegVal} \times \frac{2.6}{256} \text{ Volts}$	LevelV equation is based on LevelRegVal and used to calculate the voltage level at which the back porch is clamped to.
<u>Black Reference Level (Bottom Reference Level)</u>	
$\text{BotRefRegVal} = \left(128 + \frac{(\text{BlackRef}^* + \text{WhiteRef}^*)}{2} \right) \times \frac{196}{255} + 59$	BotRefRegVal equation is based on both white and black reference (WhiteRef* and BlackRef*) values from MIL and used to calculate the voltage value written to the D/A converter.
$\text{BotRefV} = \text{BottomRefRegVal} \times \frac{2.6}{256} \text{ Volts}$	BotRefV equation is based on BotRefRegVal and used to calculate the voltage the D/A writes to the A/D for the Bottom Reference (Black).

* Refer to the MIL/MIL-Lite User Guide or Command Reference manual for details.

Application Note

Optimizing Video Digitization

Full Scale Optimization

The following section describes optimizing for the full range of the video signal (see Figure 6A). In order to optimize the incoming signal following the variable gain amplifier, the White reference level should be adjusted first so that the top of the incoming signal is aligned with the top reference level (2.6V). Setting the correct White reference level in MIL will undoubtedly require some experimentation, however there are two methods to help determine the most appropriate reference value(s).

The first method requires the use of a highly reflective surface (i.e., white background) as a subject. Start by capturing an image of the brightest possible scene and then determine the maximum image pixel value of the image using the MIL function `MimFindExtreme()`. This function provides the minimum and maximum image pixel values and can help to establish the appropriate White reference level. Again, it may be necessary to experiment with the White reference until the desired level is reached. An alternate method involves reverse calculations using the Reference Level Equation(s) and MIL `MdigReference` equation(s) to determine the appropriate reference level to use in MIL.

Once the White reference level is determined, set the black reference to the lowest voltage level of the signal. In this case using a lens cap over the lens will provide a black reference to help determine the minimum image pixel value. Again by using the MIL function `MimFindExtreme()` or reverse calculations using the previously mentioned equations, the black reference level can be established and set in MIL. It is important to note that by setting the black reference based on the former method (lens cap), any existing electronic noise (leakage current noise) that occurs naturally in the video signal will now be digitized as black.

At this point, the full signal amplitude will be digitized optimally over 255 levels. However, in some cases it may not be desirable to optimize over the full scale of the video signal. As described in the following section, there are other possible optimization strategies depending on the desired results.

Application Note

Optimizing Video Digitization

Other Optimization Strategies

Aside from full scale, there are three other basic strategies for optimizing an incoming video signal using the digitizer reference level control: half-scale top, half-scale bottom, and binary. The half-scale strategies (bottom or top) are evidently used to optimize either the top or bottom portions of the video signal. The half-scale bottom strategy can be used to optimize low-contrast images or weak signals common in some medical imaging applications (e.g., x-rays or ultrasound). In our example (see Figure 6B), the clamp (LevelV) and the black reference (BotRefV) are both set so that we digitize only the bottom portion of the signal. Any voltage value at and below the clamp (LevelV) and black reference (BotRefV) is digitized as black (0) and any voltage at and above 2.6V is digitized as white (255).

The half-scale top strategy on the other hand, is intended to optimize only the top portion of the signal. This is useful in industrial applications where inspection or reading detail in highly reflective (metallic) subjects is necessary. In our example (see Figure 6C), the clamp (LevelV) is set close to the bottom of our frame grabber's voltage range and the black reference (BotRefV) is set to the middle of the signal's amplitude. Any voltage at and above 2.6V (TopRefV) is digitized as white (255) and any voltage at and below the bottom reference (BotRefV) is digitized as black (0).

Finally the binary strategy, as the name implies, performs a binary threshold on the incoming video. This is a specialized method for those applications that require only binary information as a final result. This method is useful in cases where the use of the LUT or a software binary threshold operation is not practical. In our example (see Figure 6D) the clamp (LevelV) is set to the middle of the frame grabber's voltage range. The black reference (BotRefV) is then set as close as possible to the frame grabber's maximum voltage level (2.6V). As a result, any voltage at and above 2.6V (TopRefV) is digitized as white (255) and any voltage at or below BotRefV is digitized as black (0). It should be noted that some experimentation will be necessary to achieve a desired result.

Application Note

Matrox Corona and Meteor-II/Multi-Channel

Optimizing Video Digitization

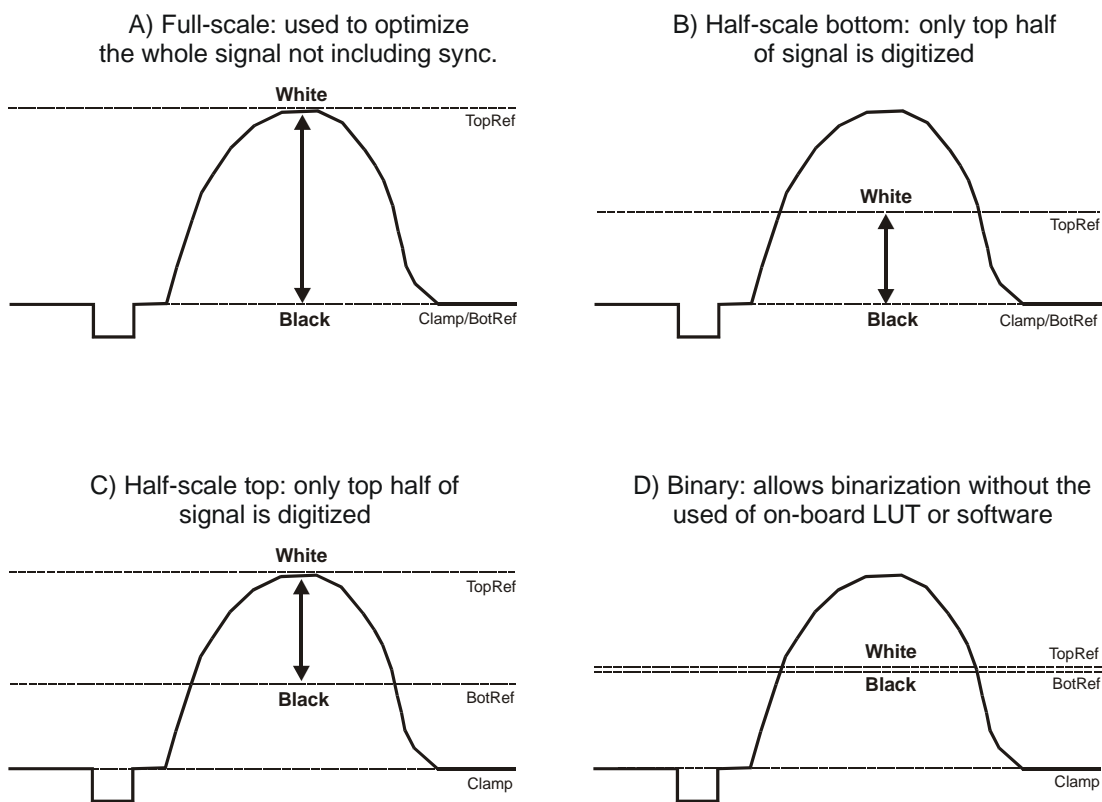


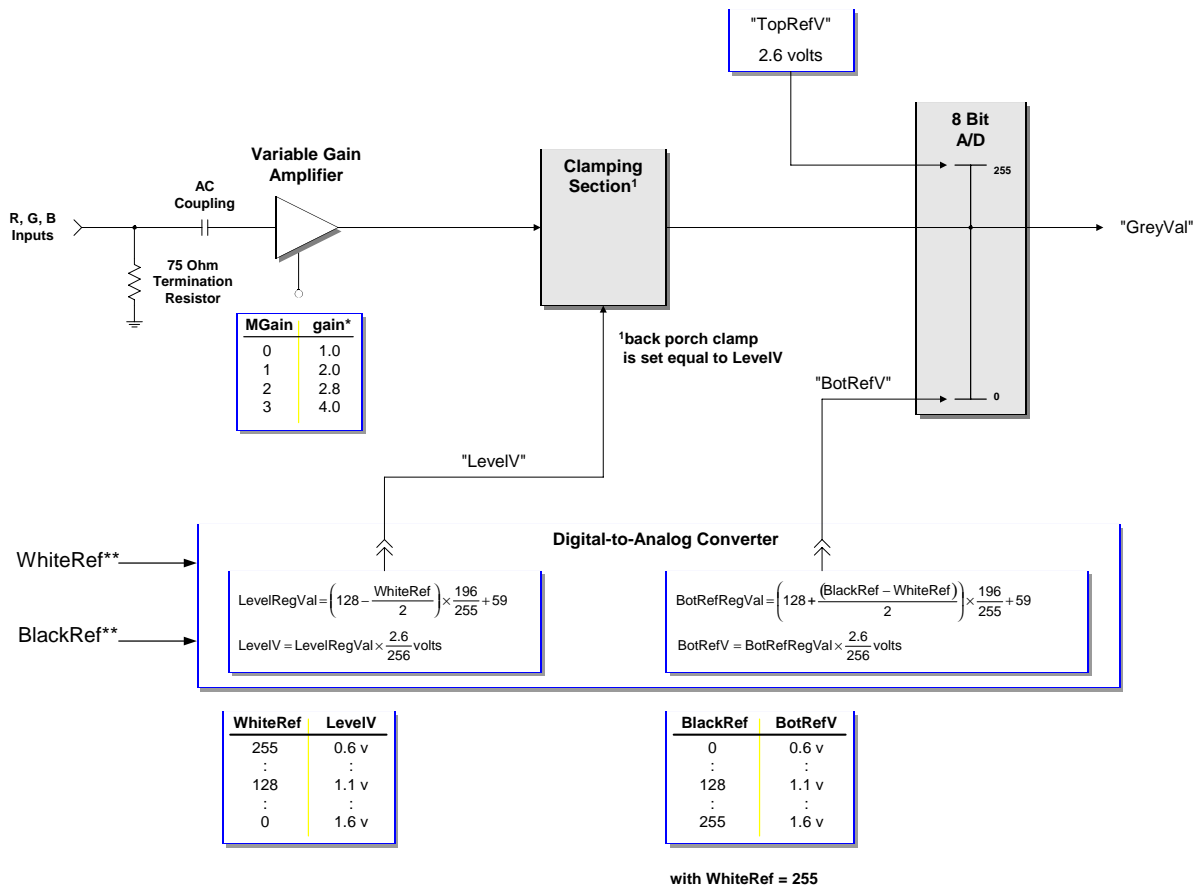
Figure 6. Different optimization strategies: full, bottom or top half, or binary.

Application Note

Optimizing Video Digitization

Matrox Corona and Meteor-II/Multi-Channel

Appendix: Matrox Corona & Meteor-II/Multi-Channel Digitization Block Diagram



*Gain settings are listed for Matrox Meteor-II/Multi-channel. For Matrox Corona gain settings refer to MIL/MIL-Lite 6.0 Board-Specific Notes manual.
 ** From MIL/MIL-Lite

Endnotes:

1. Applies only when grabbing via the RGB section of a Matrox Corona
2. Meteor-II/Multi-channel rev. 2 to start shipping in Q3 2000
3. Optimal input voltage for the frame grabber is the digitizer's overall voltage range. The minimum-to-maximum voltage range can be found in the Board Specific Notes manual for the respective frame grabber
4. In ActiveMIL/ActiveMIL-Lite use Digitizer.InputGain = mGain × x where x is dependent on the peak-to-peak voltage including synchronization
5. Reference levels are initially set in the dcf but can be overridden using MIL/ActiveMIL
6. In ActiveMIL/ActiveMIL-Lite use Digitizer.BlackReference or Digitizer.WhiteReference = x, where x is an integer between 0 and 255
7. Also referred to as M_MIN_LEVEL and M_MAX_LEVEL in MIL/ActiveMIL