



VESA GTF Standard

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Generalized Timing Formula(GTF™) Standard

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Purpose

The GTF is a standard method for generating general purpose display timings. Whilst bringing standardization, it does not restrict the market to fixed, pre-defined formats or refresh rates and thus allows differentiation within a standardized environment.

Summary

VESA has defined a standard method by which new formats and timings can be generated. This will allow much greater flexibility in the choice of refresh rates and pixel formats than currently available with existing discrete monitor timings. The VESA Generalized Timing Formula (GTF) describes a computational method that will provide standardization and yet also enables new features to be added to graphics systems and monitors, such as user defined image resolution and low-cost automatic self-alignment of display devices.

THE GENERALIZED TIMING FORMULA (GTF)

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GTF EXCEL™ SPREADSHEET

As part of this standard, a companion EXCEL™ V4.0 spreadsheet of the GTF is available from the VESA FTP site or the VESA office (**GTF_V1R1.XLS**). This spreadsheet illustrates the GTF method and allows manual computation of timing parameters and demonstration of the computation method. This written specification documents the mathematical methods behind the spreadsheet in order to demonstrate how the GTF can be programmed into software.

In case of any confusion or dispute regarding interpretation or calculation of any of the GTF variables in any implementation, the released version of GTF spreadsheet shall be used as the definitive calculation method to demonstrate correct computation of the parameters.

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Additions to Introduction include statement on pixel clock reference, usage etc.

Updated to include detailed information on the definition of syncs, sync polarity information.

Q and A appendix added.

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Acknowledgments and patent disclaimer information added.

Table of contents added.

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Definition of ROUND operator given in section 5.

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Page 1: VESA office telephone numbers added

Page 3: Reworded GTF definition to make the spec the definitive method.

Added figure 1 label to sync definition diagram: incremented all figure numbers

Added Table numbers and contents reference

Added new section 5 to define GTF compliance and renumbered old section 5 as section 6

Modified Q&A regarding matrix question, as per feedback from review

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1 INTRODUCTION

The GTF is a standard method for generating general purpose display timings. Whilst bringing standardization, it does not restrict the market to fixed, pre-defined formats or refresh rates and thus allows differentiation within a standardized environment.

The GTF is intended as a tool to be used by all parties concerned with video signal generation. Video graphics software drivers should utilize the GTF method to generate timing parameters for any new, previously unspecified video modes, either spontaneously within the PC from a set of system inputs, or in pre-defined and stored tables. Video graphic generation hardware should use and be compatible with the GTF method for definition of any new modes of operation. Monitor designs should the GTF method to determine how to interpolate for new unrecognized timings, and consequently set image size and geometry parameters.

A principle objective of the GTF is that it should allow predictable timing parameters to be derived from minimal information. Using GTF, it is possible to construct a complete set of timing parameters given the following basic information:

- 1) Pixel format (e.g. 800x600)
- 2) Whether or not overscan borders are required
- 3) Whether interlace is required
- 4) ONE of the following:
 - Vertical refresh rate required
 - or: Horizontal frequency required
 - or: Pixel clock required

Using any one of the three options in (4) above, the same timing parameters will result from the GTF. This allows the calculation to be 'driven' by intelligent system software to obtain best overall system performance, especially in conjunction with plug and play peripherals that can communicate the hardware capabilities. For example, knowing the limitations of a CRT display in vertical and horizontal scan frequencies, the maximum pixel clock rate of a graphics card, the desired vertical refresh rate of a User and the pixel format from an application, new system software can generate a new timing to meet the constraints of the hardware. Most importantly, the GTF method also allows the possibility for displays to predict where the image may fall and thus enables the possibility of automatic image set up for any new mode.

A further objective is to minimize compatibility problems that frequently result when graphics cards generate unique timings, or cannot meet the exact timing parameters of standard formats. GTF provides a means for these graphics cards to generate these unique timings based around default timing characteristics that can be supported by most monitors.

Another use of the GTF is to enable new timing parameters to be generated for displays running at a constant horizontal scan frequency, potentially allowing simplified and lower cost display designs. This will also result in maximized vertical refresh rates, which is generally seen as an ergonomic advantage.

In order to minimize the amount of information required at time of computation, and also to ensure basic standardization and compatibility in formats that are produced, it is necessary to standardize the values of all other variables that influence the calculation of timing parameters. In this specification, a standard definition and default value is given to each of these variables, in addition to a standard method of timing parameter computation.

The GTF standard can be used with any pixel clock reference frequency, and will provide timings within the hardware constraints of this and other system parameters. However, it is expected that some applications will continue to require specific discrete timing standards, as in the case of timings intended to be compatible with video or other systems. In order to permit such timings to be produced as precisely as possible, and to increase the likelihood that controllers from different manufacturers will produce identical timings using either GTF or current and future discrete timings, VESA recommends that the fixed reference frequency (i.e. typically the fixed crystal reference used by the video phase locked oscillator for subsequent programmable pixel clock synthesis) be one selected from the $N \times 2.25$ MHz family of rates. This set has been selected for its compatibility with worldwide video timing standards, and will also be used wherever possible in future Discrete Monitor Timing (DMT) standards produced by VESA. Whilst this is a recommendation, it should be noted that use of a reference from this particular set is not a requirement for compliance to the VESA GTF standard.

2 TERMS AND DEFINITIONS

2.1 Timing Parameters

Several different sync formats are used by display systems, including separate syncs, composite syncs and sync on green. GTF has been formulated for optimum compatibility. In addition, careful consideration has been given to the choice of sync width and positioning relative to the video to ensure best operation with the majority of present day display technology.

The following definitions are used within this specification to describe the important timing intervals (see figure 1):

Addressable Video (t_{video})

The period during which active image video information is transmitted.

Margin (t_{margin})

The period during which background colored border maybe displayed in order to allow the CRT image to extend beyond the limits of the surrounding bezel on overscan type monitors. Typically, the margin period cannot be addressed on an individual pixel basis by the image buffer. On most non-overscan type systems, the margin period is zero.

Blanking (t_{blank})

The period between the end of one line (horizontal) or frame (vertical) of the video and margin period and the start of the next line or frame of video.

Sync pulse width (t_{sync})

The period of the active sync pulse.

Front porch (t_{fp})

The period between the end of one line (horizontal) or frame (vertical) of the video and margin period and the start of the sync pulse.

Back porch (t_{bp})

The period between the end of the sync pulse and the start of the next line (horizontal) or frame (vertical) of the following video and margin period.

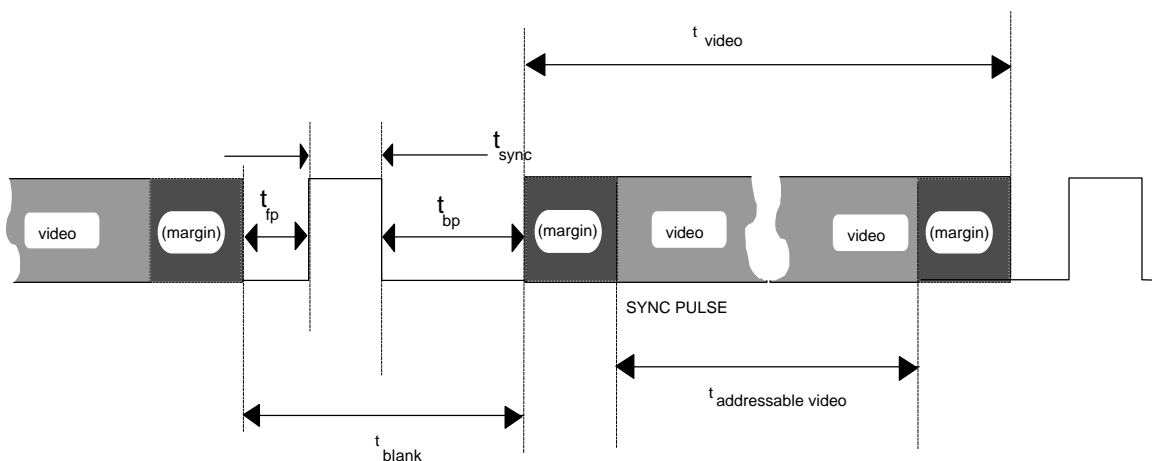


FIGURE 1: SYNC PULSE TIMING DEFINITIONS

2.2 Sync pulse position

A major source of incompatibility in discrete timings is the variability in position of the sync pulses within the blanking period, which in turn causes variation in the displayed image position. To overcome this, the GTF uses a standard definition to ensure the predictability of the sync position within the blanking period. From the following information (see also Section 3 - DEFAULT PARAMETER VALUES), and that attained during manufacturing alignment, it is possible for display devices to estimate to a reasonable degree of accuracy where to position the image of any new previously unknown modes.

The horizontal sync pulse period is defined as a fixed percentage of the total line period. The trailing edge of the pulse is positioned exactly midway within the total blanking period. This ensures there is always sufficient time after the sync pulse for the generation of video DC recovery signals. The vertical sync pulse is defined as a fixed integer number of horizontal line periods. The position of the vertical sync pulse is determined by the front porch period, which is also set as a fixed number of horizontal line periods. For the special case of interlaced displays, an additional half line is added to this period for alternate fields.

2.3 Sync pulse polarity

The sync polarities used for GTF should be as follows in Table 1:

| <u>SYNC FORMAT</u> | <u>POLARITY</u> |
|--------------------|-----------------|
| HORIZONTAL | NEGATIVE |
| VERTICAL | POSITIVE |
| COMPOSITE | NEGATIVE |

TABLE 1: GTF SYNC POLARITIES

Choice of sync pulse polarity is important because this aids the monitor in identifying which particular mode is being displayed, and hence how to set the parameters controlling the displayed image size and position etc. Whilst all combinations of polarities exist in use, some polarity combinations are used more than others; for instance, VESA DMT typically use positive going sync signals.

An additional consideration is that the GTF timing for 640x480 at 31.5kHz gives horizontal timing parameters identical to standard VGA, when no margins are used. However, under these conditions, the vertical refresh rate is slightly faster. To avoid confusion between these modes, the GTF sync polarities have been chosen to be different from that of standard VGA.

2.4 Basic Horizontal Blanking Duty Cycle Formula:

Horizontal blanking duty cycle has a great impact on the system design, particularly as there are many opposing requirements. Making blanking time long, for instance, has both advantages and disadvantages:

Advantages:

- Lower cost, lower power dissipation horizontal scan/CRT yoke design at high frequencies
- More time for video RAM update during blanking interval

Disadvantages:

- Higher power dissipation horizontal scan/CRT yoke design at low frequencies
- Higher pixel clock operation, more expensive graphics chip sets, RAM etc.
- Higher video rate and amplitude requiring expensive, high power dissipation video amplifiers.
- More RFI (radio frequency interference)

- Lower brightness/ higher instantaneous CRT drive requirements, giving poor spotsizes, focus, etc.

Variations in blanking times between formats also causes major differences in the displayed image width and position. For predictability of any standard timing, it thus imperative for the GTF to have a standard method to define (and thus predict) the blanking time at any operating point. As communication between monitor and CPU cannot be assumed, it must be possible for the monitor to be able to compute the blanking time, using either analog or digital methods, by using a simple relationship linking blanking time to the horizontal period or frequency.

When defined as a percentage of the horizontal period, blanking duty cycle is given by:

$$\text{Blanking Duty Cycle}(\%) = (1 - (t_{\text{active}} / T)) * 100 (\%) \quad [1]$$

where:

$$t_{\text{active}} = \text{the active video time}$$

$$T = \text{the horizontal period} = 1/F$$

where:

$$F = \text{Horizontal frequency}$$

Note also that active video time can be expressed as:

$$t_{\text{active}} = \frac{n}{P} \quad [2]$$

where:

$$n = \text{no of horizontal active video image pixels}$$

$$P = \text{Pixel clock frequency}$$

Combining these, the blanking duty cycle can also be simply expressed as:

$$\text{Blanking Duty Cycle} (\%) = (1 - \frac{(F * n)}{P}) * 100 (\%) \quad [3]$$

These various forms of the same definition are used within the GTF to derive different horizontal timing parameters.

The general form of the horizontal blanking equation used within the GTF is:

$$\text{Blanking Duty Cycle}(\%) = C' - (M' / F) \quad [4]$$

where:

$$F = \text{Horizontal frequency (kHz)}$$

$$C' = \text{Basic offset constant (\%)}$$

$$M' = \text{Basic gradient constant (\%/kHz)}$$

This equation has been chosen for its empirical best fit to the average existing industry standard timings used with most monitors.

Figure 2 below shows a scatter plot of some standard timings and the curve resulting from this equation using default values of:

C' = 30
M' = 300

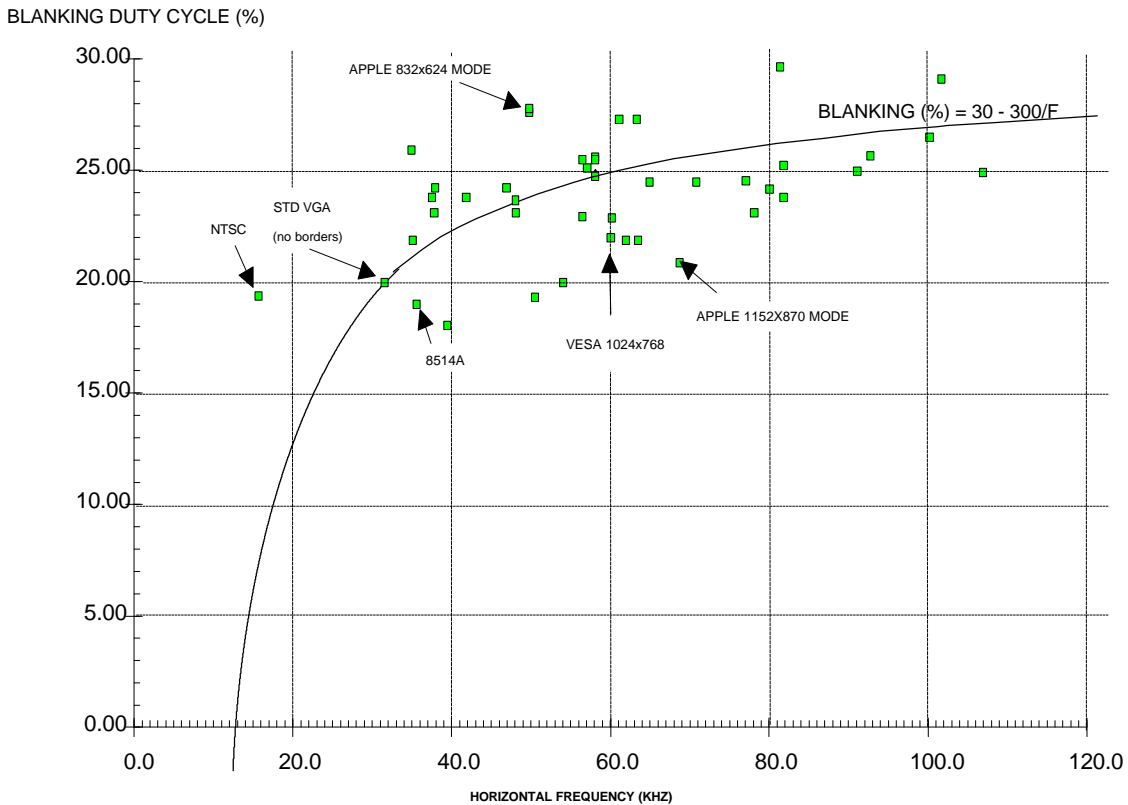


FIGURE 2: BASIC HORIZONTAL DUTY CYCLE CURVE

It can be seen that the empirically derived curve lies mid way between existing modes. It also hits the 20% point at the 60Hz VGA frequency, which is a valuable aid to compatibility.

Using the formula linking blanking time to horizontal frequency, it is possible to establish a direct relationship between pixel clock frequency and horizontal frequency:

Combining equations [3] and [4] gives:

$$F = \frac{2 * M'}{(C' - 1) \pm \sqrt{\left\{ \left((1 - C')^2 \right) + \frac{(4 * M' * n)}{P} \right\}}} \quad [5]$$

This unique relationship between these parameters is a critical feature of the GTF. For any given pixel format, there is always a direct relationship between pixel clock and horizontal frequency - if one parameter is known, the other can be computed. It is this attribute that allows the mode definition to be reduced to the simplified form of requiring only one defining frequency .

2.5 Accuracy of timing parameters

The equation given in [4] above, has a fundamental importance to the design of a system that will allow automatic centering and width adjustment in a monitor when new modes are encountered. By measuring the

horizontal frequency (a requirement in multi-sync monitors for mode recognition) blanking duty cycle, and hence period, can be easily computed.

Theoretical accuracy of the predicted image position is limited due to the quantization effect arising from the number of pixels within the character cell and subsequent rounding errors. This results in a theoretical error of +/- half a character cell in the horizontal position of either side of the image, giving a total possible error of +/- one character cell in width and overall centering. In practice, small errors may also result from inaccuracies of the deflection system, depending upon the quality of the display system design.

The accuracy of blanking period determination (and subsequent size estimation for a new mode) within the monitor will be dependent upon each individual implementation, but this allows the monitor designer considerable scope for trading off accuracy versus cost/complexity. As a standard formula is used, monitors can use microprocessors to either compute the blanking time (having measured horizontal frequency), directly or by using look-up tables. Analog monitors can use analog computational methods, converting frequency to voltage to derive an analog signal proportional to the blanking time.

2.6 Extended Horizontal Blanking Formula:

In order to make the GTF as general as possible, and also to allow future GTF versions for other display devices than CRTs (which may require considerably different values of timing parameters) the basic constants C' and M' within the basic horizontal blanking formula have been expanded:

$$[C'] = (([C] - [J]) * [K] / 256) + [J] \quad [6]$$

$$[M'] = [K] / 256 * [M] \quad [7]$$

where:

- C = Extended offset constant (%)
- M = Extended gradient constants (%/kHz)
- K = Blanking time scaling factor
- J = Scaling factor weighting

Note that:

$$\begin{aligned} C' &= J \\ M' &= 0 \\ &\text{for } K = 0 \end{aligned}$$

and:

$$\begin{aligned} C' &= C \\ M' &= M \\ &\text{for } K = 256 \end{aligned}$$

Software versions of GTF should code the coefficients C' and M' as variables defined in this way, even though they are subsequently treated as constants. Specifically, K , the blanking time scaling factor, allows a single coefficient to be used to alter the characteristics of the basic blanking equation. Altering K from its default value of 128 allows a series of curves to be produced passing through the 20% duty cycle at VGA

frequencies but with higher or lower blanking duty cycle at high frequencies, as show in figure 3.

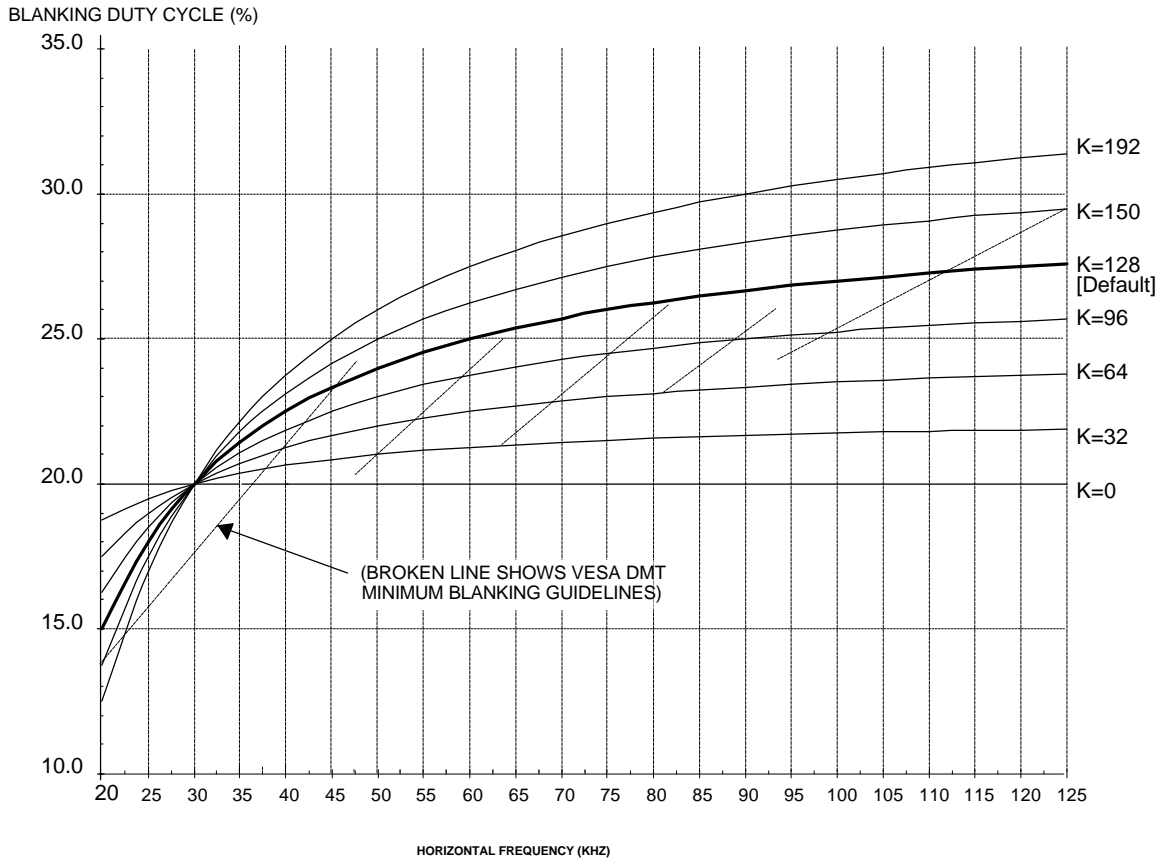
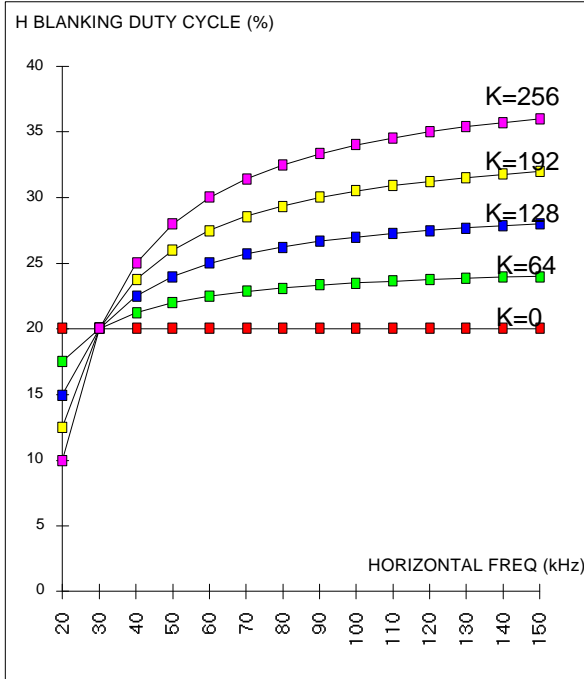
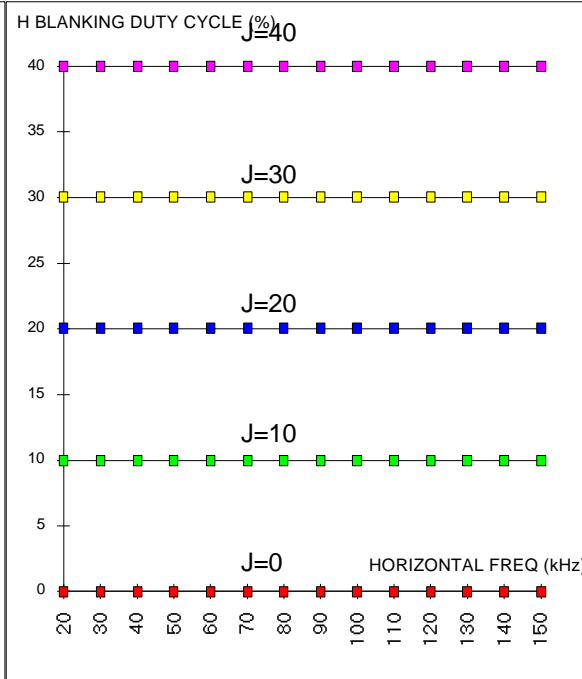


FIGURE 3: BLANKING DUTY CYCLE CURVES WITH VARIATIONS IN K

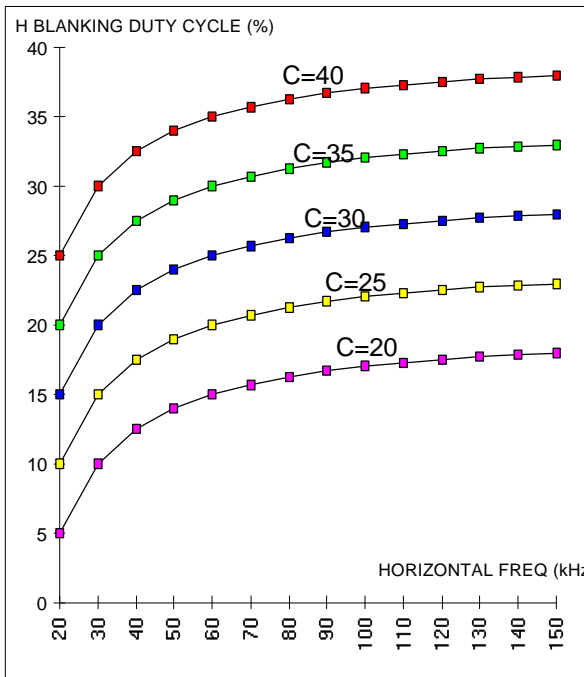
Whilst the majority of applications will use the default values for C, M, K and J, future applications where bi-directional communication can be established may wish to treat these as system variables in order to optimize the GTF equations for a particular device. However, in the absence of this communication, the defined default values must be used at all times. Figure 4 shows the effect of variations in the extended blanking constants.



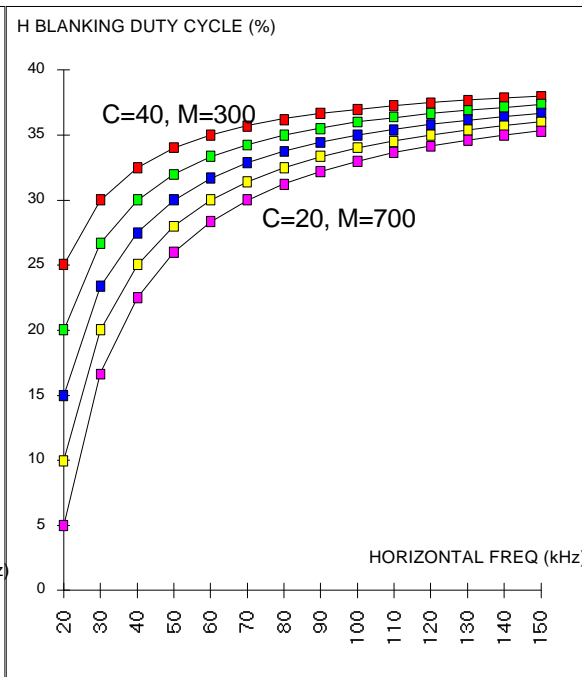
C=40, J=20, M= 600, K in increments of 64



C=30, K=0, M= ANY VALUE, J in increments of 10



M=300, K=256, J=ANY VALUE,
C in increments of 5



K=256, J=ANY VALUE,
C in increments of 5, M in increments of 100

[J] **DEFAULT VALUE: 20%**
 The blanking formula scaling factor weighting (see also section on blanking formula).

4 SYSTEM VARIABLES

As most of the parameters that define the timings have been previously defined by default values, there are only 6 variables that can normally be varied under system control to affect the timing outputs. These are:

[H PIXELS]:

This is the number of active image pixels displayed on a line, not including any margin.

[V LINES]:

This is the number of vertical lines in the displayed image.

[MARGINS RQD?]:

If margins are required, this flag is set as Y, if not, no margins are assumed. Margins maintain a constant blanking time in both vertical and horizontal scans; they add an integer number of character cells (horizontal) or lines (vertical) around the active image area. As the pixel format of the image is maintained, this consequently increases the pixel clock rate and reduces the vertical refresh rate. Margins are generally only used in over-scan applications.

[INT RQD?]:

If interlace is required, this flag is set as Y, if not, non-interlace is assumed. (If interlace is requested, the number of vertical lines assumed by the calculation must subsequently be halved, as the computation calculates the number of vertical lines per field).

[I/P PARAMETER]:

In the definition used within this spec, the variable [I/P PARAMETER] is used to indicate which frequency parameter will be specified, as in Table 2:

| [I/P PARAMETER] | REQUIRED PARAMETER | VARIABLE |
|-----------------|-------------------------------|--------------------|
| 1 | VERTICAL FRAME FREQUENCY (Hz) | [V FRAME RATE RQD] |
| 2 | HORIZONTAL FREQUENCY (kHz) | [H FREQ] |
| 3 | PIXEL CLOCK RATE (MHz) | [H PIXELS] |

TABLE 2: DEFINITION OF [I/P PARAMETER]

[I/P FREQ RQD]:

This is a real number which is used to signify the frequency in Hz for vertical refresh (i.e. 60 = 60Hz), kHz for horizontal (60=60kHz) or MHz for pixel clock (60 = 60MHz).

5 COMMUNICATING GTF COMPLIANCE THROUGH DDC/EDID

5.1. Definition of GTF Compliant Monitors and Graphics Systems

To be 'GTF compliant' a monitor should be designed such that it treats any new, unknown modes with sync signal polarities according to section 2.3 as GTF modes. The monitor hardware and/or software shall be optimized to minimize any position or size errors in the displayed image based upon that assumption. No portion of any GTF derived image should be hidden or reversed, and any GTF image should be completely visible within the displayable area.

The EDID of a GTF compliant monitor shall signify that the GTF assumption is used for new mode calculation by setting bit 0 of the 'Feature Support' byte to 1 and must communicate the limits of operation in a Monitor Descriptor Block according to section 5.2. If bit 0 of the 'Feature Support' byte is set to 1, but no limits of operation are included, the monitor must be treated as non-GTF compliant, as per section 5.4 or 5.5.

GTF compliant graphics systems must be capable of determining whether the attached monitor is GTF compliant, through reading the EDID, and must be capable of handle both GTF compliant and non-GTF monitors according to the methods outlined below. Any new formats produced by the graphics system must be created with all timing parameters according to the GTF definition.

In all cases, when the graphics system derives new timings, the system software must ensure that all timing parameters produced remain within the limits of capability of the hardware. If the value of an input parameter (such as a refresh rate requirement) causes the output parameters to lie outside of the range of capabilities of the hardware, the system should not allow the use of that timing.

5.2 Communicating Limits Of Monitor Operation For GTF Compliant Monitors

The GTF compliant monitor must communicate its range of operation by defining the Pixel clock, Horizontal and Vertical scan frequency ranges in a Monitor Descriptor block within the EDID, as per EDID version 1, revision 1.

In addition, Byte 10, bit 0 of this block signifies whether overscan margins are required:

- Byte 10, bit 0 = 0 indicates no overscan margins (default)
- Byte 10, bit 0 = 1 indicates overscan margins required

The GTF compliant graphics system must be capable of reading these limits and using them to calculate any new timing requirements.

5.3 GTF System Driver With GTF Compliant Monitors

If the EDID indicates that the monitor is GTF compliant, the graphics system using the GTF method may automatically generate new timings within the range of the operating frequencies as signified in the Monitor Descriptor block.

5.4 GTF System Driver With Non-GTF DDC Monitors

This method should only be used for non-GTF monitors (i.e.,: when bit 0 of the 'Feature Support' byte is set to 0, or if no Monitor Descriptor Block is included). It is included mainly to allow existing DDC monitors to be used with a GTF system driver.

It must be noted that the non-GTF monitor may not be capable of automatically displaying the image on the screen within acceptable limits of operation, or may require significant manual adjustment by the User. When a monitor with bit 0 of the 'Feature Support' byte is set to 0 is used, it is mandatory that the system software display a suitable warning message to the User, stating that the User should check for normal operation of the monitor and that adjustment may be necessary, before switching to the new GTF mode. It is also recommended that the system will prompt the User to confirm that the new mode is viewable within a specified time period. If no confirmation is received by the end of that period, the system can revert back to the previous known preset mode.

If bit 1 of the 'Feature Support' byte is set to 1 but no Monitor Descriptor Block is given, it can be assumed that the monitor is compatible with GTF signals, but not fully compliant, and it is optional to display the warning message within the calculated range as determined by the following method. Outside of this calculated range, it must be treated according to section 5.5.

The system driver will derive information regarding the monitor limits of operation from the list of timings supported by the monitor and listed in the EDID as follows and will not drive the monitor outside of this range, unless overridden by User defined limits (as according to section 5.5):

Horizontal rate range.

- The minimum horizontal scan rate is defined as the lowest scan rate specified in any Established, Standard or Detailed Timing supported by the monitor, or the lower limit of the GTF equation, whichever is greater.
- The maximum horizontal scan rate is defined as the highest scan rate specified in any Established, Standard or Detailed Timing supported by the monitor.

Vertical rate range.

- The minimum vertical refresh rate is defined as the lowest refresh rate specified in any Established, Standard or Detailed Timing supported by the monitor, or the lower limit of the GTF equation, whichever is greater.
- The maximum vertical refresh rate is defined as the highest refresh rate specified in any Established, Standard or Detailed Timing supported by the monitor.

Pixel clock.

- The maximum pixel clock is defined as the maximum pixel clock defined in any Established, Standard or Detailed Timing supported by the monitor.

No overscan margins can be used when range limits are specified using this method.

5.5 GTF System Driver With User Defined Limits For Non-GTF Monitors

At the system designers discretion, a manual method may be used to allow the User to check and directly override limits of monitor operation. Such a method may be useful when:

- a) the monitor is an older model that does not communicate via DDC
- b) the limits of existing modes as calculated by the method outlined in section 5.4 do not represent full use of the monitors capabilities

The manual method of setting GTF timings should not be used to override the limits as specified in a GTF compliant monitor.

It must be noted that timings produced by this method may be outside of the limits of safe operation of the monitor. Also, the monitor may not be capable of automatically displaying the image on the screen within acceptable limits of operation, or may require significant manual adjustment by the User. When the manual method is used to override limits of operation, it is mandatory that the system software display a suitable warning message to the User, stating that the User should check for normal operation of the monitor and that adjustment may be necessary, before switching to the new GTF mode. It is recommended that the system will prompt the User to confirm that the new mode is viewable within a specified time period. If no confirmation is received by the end of that period, the system can revert back to the previous known preset mode.

5.6 Summary of Monitor GTF Compliance

| GTF EDID Feat Sup byte | EDID Mon Desc block | GTF COMPLIANT | GTF SYSTEM WARNING |
|-----------------------------------|--------------------------------|----------------------|--|
| 0 | NOT PRESENT | NO | MANDATORY |
| 0 | PRESENT | NO | MANDATORY |
| 1 | NOT PRESENT | NO | OPTIONAL - inside existing limits MANDATORY - outside existing timing limits |
| 1 | PRESENT | YES | NOT NECESSARY |

TABLE 3: SUMMARY OF MONITOR GTF COMPLIANCE

6 COMPUTATION OF TIMING PARAMETERS

6.1 Flow Chart Of GTF Method

When the values of the system variables have been determined from an examination of the system constraints and capabilities, the timing parameters can be calculated as in the flow chart shown in figure 5.

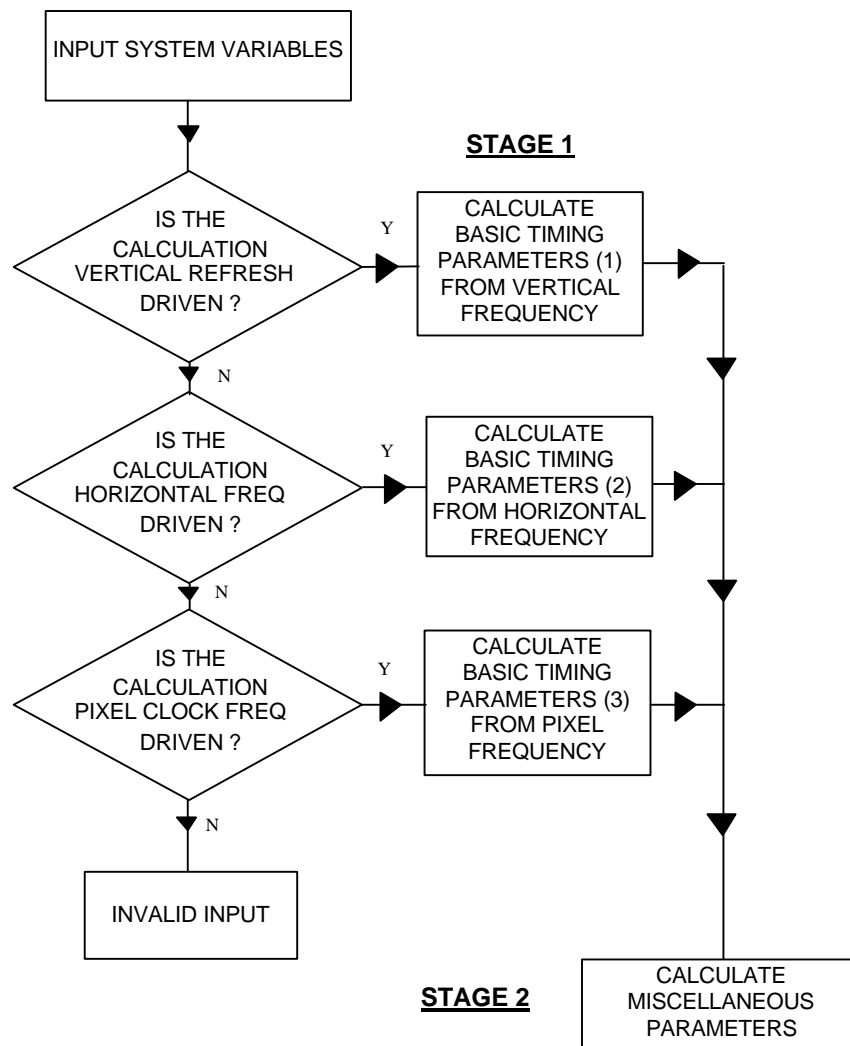


FIGURE 5: THE GTF CALCULATION

The calculation is carried out in two stages: the first stage determines basic timing parameters. Depending upon whether the input system variable is horizontal, vertical or pixel clock frequency, different methods are used for calculation of the same basic parameters.

Many of the equations used in the three alternative methods of the first stage are the same, but are carried out in a different sequence. For clarity, the calculation sequence shown below specifies each line of the calculation as if the stage were carried out in isolation, even though the same equations may be used

elsewhere. In practice, for code minimization, the same equation routine may be obviously be called from different places.

The second stage determines the remaining miscellaneous parameters.

In these equations, multiple forms of the same parameter may be calculated; e.g.: horizontal period may be calculated in us, pixels and character cells. These calculations are shown for completeness, though in some instances the actual calculation is trivial.

6.2 Rounding Definition

In the following formulae, the Microsoft™ EXCEL™ definition of ROUND(X,Y) has been used, where

X is the number to be rounded

and Y defines the number of digits to round the number to.

If $Y > 0$ then the number is rounded to the specified number of decimal places.

If $Y = 0$, then the number is rounded to the nearest integer

If $Y < 0$, then the number is rounded to the left of the decimal point.

6.3 Using Vertical Refresh Frequency To Find Stage 1 Parameters

Overview:

Initially, the horizontal period is estimated [H PERIOD EST] by subtracting [MIN VSYNC+BP] from the known vertical period and then dividing by the total number of image lines, including the margin where used. This is only an estimate because the variable [MIN VSYNC+BP] is not exact (i.e. it is not necessarily an integer multiple of the line period).

From this estimate, the number of lines in the period [MIN VSYNC+BP] can be calculated. This then allows the total number of lines in the field to be estimated. When the total number of lines in the field are known, the horizontal period can be accurately found.

Subsequent horizontal timing parameters can be accurately found using the blanking duty cycle equation.

1. In order to give correct results, the number of horizontal pixels requested is first processed to ensure that it is divisible by the character size, by rounding it to the nearest character cell boundary:

$$[H \text{ PIXELS RND}] = ((\text{ROUND}([H \text{ PIXELS}]/[CELL \text{ GRAN RND}],0)) * [CELL \text{ GRAN RND}])$$

2. If interlace is requested, the number of vertical lines assumed by the calculation must be halved, as the computation calculates the number of vertical lines per field. In either case, the number of lines is rounded to the nearest integer.

$$[V \text{ LINES RND}] = (\text{IF}([INT \text{ RQD?}] = "y", \text{ROUND}([V \text{ LINES}]/2,0), \text{ROUND}([V \text{ LINES}],0)))$$

3. Find the frame rate required:

$$[V \text{ FIELD RATE RQD}] = (\text{IF}([INT \text{ RQD?}] = "y", [I/P \text{ FREQ RQD}] * 2, [I/P \text{ FREQ RQD}]))$$

4. Find number of lines in Top margin:

$$[TOP \text{ MARGIN (LINES)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", \text{ROUND}([MARGIN\%]/100 * [V \text{ LINES RND}],0),0))$$

5. Find number of lines in Bottom margin:

$$[BOT \text{ MARGIN (LINES)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", \text{ROUND}([MARGIN\%]/100 * [V \text{ LINES RND}],0),0))$$

6. If interlace is required, then set variable [INTERLACE]=0.5:

$$[INTERLACE] = (\text{IF}([INT \text{ RQD?}] = "y", 0.5, 0))$$

7. Estimate the Horizontal period

$$[H \text{ PERIOD EST}] = ((1/[V \text{ FIELD RATE RQD}]) - [MIN \text{ VSYNC} + BP]/1000000) / ([V \text{ LINES RND}] + (2 * [TOP \text{ MARGIN (LINES)}]) + [MIN \text{ PORCH RND}] + [INTERLACE]) * 1000000$$
8. Find the number of lines in V sync + back porch:

$$[V \text{ SYNC} + BP] = \text{ROUND}(([MIN \text{ VSYNC} + BP] / [H \text{ PERIOD EST}]), 0)$$
9. Find the number of lines in V back porch alone:

$$[V \text{ BACK PORCH}] = [V \text{ SYNC} + BP] - [V \text{ SYNC RND}]$$
10. Find the total number of lines in Vertical field period

$$[TOTAL \text{ V LINES}] = [V \text{ LINES RND}] + [TOP \text{ MARGIN (LINES)}] + [BOT \text{ MARGIN (LINES)}] + [V \text{ SYNC} + BP] + [INTERLACE] + [MIN \text{ PORCH RND}]$$
11. Estimate the Vertical field frequency:

$$[V \text{ FIELD RATE EST}] = 1 / [H \text{ PERIOD EST}] / [TOTAL \text{ V LINES}] * 1000000$$
12. Find the actual horizontal period:

$$[H \text{ PERIOD}] = [H \text{ PERIOD EST}] / ([V \text{ FIELD RATE RQD}] / [V \text{ FIELD RATE EST}])$$
13. Find the actual Vertical field frequency:

$$[V \text{ FIELD RATE}] = 1 / [H \text{ PERIOD}] / [TOTAL \text{ V LINES}] * 1000000$$
14. Find the Vertical frame frequency:

$$[V \text{ FRAME RATE}] = (\text{IF}([INT \text{ RQD?}] = "y", [V \text{ FIELD RATE}] / 2, [V \text{ FIELD RATE}]))$$
15. Find number of pixels in left margin:

$$[LEFT \text{ MARGIN (PIXELS)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", (\text{ROUND}([H \text{ PIXELS RND}] * [MARGIN\%] / 100 / [CELL \text{ GRAN RND}]), 0)) * [CELL \text{ GRAN RND}], 0))$$
16. Find number of pixels in right margin:

$$[RIGHT \text{ MARGIN (PIXELS)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", (\text{ROUND}([H \text{ PIXELS RND}] * [MARGIN\%] / 100 / [CELL \text{ GRAN RND}]), 0)) * [CELL \text{ GRAN RND}], 0))$$
17. Find total number of active pixels in image and left and right margins:

$$[TOTAL \text{ ACTIVE PIXELS}] = [H \text{ PIXELS RND}] + [LEFT \text{ MARGIN (PIXELS)}] + [RIGHT \text{ MARGIN (PIXELS)}]$$
18. Find the ideal blanking duty cycle from the blanking duty cycle equation:

$$[IDEAL \text{ DUTY CYCLE}] = [C'] - ([M'] * [H \text{ PERIOD}] / 1000)$$
19. Find the number of pixels in the blanking time to the nearest double character cell:

$$[H \text{ BLANK (PIXELS)}] = (\text{ROUND}([TOTAL \text{ ACTIVE PIXELS}] * [IDEAL \text{ DUTY CYCLE}] / (100 - [IDEAL \text{ DUTY CYCLE}]) / (2 * [CELL \text{ GRAN RND}]), 0)) * (2 * [CELL \text{ GRAN RND}])$$
20. Find total number of pixels:

$$[TOTAL \text{ PIXELS}] = [TOTAL \text{ ACTIVE PIXELS}] + [H \text{ BLANK (PIXELS)}]$$
21. Find pixel clock frequency:

$$[PIXEL \text{ FREQ}] = [TOTAL \text{ PIXELS}] / [H \text{ PERIOD}]$$
22. Find horizontal frequency:

$$[H \text{ FREQ}] = 1000 / [H \text{ PERIOD}]$$

6.4 Using Horizontal Scan Frequency To Find Stage 1 Parameters

Overview:

The total number of lines in each field is first calculated, similarly to the vertical case above, and from that the vertical refresh rate can be found. Then, using the blanking duty cycle, the blanking duration, and subsequently the associated horizontal parameters, can be found.

1. In order to give correct results, the number of horizontal pixels requested is first processed to ensure that it is divisible by the character size, by rounding it to the nearest character cell boundary:

$$[H \text{ PIXELS RND}] = ((\text{ROUND}([H \text{ PIXELS}] / [CELL \text{ GRAN RND}], 0)) * [CELL \text{ GRAN RND}])$$
2. If interlace is requested, the number of vertical lines assumed by the calculation must be halved, as the computation calculates the number of vertical lines per field. In either case, the number of lines is rounded to the nearest integer.

$$[V \text{ LINES RND}] = (\text{IF}([INT \text{ RQD?}] = "y", \text{ROUND}([V \text{ LINES}] / 2, 0), \text{ROUND}([V \text{ LINES}], 0)))$$
3. Find the horizontal frequency required:

$$[H \text{ FREQ}] = [I/P \text{ FREQ RQD}]$$
4. Find number of lines in Top margin:

$$[TOP \text{ MARGIN (LINES)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", \text{ROUND}([MARGIN\%] / 100 * [V \text{ LINES RND}], 0), 0))$$
5. Find number of lines in bottom margin:

$$[BOT \text{ MARGIN (LINES)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", \text{ROUND}([MARGIN\%] / 100 * [V \text{ LINES RND}], 0), 0))$$
6. If interlace is required, then set variable $[INTERLACE] = 0.5$

$$[INTERLACE] = (\text{IF}([INT \text{ RQD?}] = "y", 0.5, 0))$$
7. Find the number of lines in V sync + back porch:

$$[V \text{ SYNC+BP}] = \text{ROUND}([MIN \text{ VSYNC+BP}] * [H \text{ FREQ}] / 1000, 0)$$
8. Find the number of lines in V back porch alone:

$$[V \text{ BACK PORCH}] = [V \text{ SYNC+BP}] - [V \text{ SYNC RND}]$$
9. Find the total number of lines in Vertical field period

$$[TOTAL \text{ V LINES}] = [V \text{ LINES RND}] + [TOP \text{ MARGIN (LINES)}] + [BOT \text{ MARGIN (LINES)}] + [INTERLACE] + [V \text{ SYNC+BP}] + [MIN \text{ PORCH RND}]$$
10. Find the actual Vertical field frequency:

$$[V \text{ FIELD RATE}] = [H \text{ FREQ}] / [TOTAL \text{ V LINES}] * 1000$$
11. Find the Vertical frame frequency:

$$[V \text{ FRAME RATE}] = (\text{IF}([INT \text{ RQD?}] = "y", [V \text{ FIELD RATE}] / 2, [V \text{ FIELD RATE}]))$$
12. Find number of pixels in left margin:

$$[LEFT \text{ MARGIN (PIXELS)}] = (\text{IF}([MARGINS \text{ RQD?}] = "Y", (\text{ROUND}([H \text{ PIXELS RND}] * [MARGIN\%] / 100 / [CELL \text{ GRAN RND}], 0)) * [CELL \text{ GRAN RND}], 0))$$

13. Find number of pixels in right margin:
 [RIGHT MARGIN (PIXELS)]

$$=(\text{IF}([\text{MARGINS RQD?}]="Y",(\text{ROUND}([\text{H PIXELS RND}]*[\text{MARGIN\%}]/100/[\text{CELL GRAN RND}],0))*[\text{CELL GRAN RND}],0))$$
14. Find total number of active pixels in image and left and right margins:
 [TOTAL ACTIVE PIXELS]=[H PIXELS RND]+[RIGHT MARGIN (PIXELS)]+[LEFT MARGIN (PIXELS)]
15. Find the ideal blanking duty cycle from the blanking duty cycle equation:
 [IDEAL DUTY CYCLE]=[C'] -([M']/[H FREQ])
16. Find the number of pixels in the blanking time to the nearest double character cell:

 [H BLANK (PIXELS)]

$$=(\text{ROUND}([\text{TOTAL ACTIVE PIXELS}]*[\text{IDEAL DUTY CYCLE}]/(100-[\text{IDEAL DUTY CYCLE}]))/(2*[\text{CELL GRAN RND}]),0))*2*[\text{CELL GRAN RND}]$$
17. Find total number of pixels:
 [TOTAL PIXELS]=[TOTAL ACTIVE PIXELS]+[H BLANK (PIXELS)]
18. Find horizontal period:
 [H PERIOD]=1000/[H FREQ]
19. Find pixel clock frequency:
 [PIXEL FREQ]=[TOTAL PIXELS]*[H FREQ]/1000

6.5 Using Pixel Clock Frequency To Find Stage 1 Parameters

Overview:

The total number of active pixels on each line is first calculated. The blanking equation can then be used to find the ideal horizontal period, and from that, the ideal blanking duty cycle can be simply found. The actual blanking duration is found by rounding the ideal blanking time to the nearest multiple of twice the character cell granularity. Knowing that, the total number of pixels on a line is found, and hence the remaining horizontal parameters can be simply calculated.

When the horizontal parameters are known, the vertical parameters can be found in the same way as in above methods.

1. In order to give correct results, the number of horizontal pixels requested is first processed to ensure that it is divisible by the character size, by rounding it to the nearest character cell boundary:
[H PIXELS RND]=((ROUND([H PIXELS]/[CELL GRAN RND],0))*[CELL GRAN RND])
2. If interlace is requested, the number of vertical lines assumed by the calculation must be halved, as the computation calculates the number of vertical lines per field. In either case, the number of lines is rounded to the nearest integer.
[V LINES RND]=(IF([INT RQD?]="y",ROUND([V LINES]/2,0),ROUND([V LINES],0)))
3. Find the pixel clock rate required:
[PIXEL FREQ]=[I/P FREQ RQD]
4. Find number of pixels in left margin:
[LEFT MARGIN (PIXELS)]
=(IF([MARGINS RQD?]="Y",(ROUND(([H PIXELS RND]*[MARGIN%]/100/[CELL GRAN RND]),0))*[CELL GRAN RND],0))
5. Find number of pixels in right margin:
[RIGHT MARGIN (PIXELS)]
=(IF([MARGINS RQD?]="Y",(ROUND(([H PIXELS RND]*[MARGIN%]/100/[CELL GRAN RND]),0))*[CELL GRAN RND],0))
6. Find total number of active pixels in image and left and right margins:
[TOTAL ACTIVE PIXELS] =[H PIXELS RND]+[RIGHT MARGIN (PIXELS)]+[LEFT MARGIN (PIXELS)]
7. Find the ideal horizontal period from the blanking duty cycle equation:
[IDEAL H PERIOD]
=((([C]-100)+(SQRT(((100-[C])^2)+(0.4*[M]*([TOTAL ACTIVE PIXELS]+[RIGHT MARGIN (PIXELS)]+[LEFT MARGIN (PIXELS)])/[PIXEL FREQ]))))/2/[M]*1000
8. Find the ideal blanking duty cycle from the blanking duty cycle equation:
[IDEAL DUTY CYCLE]=[C] -([M]*[IDEAL H PERIOD]/1000)
9. Find the number of pixels in the blanking time to the nearest double character cell:
[H BLANK (PIXELS)]
=(ROUND((([TOTAL ACTIVE PIXELS]*[IDEAL DUTY CYCLE]/(100-[IDEAL DUTY CYCLE]))/(2*[CELL GRAN RND])),0))*2*[CELL GRAN RND])
10. Find total number of pixels:
[TOTAL PIXELS]=[TOTAL ACTIVE PIXELS]+[H BLANK (PIXELS)]
11. Find horizontal frequency:
[H FREQ]=[PIXEL FREQ]/[TOTAL PIXELS]*1000
12. Find horizontal period:
[H PERIOD]=1000/[H FREQ]

13. Find number of lines in Top margin:
 [TOP MARGIN (LINES)]
 =(IF([MARGINS RQD?]="Y",ROUND(((MARGIN%)/100*[V LINES RND]),0),0))
14. Find number of lines in Bottom margin:
 [BOT MARGIN (LINES)]
 =(IF([MARGINS RQD?]="Y",ROUND(((MARGIN%)/100*[V LINES RND]),0),0))
15. If interlace is required, then set variable [INTERLACE]= 0.5:
 [INTERLACE]=(IF([INT RQD?]="y",0.5,0))
16. Find the number of lines in V sync + back porch:
 [V SYNC+BP]=ROUND((([MIN VSYNC+BP]*[H FREQ]/1000),0))
17. Find the number of lines in V back porch alone:
 [V BACK PORCH]=[V SYNC+BP]-[V SYNC RND]
18. Find the total number of lines in Vertical field period
 [TOTAL V LINES]
 =[V LINES RND]+[TOP MARGIN (LINES)]+[BOT MARGIN (LINES)]+[INTERLACE]+[V SYNC+BP]+[MIN PORCH RND]
19. Find the Vertical field frequency:
 [V FIELD RATE]=[H FREQ]/[TOTAL V LINES]*1000
20. Find the Vertical frame frequency:
 [V FRAME RATE]=(IF([INT RQD?]="y",[V FIELD RATE]/2,[V FIELD RATE]))

6.6 Using Stage 1 Parameters To Derive Stage 2 Parameters

The stage 2 parameters uses the output from stage 1 and calculates remaining parameters according to the needs of the system. Not all of these parameters would be needed in a typical system - some are shown for reference only.

1. Find the addressable lines per frame:
[ADDR LINES PER FRAME]=[IF([INT RQD?]="y",[V LINES RND]*2,[V LINES RND])]
2. Find the character time (in ns):
[CHAR TIME]=[CELL GRAN RND]/[PIXEL FREQ]*1000
3. Find the total number of lines in a frame:
[TOTAL LINES PER FRAME]
=[IF([INT RQD?]="y",2*[V LINES RND]+[TOP MARGIN (LINES)]+[BOT MARGIN (LINES)]+[V SYNC+BP]+[INTERLACE]+[MIN PORCH RND]),([V LINES RND]+[TOP MARGIN (LINES)]+[BOT MARGIN (LINES)]+[V SYNC+BP]+[INTERLACE]+[MIN PORCH RND]))]
4. Find the total number of characters in a horizontal line:
[TOTAL H TIME (CHARS)]=ROUND([TOTAL PIXELS]/[CELL GRAN RND],0)
5. Find the horizontal addressable time (in us):
[H ADDR TIME]=[H PIXELS RND]/[PIXEL FREQ]
6. Find the horizontal addressable time (in chars):
[H ADDR TIME (CHARS)]=ROUND([H PIXELS RND]/[CELL GRAN RND],0)
7. Find the horizontal blanking time (in us):
[H BLANK]=[H BLANK (PIXELS)]/[PIXEL FREQ]
8. Find the horizontal blanking time (in chars):
[H BLANK (CHARS)]=ROUND([H BLANK (PIXELS)]/[CELL GRAN RND],0)
9. Find the horizontal blanking + margin time (in us):
[H BLANK + MARGIN]
=[([H BLANK (PIXELS)]+[RIGHT MARGIN (PIXELS)]+[LEFT MARGIN (PIXELS)])/[PIXEL FREQ]
10. Find the horizontal blanking + margin time (in chars):
[H BLANK + MARGIN(CHARS)]
=ROUND([([H BLANK (PIXELS)]+[RIGHT MARGIN (PIXELS)]+[LEFT MARGIN (PIXELS)])/[CELL GRAN RND],0)
11. Find the actual horizontal active video duty cycle (in %):
[ACTUAL DUTY CYCLE]=[H BLANK (CHARS)]/[TOTAL H TIME (CHARS)]*100
12. Find the image video duty cycle (in %):
[BLANK + MARGIN DUTY CYCLE]
=[H BLANK + MARGIN(CHARS)]/[TOTAL H TIME (CHARS)]*100
13. Find the left margin time (in us)
[LEFT MARGIN]=[LEFT MARGIN (PIXELS)]/[PIXEL FREQ]*1000
14. Find the number of characters in the left margin (in chars):
[LEFT MARGIN (CHARS)]=[LEFT MARGIN (PIXELS)]/[CELL GRAN RND]
15. Find the right margin time (in us)
[RIGHT MARGIN]=[RIGHT MARGIN (PIXELS)]/[PIXEL FREQ]*1000
16. Find the number of characters in the right margin (in chars):

[RIGHT MARGIN (CHARS)]=[RIGHT MARGIN (PIXELS)]/[CELL GRAN RND]

17. Find the number of pixels in the horizontal sync period:

[H SYNC (PIXELS)]
=(ROUND((([H SYNC%]/100*[TOTAL PIXELS]/[CELL GRAN RND]),0))*[CELL GRAN RND])

18. Find the number of pixels in the horizontal front porch period:

[H FRONT PORCH (PIXELS)]=(([H BLANK (PIXELS)]/2)-[H SYNC (PIXELS)])

19. Find the number of pixels in the horizontal back porch period:

[H BACK PORCH (PIXELS)]=[H FRONT PORCH (PIXELS)]+[H SYNC (PIXELS)]

20. Find the number of characters in the horizontal sync period:

[H SYNC (CHARS)]=[H SYNC (PIXELS)]/[CELL GRAN RND]

21. Find the horizontal sync period (in us):

[H SYNC]=[H SYNC (PIXELS)]/[PIXEL FREQ]

22. Find the number of characters in the horizontal front porch period:

[H FRONT PORCH (CHARS)]=[H FRONT PORCH (PIXELS)]/[CELL GRAN RND]

23. Find the horizontal front porch period(in us):

[H FRONT PORCH]=[H FRONT PORCH (PIXELS)]/[PIXEL FREQ]

24. Find the number of characters in the horizontal back porch period:

[H BACK PORCH (CHARS)]=[H BACK PORCH (PIXELS)]/[CELL GRAN RND]

25. Find the horizontal back porch period(in us):

[H BACK PORCH]=[H BACK PORCH (PIXELS)]/[PIXEL FREQ]

26. Find the vertical frame period(in ms):

[V FRAME PERIOD]
=(IF([INT RQD?]="y",[TOTAL V LINES]*[H PERIOD]/1000*2,[TOTAL V LINES]*[H PERIOD]/1000))

27. Find the vertical field period(in ms):

[V FIELD PERIOD]=[TOTAL V LINES]*[H PERIOD]/1000

28. Find the addressable vertical period per frame (in ms):

[V ADDR TIME PER FRAME]
=(IF([INT RQD?]="y",[V LINES RND]*[H PERIOD]/1000*2,[V LINES RND]*[H PERIOD]/1000))

29. Find the addressable vertical period per field (in ms):

[V ADDR TIME PER FIELD]=[V LINES RND]*[H PERIOD]/1000

30. Find the number of lines in the odd blanking period:

[V ODD BLANKING (LINES)]=[V SYNC+BP]+[MIN PORCH RND]

31. Find the odd blanking period (in ms):

[V ODD BLANKING]=([V SYNC+BP]+[MIN PORCH RND])*[H PERIOD]/1000

32. Find the number of lines in the even blanking period:

[V EVEN BLANKING (LINES)]=[V SYNC+BP]+(2*[INTERLACE])+[MIN PORCH RND]

33. Find the even blanking period (in ms):

[V EVEN BLANKING]
=([V SYNC+BP]+(2*[INTERLACE])+[MIN PORCH RND])/1000*[H PERIOD]

34. Find the top margin period (in us):

[TOP MARGIN]=[TOP MARGIN (LINES)]*[H PERIOD]

35. Find the odd front porch period (in us):
 $[V \text{ ODD FRONT PORCH}] = ([\text{MIN PORCH RND}] + [\text{INTERLACE}]) * [\text{H PERIOD}]$
36. Find the number of lines in the odd front porch period:
 $[V \text{ ODD FRONT PORCH (LINES)}] = ([\text{MIN PORCH RND}] + [\text{INTERLACE}])$
37. Find the even front porch period (in us):
 $[V \text{ EVEN FRONT PORCH}] = [\text{MIN PORCH RND}] * [\text{H PERIOD}]$
38. Find the vertical sync period (in us):
 $[V \text{ SYNC}] = [V \text{ SYNC RND}] * [\text{H PERIOD}]$
39. Find the even front porch period (in us):
 $[V \text{ EVEN BACK PORCH}] = ([V \text{ BACK PORCH}] + [\text{INTERLACE}]) * [\text{H PERIOD}]$
40. Find the number of lines in the even front porch period:
 $[V \text{ EVEN BACK PORCH (LINES)}] = ([V \text{ BACK PORCH}] + [\text{INTERLACE}])$
41. Find the odd back porch period (in us):
 $[V \text{ ODD BACK PORCH}] = [V \text{ BACK PORCH}] * [\text{H PERIOD}]$
42. Find the bottom margin period (in us):
 $[\text{BOT MARGIN}] = [\text{BOT MARGIN (LINES)}] * [\text{H PERIOD}]$

APPENDIX A

GTF: Q & A

Q: Why are the timing parameters that define the sync signal so important?

A: Sync signals for displays drastically affect the quality, performance and even reliability of CRT displays. Even small differences in timing parameters can significantly affect image position and size, causing problems for the user. Difference in blanking times can lead to excessive power dissipation and electrical stress in the scanning circuits, or at the other extreme, incomplete or distorted images being displayed.

Q: Why can't the monitor automatically set itself to any timing format?

A: Multi-mode monitors can measure the incoming sync signal frequencies and thus sync to any frequency within its range of operation. But the sync signals carry no information regarding the relationship of the video signal to the sync pulses. Each timing format, up until now, has had a unique definition of these parameters, and so it has not even been possible for the display to accurately 'guess' where the image might be, though modern displays do make an attempt to do this, based usually on the preset timing information that it does have.

Q: How will GTF help the monitor to automatically set itself to any timing format?

A: GTF defines the relationship between syncs and video signals at any frequency of operation. The display can measure the incoming sync frequency, and thus can predict where the image will start and finish, even though it may not have been preset at that operating point.

Q: Will this require all monitors to have complex micro-controllers?

A: Most present day multi-sync monitors use a simple micro-controller to measure syncs in order to identify the mode. The GTF will simplify the micro-code in that it will eliminate the guess-work presently required when an unknown sync signal is applied. However, even analog multisyncs can use simple frequency to voltage conversions to compute the new image size and position within a reasonable accuracy if required.

Q: Is this GTF system compatible with existing monitors?

A: The GTF algorithm was purposefully chosen to create timings that lie centered in the range of a large number of existing formats. However, older monitors may still require some user adjustment typical of any other new format, as these monitors will not have knowledge of the GTF system.

Q: There are many standard timing formats, including those created by VESA. Will GTF replace these?

A: Standard timings, such as the standard VGA 60Hz timing, will continue to exist and be used, but may eventually be replaced by GTF versions. VESA will still maintain its existing Display Monitor Timings (DMT) and may even produce new discrete timings in the future that do not comply to the GTF method. This may be necessary when particular circumstances dictate precise parameter definition to meet a number of simultaneous constraints. An example would be when a specific timing signal is required that defines pixel clock, vertical refresh rate and horizontal rate simultaneously, say for a HDTV format. In contrast the GTF fixes the relationship between these parameters in order to guarantee its predictable nature, which is usually of much greater importance to the average user.

Q: Will VESA produce a matrix of GTF formats and timings at, say, 5 Hz refresh rate intervals (i.e., 75 Hz, 80 Hz, 90 Hz...)?

A: No. GTF permits a common "standard" timing to be calculated for practically any format and refresh rate, and so it would be meaningless to try to develop a restricted matrix of relatively few timings using this method. The need for standards for specific, EXACT refresh rates, such as might be needed for video compatibility or other applications, are better handled by discrete monitor timing standards, and will be developed by VESA as needed.

Q: GTF allows very high vertical refresh rates to be generated, e.g. above 150Hz. Is VESA implying that faster refresh rates are better?

A: By allowing a standard method of defining refresh rates, any rate can be computed as required by the industry and/or user. Thus VESA is neither limiting or recommending the use of higher refresh rates, though most users generally seem to prefer higher rates. Also, there are emerging applications that need high refresh rate, such as stereo vision. The GTF will allow a method of defining these.

Q: For best compatibility with video systems, programmable pixel clocks should be synthesized from a master oscillator with a base frequency that is a multiple of 2.25MHz. Why doesn't the GTF specification mandate this?

A: The GTF can generate timings based upon any given pixel clock frequency. The $N \times 2.25\text{MHz}$ base reference is a hardware consideration, that will determine the available set of actual pixel rates, in conjunction with the complexity of the pixel clock synthesizing hardware. These constraints must be determined before hand by the system software to determine which pixel clocks can be used and the GTF should be used accordingly, specifying the pixel clock as the defining parameter. However, generally such system restraints also call for precise vertical refresh rates to be used (i.e. TV, HDTV etc.). In those limited applications, VESA Discrete Monitor Timings (DMT) are a better choice.

Q: How can I use the GTF to give me an exact refresh rate and an exact pixel clock frequency?

A: The GTF cannot be used in this way. Either an exact refresh rate can be specified, an exact horizontal scan frequency or exact pixel clock. In most cases the pixel clock will be subject to some quantization due to the limitations of the clock synthesis hardware. In that case, the desired refresh rate should be used as the input in a first pass GTF calculation to find the ideal pixel clock. The pixel clock should then be rounded to the nearest achievable frequency and then used as the defining input to a second calculation of the GTF. Because of this rounding error, the actual final refresh rate will be slightly different than the desired refresh, the error being set by the accuracy of the pixel clock.

Q: Why doesn't the GTF allow me to set both refresh and pixel clock accurately? VESA discrete timings achieve this!

A: The DMT achieve this by varying the blanking times. However, this destroys the predictability of the blanking time from a simple measurement of the horizontal frequency and hence prevents the monitor from being able to accurately 'auto align' to an unknown new mode. Where precise refresh rate and pixel clock requirements are mandatory in the system, DMT should be used.