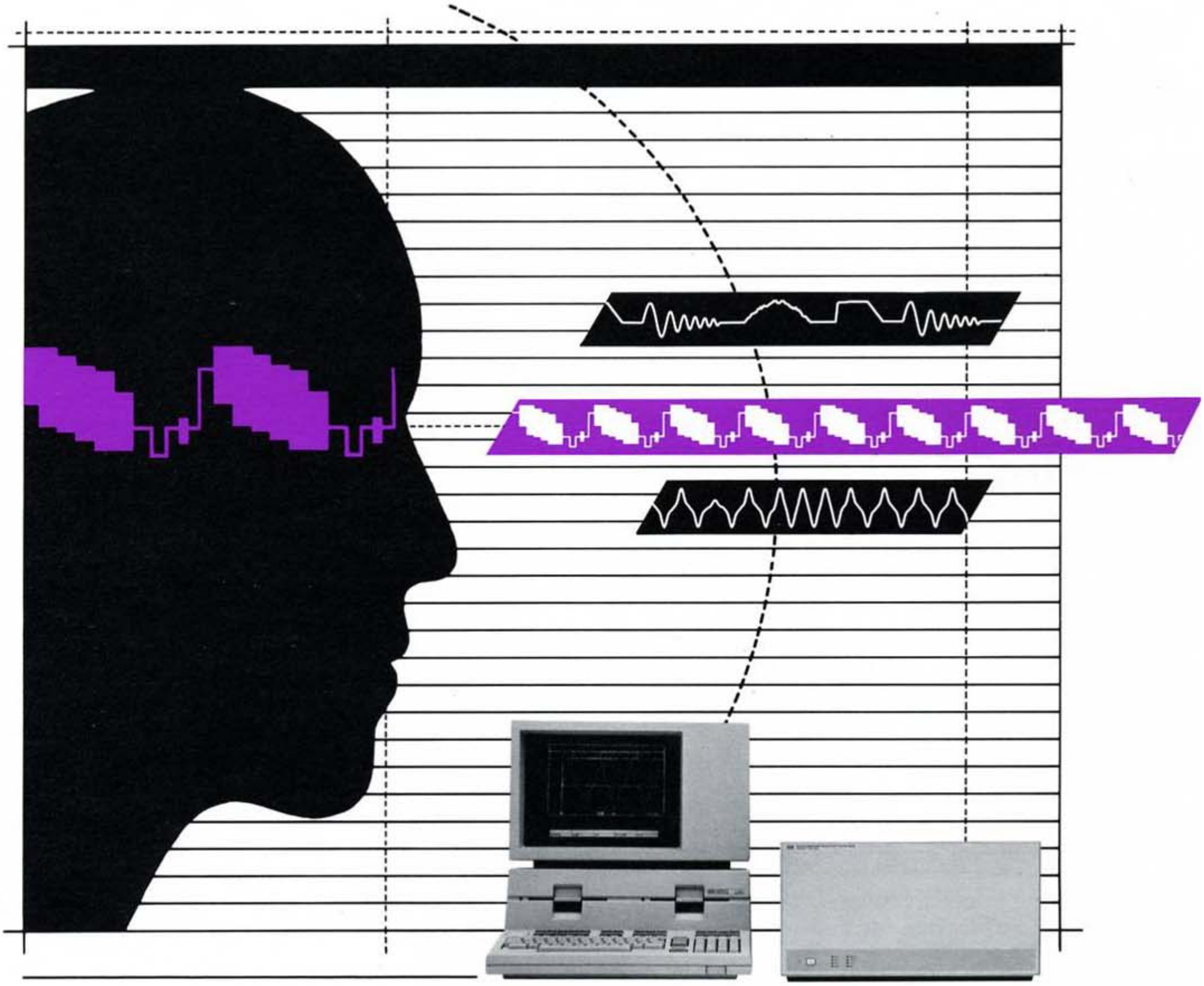
APPLICATION NOTE 314-3

Television Signal Simulation with the HP 8770S Arbitrary Waveform Synthesizer System



HEWLETT PACKARD

Television Signal Simulation with the HP 8770S Arbitrary Waveform Synthesizer System

INTRODUCTION

This application note describes the use of the HP 8770S to test television transmission systems and receivers. It includes some examples of complex TV test waveform creation and modification. General familiarity with the HP 8770S is assumed. If you have not already been introduced to the system, reading the data sheet and product note will be helpful (available at no charge from your local HP sales and service office; ask for HP literature numbers 5954-6355 and 5954-6360.)

Ideal vs. "Real-life" Signals

A television system has low tolerance for signals containing noise, spurious, or distortion from non-ideal transmission. Any gain or group delay variation with frequency affects the quality of the received picture. Color signals are particularly affected by these mechanisms. Thus, the most useful signals for testing TV systems duplicate the actual operating environment, i.e.,

Ideal signal + noise + distortion = "real-life" signal.

By testing with "real-life" signals, designers can predict the performance of video systems and subsystems under worst-case conditions, precisely determining operating margins. With this approach, TV system performance can be predicted with greater confidence.

An arbitrary waveform generator is a source of complex TV signals, eliminating the need for several generators for each waveform type. Up until now, however, arbitrary waveform generators have been limited by digital-to-analog converter (DAC) technology; they simply didn't have the frequency coverage to match TV needs. In addition, small memory and limited front panel functions have also been major drawbacks.

THE HP 8770S ARBITRARY WAVEFORM SYNTHESIZER SYSTEM

The HP 8770S provides the capability needed to test TV systems. It consists of the HP 8770A Arbitrary Waveform Synthesizer, the HP 11775A Waveform Generation Software, and an HP Series 200 Model 216A or 236A technical computer. The system software features the Waveform Generation Language (WGL), enabling the user to create and modify waveforms as easily as using a calculator to work with numbers. Complex test signals can be constructed with simple operations and then data representing these signals downloaded to HP 8770A for generation.

With state-of-the-art gallium arsenide technology, the HP 8770S outputs waveform samples at a 125 MHz rate, giving signal generation bandwidths up to 50 MHz. It has a 12 bit, 128K word waveform sample memory for accurate simulation of television test signals. It also has a separate sequencer memory. "Packets" of waveform data can be computed with WGL and stored in arbitrary order in the waveform memory. The sequencer memory is then used to determine the order in which the corresponding waveforms will be generated, including the number of times each waveform is repeated.

Unique Technical Design Provides "Real-Life" Signals for Testing Video Systems

The HP 8770S has several important features that make it a powerful tool for generation of TV signals:

External timebase capability

The HP 8770A can accept external clocks for its timebase. This means that by selecting an appropriate external clock frequency, the HP 8770A can be used to generate signals for various TV formats. NTSC, PAL, SECAM, and other formats can be generated with one system. This feature greatly simplifies test equipment requirements for testing televisions, VCR's, and other video equipment that can operate with different formats.

Deep memory and sequencing

Signals such as standard video test patterns, VITS, and synchronizing signals can be stored simultaneously in memory. The sequencer can then be used to access any portion of the memory to generate the desired signal. Test signals can have different formats (i.e. NTSC, PAL, etc.), and the synthesizer can generate a different format instantaneously by a sequence advance to the new pattern and, if required, a change in the external clock frequency.

12 bit amplitude resolution

The 12 bit DAC enables the synthesizer to generate signals with .024% resolution; i.e., ±1 volt with .000488V resolution. In addition, a 110 dB output attenuator shifts full scale DAC output from ±1 volt to ±3 microvolts in 10 dB steps. The result is more accurately known television receiver thresholds.

50 MHz coverage

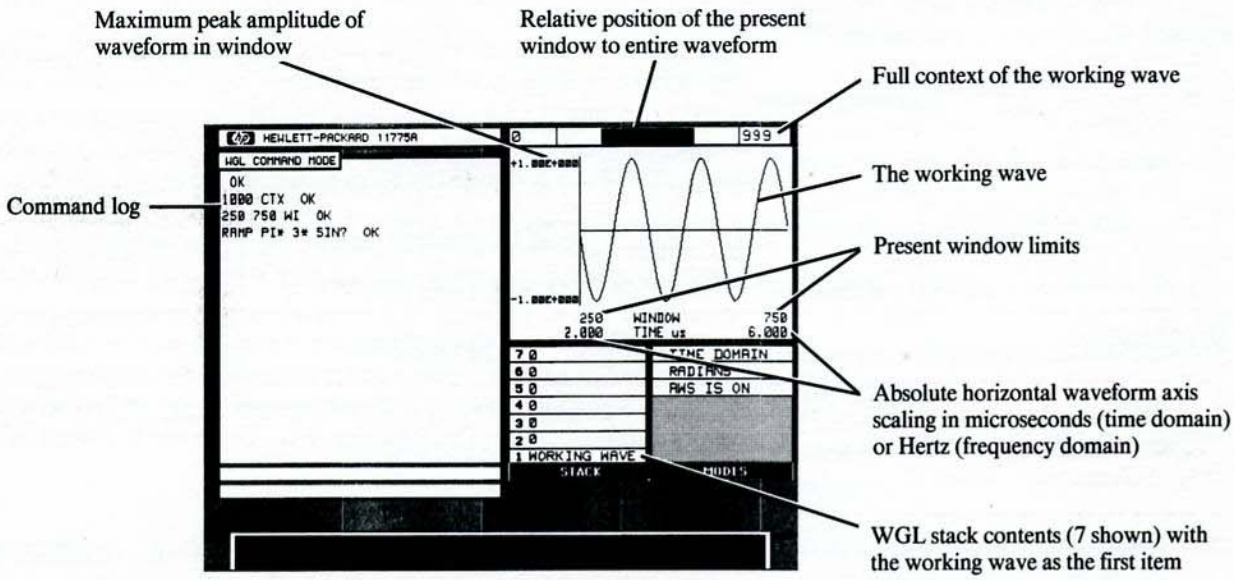
The IF and post-detection sections of video and broadcast systems can be directly tested. For the RF sections of these systems, the HP 8770S can provide complex modulation inputs to a signal generator covering the RF band of interest.

A waveform calculator

WGL is a powerful waveform generation language that is designed to create data arrays representing desired waveforms. Using simple operations, waveforms can be shaped to fit test signal generation requirements. A video line pattern can be constructed piece-by-piece and strung together to form the desired signal. Noise and distortion can be added to any part of the standard waveforms to simulate non-ideal effects.

Only 17 WGL commands are required to develop all the waveforms in this note, giving an indication of the power of the language. A glossary of the WGL commands used in the examples is provided for convenient reference (see Appendix). **Figure 1** shows the WGL computer display and some of the common WGL terms.

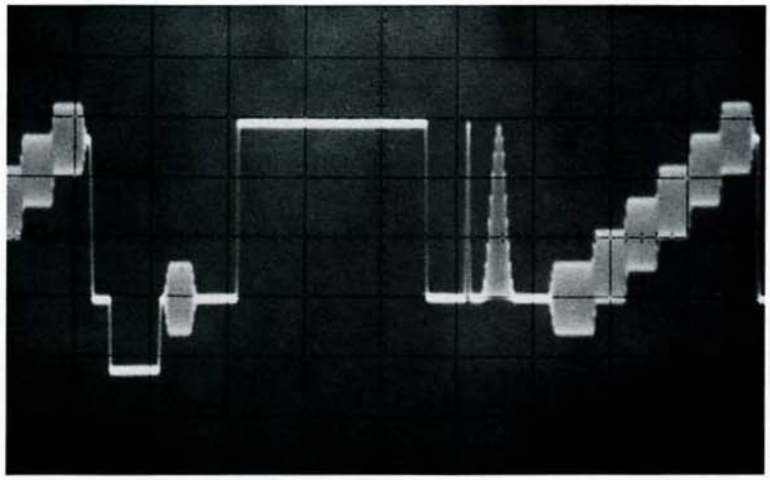
Figure 1. A typical HP 8770S computer display during waveform creation.



GENERATING VIDEO SIGNALS WITH THE HP 8770S

In the following sections, the NTC-7 test signal will be created using WGL. The NTC-7 composite test signal consists of four parts: line bar, 2T pulse, modulated sine-squared pulse, and the modulated 5-riser staircase (see **Figure 2a**).

Figure 2a. The NTC-7 composite test signal.



Selecting the Sampling Rate

Before proceeding, we choose an appropriate external clock frequency to match the timing of the desired waveform. The horizontal scan rate of all TV signals is based on subcarrier frequency. For the NTSC format, the color subcarrier frequency is f_{sc} = 3.579545 MHz. The horizontal scan rate of each line of a TV pattern is $f_H = (2 \times f_{sc})/455$ = 15734.264 Hz (period = 63.6 μs). Using an external clock rate of 14.31818 MHz ($4 \times f_{sc}$) results in 69.8 ns between waveform samples. Each video line should therefore consist of 910 waveform samples spaced by 69.8 ns (i.e., 910 $\times$ 69.8 ns = 63.6 μs). Due to the internal architecture of the HP 8770A, however, the total length of individual waveform packets stored in the memory must be a multiple of 8. Since 910 is not a multiple of 8, 912 waveform elements, or "points," are chosen to define one video line. This results in a line length of 63.7 μs, or a 15699.76 Hz scan rate.

Note: In some situations, the multiple of 8 requirement results in unacceptable time or frequency error. If this occurs, the external clock rate can be increased either slightly so that 912 points = 63.6 μs, or dramatically so that the number of samples for 63.6 μs is nearly (or exactly) a multiple of 8. Using 114.54544 MHz ($32 \times f_{sc}$), for example, results in 7280 samples spaced by 8.7 ns equalling 63.6 us, reducing the error to zero.

An external low-pass filter must be used to remove the high frequency components introduced when the external clock frequency is reduced below 100 MHz.

Windowing

The **WINDOW** command selects a section of a waveform to be manipulated. Waveforms can be defined piece-by-piece and combined into the complete signal. To design the NTC-7 composite test signal in the following examples, 912 points will be used to define the complete line. The following WGL command is entered to specify the waveform length:

912 CTX

Next, the four sections of the test signal (i.e. line bar, 2T pulse, modulated SIN^2 pulse, and the modulated 5-riser staircase) are designed separately by selecting an appropriate time window, or subset, of the 912 points. Waveforms are constructed piece-by-piece in a window corresponding to each section of the test signal. In the following examples, the waveforms are based on the nominal timing parameters of **Figure 2b**.

Figure 2b. Using a 14.31818 MHz external clock rate, 912 waveform elements are used to define the NTC-7 line. The placement of each individual test signal is based on nominal timing.

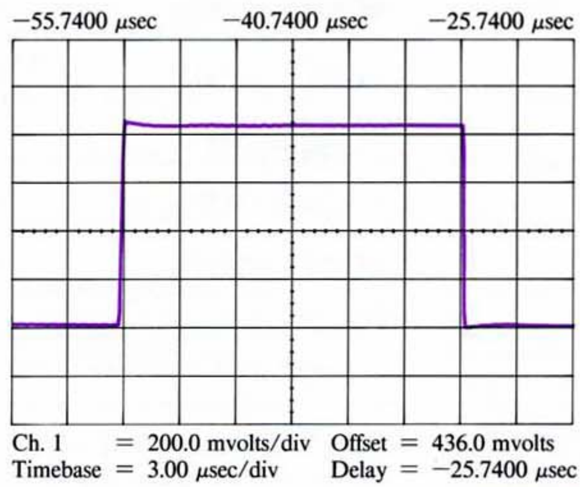


Figure 3. The Line Bar test signal generated by the HP 8770S.

Line Bar

In designing the line bar test signal, we set the rise/fall times by the number of samples required to make a transition. The **WINDOW** command selects a desired time span for each portion of the signal. The following WGL commands are entered into the computer to construct the line bar waveform of **Figure 3**:

Risetime

162 164 WINDOW? Select the time span (points 162, 163, and 164) for the risetime. This window represents 140 ns (2 x 69.8 ns/point).

RAMP? Generate a linear ramp to simulate the risetime.

1+? Add 1 to place the ramp between 0 and 2.

NORM? Normalize maximum amplitude to 1.

100*?	Set the peak amplitude to 100 IRE.
STORE A	Store the risetime temporarily for later use to design the falltime.

Peak Amplitude

164 423 WINDOW?	Set the window to correspond to the pulse top (259 x 69.8 ns = 18.1 μs).
100 LOAD?	Set constant amplitude to 100 IRE.

Falltime

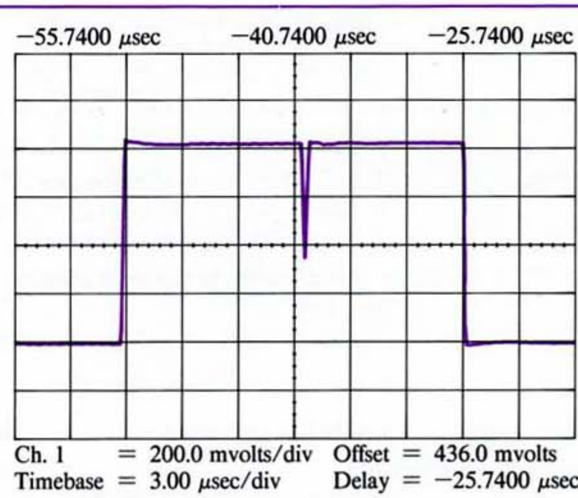
423 425 WINDOW?	Set the window for the falltime.
A REFL?	Since the falltime is equal to the risetime, the risetime waveform is recalled and reflected to describe the falltime.

The line bar test signal is used for the measurement of insertion gain, field-time distortion, and line-time distortion of video equipment. A particular test may require an arbitrary glitch in the line bar waveform. This is constructed by using the **STOREIN** command to add 5 arbitrary amplitude levels, point-by-point:

80 300 STOREIN	Store 80 (IRE) at point 300.
60 301 STOREIN	Store 60 (IRE) at point 301.
40 302 STOREIN	Store 40 (IRE) at point 302.
60 303 STOREIN	Store 60 (IRE) at point 303.
80 304 STOREIN	Store 80 (IRE) at point 304.

Figure 4 shows the line bar waveform with the added glitch. The glitch can be designed to have any arbitrary width or amplitude.

Figure 4. The Line Bar test signal is distorted by the addition of an arbitrary glitch. WGL offers easy modification of test signals to simulate "real-life" conditions.



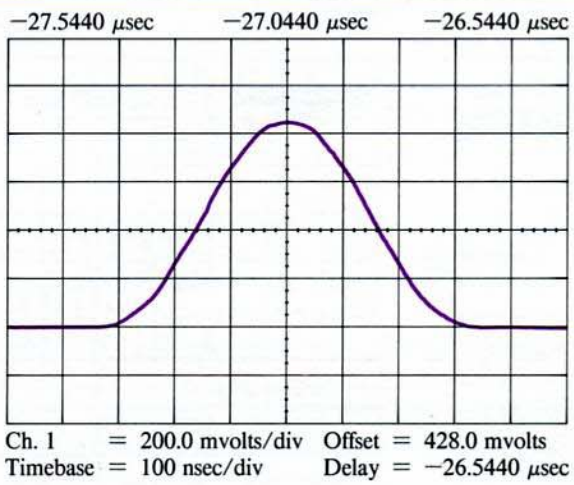
2T Pulse

The 2T pulse test signal is described mathematically by squaring half a cycle of a sinewave. The following WGL commands are used to generate the 2T pulse in **Figure 5:**

486 495 WINDOW?	Set the appropriate time span (0.6 μs).
RAMP 1+ NORM?	Define a ramp between 0 and 1.
PI*?	Multiply the ramp by PI to define the phase values ranging from 0 to PI (half cycle of a sine wave).
SIN?	Compute the sine wave.
SQ?	Square the waveform to obtain the 2T pulse.
NORM 100*?	Normalize amplitude and set to 100 IRE level.

The 2T pulse signal is used in short-time waveform distortion measurements. Using the **WINDOW** command, the pulse width can be set to any desired value. The peak amplitude can be varied by selecting a different scale factor.

Figure 5. The 2T Pulse test signal generated by the HP 8770S.



The Modulated Sine-Squared Pulse

Gain and delay inequalities between the chrominance and luminance components of a video signal are important in transmission of color signals. Gain error will cause saturation errors in the received picture, and any differential delay between the luminance and chrominance components appears as color registration error.

The following WGL commands are entered to generate the standard SIN^2 pulse of **Figure 6**:

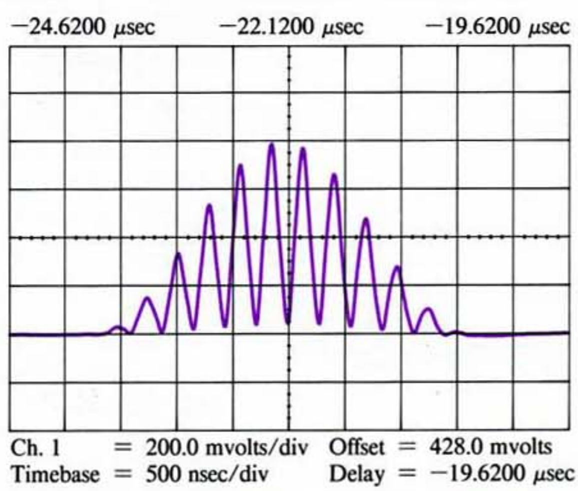
536 585 WINDOW?	Select the appropriate time span (3.4 μs).
RAMP 1 + NORM PI*?	Define phase values between 0 and PI.
SIN SQ?	Generate the pulse.

STORE A?	Store the pulse temporarily.

The next step is to generate the 3.579545 MHz subcarrier signal. Since the clock frequency is 14.31818 MHz (4 x f_{sc}), there will be 4 waveform elements per cycle to define the modulation signal. The following commands generate the 3.579545 MHz subcarrier signal:

536 539 WINDOW?	Set the window for 4 points.
RAMP PI* SIN?	Generate one cycle of the subcarrier signal.
536 585 WINDOW?	Set the window to the width of the SIN^2 pulse.
4 CLONE?	Copy the first cycle of the subcarrier signal across the pulse time span.
1+ NORM 100*?	Normalize and scale to 100 IRE.
STORE B?	Store the subcarrier signal for later use.
A*?	Modulate the subcarrier with the stored pulse.
NORM 100*?	Normalize to 1 and scale to 100 IRE.

Figure 6. The Modulated SIN^2 Pulse test signal generated by the HP 8770S.



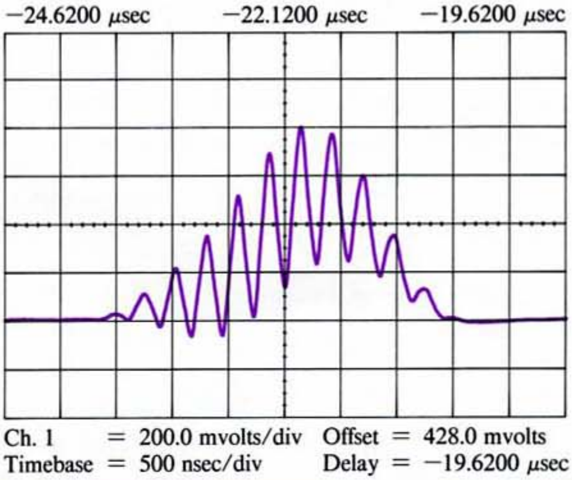
Using the HP 8770S, the standard SIN^2 pulse can be distorted by adding desired amounts of gain and delay errors. The error conditions can be varied in precise steps to test the marginal operation of the device-under-test providing higher confidence in the performance of the device under "real-life"conditions.

In the following example, an arbitrary amount of chroma delay is added to the standard SIN^2 pulse test signal. The delay is simulated by adding one cycle of a sinewave, with an arbitrary scale and offset, to the 3.579545 MHz subcarrier signal. The resulting signal is then modulated by the standard pulse which was created and stored in the last example. The following WGL commands are used to generate the distorted SIN^2 pulse of **Figure 7**:

536 585 WINDOW?	Set the window to the full pulsewidth.
RAMP PI* SIN 100*?	Generate the distortion signal.
40+ NORM 50*?	Offset by 40 IRE's and scale to 50 IRE.
B+?	Add the distortion to the subcarrier signal stored in the last example.
A*?	Multiply with the SIN^2 pulse.
NORM 100*?	Normalize and scale to 100 IRE.

The modulated SIN^2 pulse of **Figure 7** has negative chroma delay distortion. The amplitude of the error signal can be set to any desired level. Gain errors can also be simulated by modifying the modulation signal.

Figure 7. The Modulated SIN^2 Pulse signal distorted with arbitrary negative chromo delay.



The Modulated 5-Riser Staircase Test Signal

Differential gain and phase measurements are made using a staircase waveform modulated with the color subcarrier signal. The staircase extends from the blanking to the peak white level. The subcarrier signal peak amplitude is 20 IRE. The following WGL commands generate the 5-riser staircase signal of **Figure 8** in two steps. First, the subcarrier signal is generated:

616 619 WINDOW?	Set up window for 4 points.
RAMP PI* SIN?	Generate one cycle of the subcarrier signal.
616 894 WINDOW?	Set up window for the full signal time span.
4 CLONE?	Copy the first cycle of the subcarrier signal to cover the full span.
20*?	Scale to 20 IRE.

The second step is to construct the staircase by offseting the subcarrier signal:

710 746 WI 18+?	Offset to 18 IRE level.

747 783 WI 36+?	Offset to 36 IRE level.
784 820 WI 54+?	Offset to 54 IRE level.
821 857 WI 72+?	Offset to 72 IRE level.
858 894 WI 90+?	Offset to 90 IRE level.
895 909 WI 100 LOAD?	Load a constant 100 IRE level.
50 910 STOREIN?	Load a 50 IRE transition level.
0 911 STOREIN?	Load a 0 IRE transition level.
616 911 WI?	Display the complete 5-riser staircase signal.

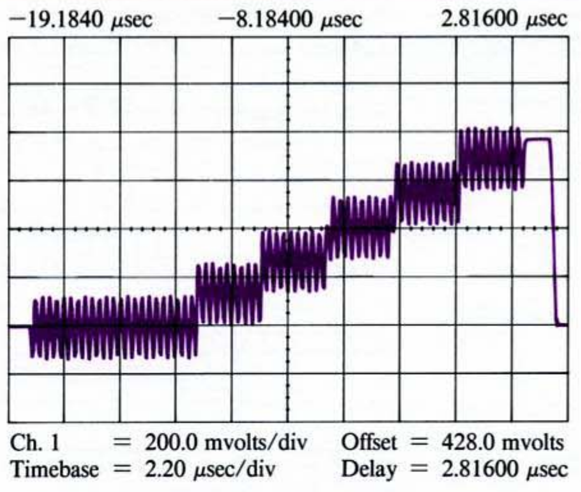
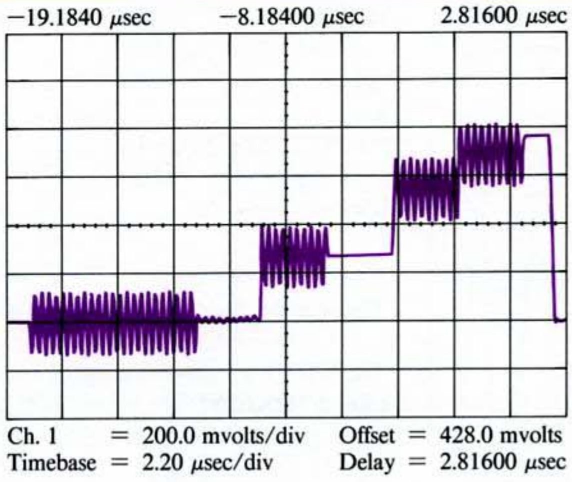


Figure 8. The Modulated 5-riser Staircase test signal generated by the HP 8770S.

The modulated 5-riser staircase test signal is used in differential gain/phase, and luminance non-linear distortion measurements. The amplitude level of each step must be accurately adjusted for distortion measurements. The phase of the subcarrier can also be varied by windowing on the desired portion of the waveform and modifying the signal. The following commands are used to construct the modified staircase test signal of **Figure 9**:

710 746 WI .1*?	Scale the step level by 0.1.
784 820 WI 0* 38 LOAD?	Reduce level to 0 and load a constant 38 IRE level.
616 911 WI?	The complete staircase signal.

Figure 9. The 5-riser Staircase signal of Fig. 8 is distorted by multiplying sections of the waveform by arbitrary scale factors.



Blanking and Synchronizing Pulses

Horizontal and vertical blanking and synchronizing signals consist of simple pulses. These pulses are constructed using the **LOAD** command which generates constant amplitude levels in a specified window. Horizontal sync pulses consist of 8-10 cycles of the color subcarrier signal. The following WGL commands are used to generate the horizontal blanking pulse with 9 cycles of the color sync subcarrier signal (**Figure 10**).

0 21 WINDOW 0 LOAD?	Load the constant 0 IRE level ("front porch").
-20 22 STOREIN?	Load a -20 IRE transition level.
23 91 WINDOW -40 LOAD?	The -40 IRE blanking pulse.
-20 92 STOREIN?	Load a -20 IRE transition level.
93 99 WINDOW 0 LOAD?	The 0 IRE "breezeway" level.
100 135 WINDOW?	Set up a 36 point window for 9 cycles of the color burst (9 x 4 points/cycle).
RAMP PI* 9* SIN?	Generate 9 cycles of the subcarrier.
NORM 20*?	Set peak amplitude to 20 IRE*.
STORE A?	Store for later use.
136 161 WINDOW 0 LOAD?	Complete the "back porch".

*By windowing on different portions of the sync pulse, each cycle can be scaled to set a desired rise and fall time.

To fully excercise the performance of the chroma detection circuitry of a video system, test signals with variable parameters must be generated. For example, testing the color subcarrier regeneration circuitry requires signals with programmable burst frequency, phase, and amplitude. In the following example, the burst signal is distorted by the addition of a noise signal:

100 135 WINDOW?	Set the window to the color burst.

NOISE?	Generate random noise over the burst window (1 IRE peak level).
5*?	Scale to 5 IRE, 25% of the burst level (20 IRE).
A+?	Add the noise waveform to the color burst saved from the last example.

The resulting burst signal is shown in **Figure 11**.

The NTC-7 composite test signal is now complete. **Figure 12** presents the computer display of the complete, "ideal" NTC-7 composite test signal. Any portion of the test signal can be modified to include desired distortion or non-ideal effects.

Many test signals and TV line patterns can be stored in the HP 8770A memory, and a complex video test signal can be generated.

Figure 10. The horizontal blanking pulse generated by the HP 8770S.

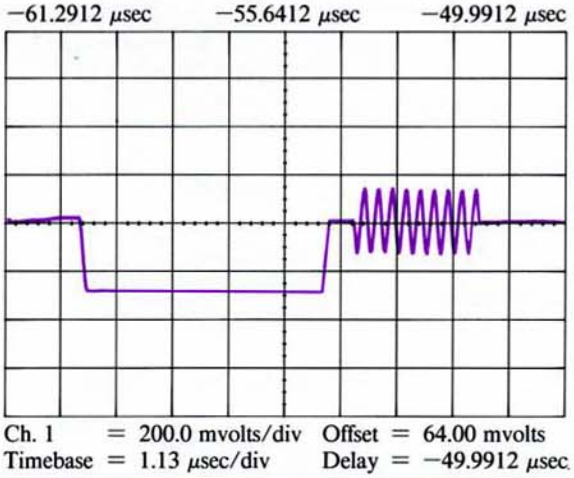
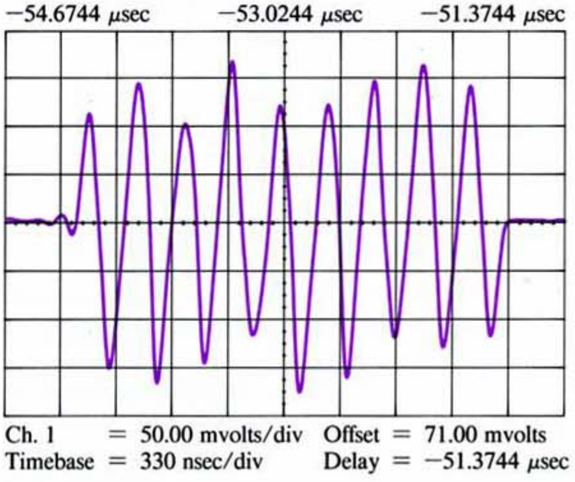


Figure 11. The color burst sync pulse is distorted by the addition of an arbitrary noise waveform.



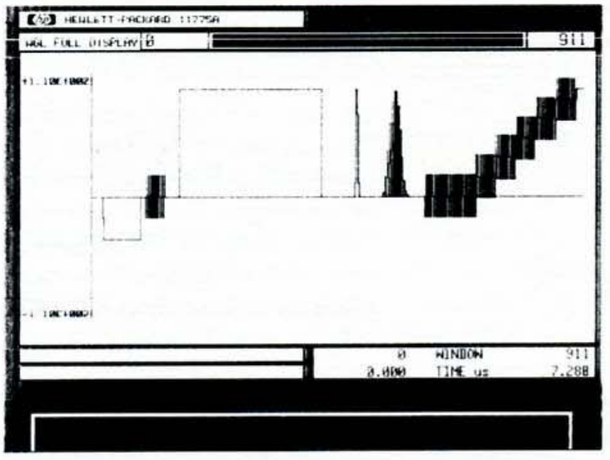


Figure 12. HP 8770S computer display of the NTC-7 composite test signal.

Specifying Waveform Sequences

It is often desirable to define an overall waveform as a string of waveforms in a sequence. A composite video waveform consists of horizontal and vertical blanking/sync pulses, video information, and test signals. Each of these waveforms can be stored in the memory of the HP 8770A with an assigned filename. A sequencer program is simply a list of waveform names in the order they should be generated and the number of times each waveform repeats. **Figure 13** is a conceptual presentation of the HP 8770A memory and the sequencer program for generating a full field NTSC signal. The following WGL commands construct the sequencer program presented in **Figure 13**:

NEWSEQ	Initiate the sequencer program.
"EQP;6;AUTO" $PACKET	Generate the equalizing pulse waveform (previously defined via WGL and stored under the name EQP) 6 times. The third command parameter is packet advance information. When this parameter is set to AUTO, the sequencer automatically advances to the next packet after the 6th equalizing pulse is generated.
"VSP;6;AUTO" $PACKET	Generate the vertical sync pulse 6 times.
"EQP;9;AUTO" $PACKET	Generate the equalizing pulse 6 times.
"BL;9;AUTO" $PACKET	Generate the blank line waveform 9 times.
"VIR;1;AUTO" $PACKET	Generate the VIR (Vertical Interval Reference) waveform once.
"VITS;1;AUTO" $PACKET	Generate the VITS (Vertical Interval Test Signal) once.
"VP1;262;AUTO" $PACKET	Generate a video waveform 262 times.
GO	Starts the synthesizer generating the sequence.

The above commands will generate an NTSC vertical blanking period and one field of the video pattern (262 lines of VP1). Similar commands must be used to generate the second field for a complete frame.

The sequencer is a powerful tool in generating arbitrary TV signals. Arbitrary VITS (Vertical Interval Test Signal) and video patterns can be designed by the user and stored with a different filename in the memory. By simply modifying the standard sequencer program, the performance of video equipment can be exercised with various test signals. VITS signals can be inserted on any line number in the vertical interval. As test requirements change, new test signals can be developed with WGL, without a need to change the test instrumentation.

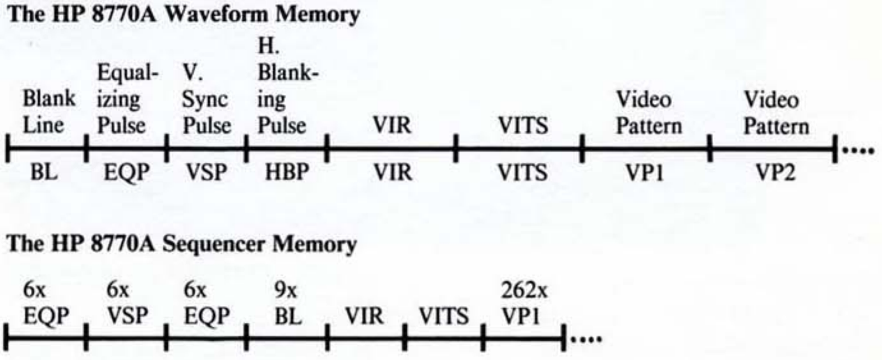


Figure 13. The HP 8770A memory is loaded with the desired video patterns, vertical interval test signals (VITS), and synchronizing and blanking pulses—each identified by name. The sequencer memory contains user-defined instructions for generating the stored waveforms in any sequence.

Creating Application Programs:

A WGL string often repeats in creating a set of waveforms. To further increase efficiency, WGL allows personalized application commands to be defined as strings of WGL commands. The new application commands can then be entered as a shorthand for the full sequence of WGL commands. In this way, entire test procedures may consist of just a few application commands. If the application commands have been so structured, the calling command can pass parameters to specify time and amplitude variables. For example, an application program can be written that accepts variable phase and amplitude parameters for the modulated staircase portion of the NTC-7 test signal. Such a program expedites differential gain and phase measurements.

SUMMARY

This application note presents a few examples of waveform creation for TV measurements with the HP 8770S Arbitrary Waveform Synthesizer System. It shows that various test conditions and "real-life" operating environments can be simulated, eliminating the need for complicated test stations. The HP 8770S is a powerful source of standard and customized TV test signals.

Appendix: Glossary of WGL Commands Used in this Note:

CLONE	Duplicates the specified number of waveform sample elements in the working wave as many times as necessary to fill the present window.
CTX or CONTEXT	Sets the total number of waveform sample elements to make up a waveform.
FULL	Selects all the elements of the present waveform to be manipulated; i.e., it sets the **WINDOW** to equal the full **CONTEXT**.
LOAD	Fills all elements of the working wave in the present window with a specified value.
NOISE	Fills all elements of the working wave in the present window with random values ranging from –1 to 1.
NORM or NORMALIZE	The elements in the working wave are scaled (multiplied by a suitable factor) such that their values fall between ±1.
PI	The constant 3.14159265359.
RAMP	Fills all elements of the present window with linearly increasing values starting with –1. The incremental increase is 2/(number of elements contained within the present window). For example, a **RAMP** generated in a window of 200 elements would have the following values: –1.00, –.99, –.98, ... , .97, .98, .99.
REFL	Reflects a waveform in a window about the center of the horizontal axis.
SIN	Takes the sin of each value in the working wave.
SQ	Squares a waveform or an element value.
STORE	Allows temporary storage of up to 5 waveforms and 150 real numbers.
STOREIN	Stores a single value into the specified element of a waveform.
WINDOW	Selects portions of the entire waveform for manipulation.
+	Adds first two items on the stack.
*****	Multiplies the first and second items on the stack.
?	Updates the WGL display screen.

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