MODEL DG535
Digital Delay / Pulse Generator

SRS **Stanford Research Systems**

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DG535 DIGITAL DELAY / PULSE GENERATOR
OPERATION AND SERVICE MANUAL

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******CAUTION******

This instrument may be damaged if it is operated with the LINE VOLTAGE SELECTOR set for the wrong ac line voltage or if the wrong fuse is installed.

LINE VOLTAGE SELECTION

The DG535 operates from a 100V, 120V, 220V or 240V (50 or 60 Hz) ac power source. Before applying a power source, verify that the line voltage selector card (located in the rear panel power entry module) is in the correct position. The selected voltage may be seen through the clear window by viewing the power entry module from below.

To change the line voltage selection, remove the line cord, slide the window to the right, and pull the "fuse pull" lever out. Verify that the correct fuse is installed for the ac line voltage: 1 Amp for 100 or 120V, and 1/2 Amp for 220 or 240V. Pull out the line voltage selector card with a pair of needle nose pliers, and insert it with the correct line voltage facing the bottom of the instrument and towards the line cord. Verify that the correct

line voltage can be seen through the slot that is just above thefuse holder. Push the fuse holder back in, and install the correct fuse. Slide the window to the left, and replace the line cord.

LINE CORD

The DG535 uses a three wire power cord for connection to the power source and to a protective ground. The exposed metal parts of the instrument are connected to the outlet ground: to protect against electrical shock, always use an outlet which has a properly connected protective ground.

To avoid shock or injury do not remove product covers or panels. Do not operate the product without all covers and panels in place.

CONNECTION TO OTHER INSTRUMENTS

All front panel BNC shields are connected to the chassis ground and to the power outlet ground via the power cord. Do not apply any voltage to either the shields or to the outputs. The outputs are not protected against connection to any potential other than ground.

QUICK START INSTRUCTIONS

(1) Make certain that the correct line voltage is selected on the rear panel.

(2) Press the power button "in" to turn on the unit.

(3) Press the RECALL Menu key, the "0" digit, and the EXC key in sequence to recall default settings.

(4) Press the left cursor key (<) twice to select internal trigger.

(5) Trigger the oscilloscope on the rising edge of T0's output, and display A's output on the 1µs/div scale.

(6) Press the DELAY Menu key and use the cursor keys to change the A delay from 0.0 seconds.

(7) If you ever change the OUTPUT Menu, be sure to specify the correct load impedance.

(8) If you have problems, read the detailed descriptions and troubleshooting sections that follow.

DG535 SPECIFICATIONS

DELAYS	Channels	Four independent delay outputs : A, B, C and D
	Range	0 to 999.999,999,999,995 seconds
	Resolution	5 ps
	Accuracy	1500 ps + timebase error x delay
	Timebase	Standard: 25 ppm crystal oscillator
		Optional: 1ppm TCXO (Opt. 03)
		External: user provides 10.0 MHz reference
	RMS Jitter	Ext Trig to any output: 60 ps + delay x 10-8
		T0 to any output: 50 ps + delay x 10-8
	Trig Delay	Ext Trig to T0 output : 85 ns

INTERNAL RATE GENERATOR	Rate	Single shot, .001 Hz to 1.000 MHz, or Line
	Resolution	0.001 Hz below 10 Hz, otherwise 4 digits
	Accuracy	Same as timebase
	Jitter	1:10,000
	Settling	<2 seconds for any rate change
	Burst Mode	2 to 32766 pulses per burst at integer multiples
		(4 to 32767) of the trigger period

INPUTS	External Trigger	Rate: dc to 1/(1 µs + longest delay)
		Threshold: ±2.56 Vdc
		Slope: Trigger on rising or falling edge
		Impedance: 1 MΩ + 40 pF or 50Ω
	Option 06	TTL front panel trigger inhibit input.

OUTPUTS	T0, A, B, C, D, AB, -AB, CD and -CD	
	Load	50Ω or high impedance
	Risetime	2 to 3 ns (typical)
	Slew Rate	1 Volt/ ns
	Overshoot	<100mV + 10% of pulse amplitude
	Levels	TTL: 0 to 4 Vdc, normal or inverted
		ECL: -1.8 to -.8 Vdc, normal or inverted
		NIM: -.8 to 0 Vdc, normal or inverted
		VAR: Adjustable offset and amplitude
		between -3 and +4 Vdc with 4V
		maximum step size
	Accuracy	50 mV + 3% of pulse amplitude
	Option 02	Rear panel T0, A, B, C, D outputs for 1µs
		pulses, amplitudes typically x8 of corresponding front
		outputs at 1kHz rep. rate. Output level is reduced by
		2V/mA of additional average output current.

COMPUTER INTERFACE	IEEE488 Standard GPIB
	SH1, AH1, T6, TE0, L4, LEO, SR1, RL1, PP0, DC1, DT1, C0 and E1.
	256 characters are remembered in the command buffer.
	All instrument functions and settings may be controlled over the
	interface bus.

GENERAL Dimensions:	14" x 8.5" x 4.75"
	Weight: 10 lbs
	Power: 70 Watts from 100, 120, 220, or 240 Vac
	Warranty: One year parts and labor on materials and workmanship.

ABRIDGED COMMAND LIST

INITIALIZATION

CL	Clear instrument
GT{i}{,j}{,k}	Specify one to three ASCII codes which will terminate each response from the DG535

STATUS

ES	Returns the Error Status byte
ES i	Returns bit i of the Error Status Byte
IS	Returns the Instrument Status byte
IS i	Returns bit i of the Instrument Status Byte
SM {i}	Set Status Mask for service request to i.

DISPLAY

DL {i,j,k}	Select Display Line to menu i, submenu j, line k.
CS {i}	Set Cursor Mode (i=0) or Number mode (i=1)
SC {i}	Move cursor to column i= 0 to 19
MC i	Move cursor left (i=0) or right (i=1)
IC i	Increment (i=1) or decrement (i=0) the digit at the current cursor location.
DS string	Display a string of 1-20 characters. Do not use spaces (use_underline_instead) or semicolons.
DS	Clear Display String

DELAYS

DT i{,j,t}	Delay Time of channel i is set to t seconds relative to channel j. Example: DT 3,2,1.2E-6 will set B=A+000.000,001,200,000 seconds

OUTPUTS

TZ i{,j}	Set the Termination Impedance (Z). Output i is configured to drive a 50Ω load (j=0) or a high-Z load (j=1)
OM i{,j}	Set Output i to Mode j where j=0,3 for TTL, NIM, ECL, or VARiable.
OA i{,v}	Output amplitude of output i is set to v Volts if in the VARiable mode
OO i{,v}	Output Offset of output i is set to v Volts if in the VARiable mode
OP i{,j}	Output Polarity of channel i is inverted (j=0) or normal (j=1) for TTL, ECL or NIM.

TRIGGER

TM {i}	Set Trigger Mode to Int, Ext, SS or Burst (i=0,1,2,3)
TR i{,f}	Set Int Trigger Rate (i=0) or Burst Trigger Rate (i=1) to f Hz.
TZ 0{,j}	Set Trigger input impedance to 50Ω (i=0) or to high impedance (j=1)
TL {v}	Set External Trigger Level to v Volts.
TS {i}	Trigger Slope set to falling (i=0) or Rising Edge (i=1)
SS	Single-Shot trigger if Trigger Mode = 2
BC {i}	Burst Count of i (2 to 32766) pulses per burst
BP {i}	Burst period of i (4 to 32766) triggers per burst

STORE and RECALL

ST i	Store all instrument settings to location i=1 to 9
RC i	Recall all settings from location i=1 to 9 Default settings may be recalled from location 0.

ERROR STATUS BYTE		INSTRUMENT STATUS BYTE	
Bit	Description	Bit	Description
7	Always zero	7	Memory contents corrupted
6	Recalled data was corrupt	6	Service request
5	Delay range error	5	Always zero
4	Delay linkage error	4	Trigger rate too high
3	Wrong mode for the command	3	80MHz PLL is unlocked
2	Value is outside allowed range	2	Trigger has occurred
1	Wrong number of parameters	1	Busy with timing cycle
0	Unrecognized command	0	Command error detected

NOTES

In all of the commands listed here, i, j and k are integer values and f, t and v may be integer, floating point or exponential notation. Optional parameters are enclosed in curly brackets. If optional parameters are omitted then the current value of those parameters will be sent back to the GPIB controller. For example, the command "TM 3" sets the Trigger Mode to mode 3 while the command "TM" will return the response "3".

Also, blanks are ignored, case is ignored, multiple commands may be sent on one line if separated by semicolons. All responses are terminated by a carriage return and a line feed. The line feed is sent with an EOI.

The Delay and Output commands use integer codes which are assigned to each front panel BNC. The table for these assignment is given below.

Integer	Assignment
0	Trigger Input
1	T0 Output
2	A Output
3	B Output
4	AB and -AB Outputs
5	C Output
6	D Output
7	CD and -CD Outputs

GUIDE TO OPERATION

INTRODUCTION

The DG535 Digital Delay and Pulse Generator can provide four precisely timed logic transitions, or two precisely controlled pulses. The four digitally controlled time intervals may be programmed from the front panel or via the GPIB. Front panel BNC's provide high slew rate outputs at TTL, NIM, ECL or continuously adjustable levels. The outputs may be set to drive either 50Ω or high impedance loads.

The high accuracy (1 ppm), precision (5 ps), wide range (0 to 1000 s), and low jitter (50 ps rms) recommend the DG535 as the solution to many difficult timing problems in science and industry.

FRONT PANEL OPERATION SUMMARY

POWER BUTTON

The unit is turned on by depressing the POWER button. All instrument settings are stored in nonvolatile RAM, and so the settings are not affected by turning the power on and off. The model, firmware version, and serial numbers for the unit will be displayed briefly when the power is first applied.

LIQUID CRYSTAL DISPLAY

The 20 character LCD is the user interface for all front panel programming operations. The wide viewing angle LCD is backlit by an electroluminescent panel for convenient operation in low light level conditions. When the keypad is in the cursor mode, the contrast of the LCD may be adjusted for optimum viewing by the two right most keys on the front panel.

MENU KEYS

Six Menu Keys select the function to be programmed. Most menu items are self-explanatory:
> TRIG defines the trigger source
> DELAY is used to adjust the four digital delays
> OUTPUT sets the output pulse levels

> GPIB allows the user to see data received via the GPIB and to set the GPIB address
> STORE and RECALL provide a convenient method to save all of the instrument settings.

Detailed descriptions of each of these menus will be given.

DATA ENTRY KEYS

Sixteen keys are used to enter and modify data. There are three modes of operation for this keypad: the mode is indicated by the three LED's in the center of the panel. The cursor mode ($<$ $>$) allows individual digits to be modified in a fashion similar to the operation of thumbwheel switches. The numeric mode (NUM) allows the data to be entered as a numeric string. The remote mode (REM) lets the GPIB controller lock-out front panel operation. The key beneath the Mode LED's allows the user to change the keypad mode, if not locked-out by the GPIB controller.

TRIGGER STATUS

Five LED's are used to indicate the trigger status. The TRIG LED blinks each time the unit is triggered, the BUSY LED is on whenever a timing cycle is in progress, the RATE LED is lit if a trigger is received while BUSY. The INT LED indicates that the internal rate generator is the trigger source, and the 50Ω LED is on when the EXT TRIG input is terminated in 50Ω. The EXT TRIG BNC is the input for external triggers.

DELAY OUTPUTS

There are five delay output BNC's: T0, A, B, C and D. T0 marks the start of the timing interval and is most useful when an internal trigger source has been selected. The logic transitions at the outputs of A, B, C and D may be set from 0 to 1000s in 5 ps increments with respect to T0. The outputs may be programmed for TTL, NIM, ECL or adjustable output levels, and can drive 50Ω or high impedance loads. The polarity of each output may be set to provide a rising or a falling edge when the channel times out. The outputs will remain asserted until 800 ns after the longest delay.

PULSE OUTPUTS

There are four, pulse output BNC's: AB, -AB, CD and -CD. The AB output provides a pulse for the interval between the time set for channel A and channel B. The CD output provides a pulse for the interval between the time set for channel C and channel D. These outputs allow the DG535 to generate two precisely timed complementary pulses.

OPTION 06 - TRIGGER INHIBIT INPUT

If the DG535 was ordered with the option 06, there will be a BNC connector located directly under the power button on the front panel to which the trigger inhibit input is applied. This input is active low and is used to disable the trigger mode. A TTL low inhibits triggers while a TTL high permits triggers. If there is no input signal, the input floats high and all triggers are enabled.

REAR PANEL FUNCTIONS

POWER ENTRY MODULE

The power entry module is used to fuse the line, select the line voltage, and block high frequency noise from entering or exiting the instrument. Refer to the section at the front of this manual for instructions on selecting the correct line voltage and fuse.

IEEE-488 STD PORT

The 24 pin IEEE-488 rear panel connector allows a computer to control the DG535. The command syntax for the GPIB transactions is detailed in the programming section of this manual. The address of the instrument on the GPIB is set from the front panel by the GPIB menu.

10.000 MHz REFERENCE

Internal or external references may be used as the timebase for the digital delays. If the internal timebase is to be used, the rear panel switch should be in the INT position. In this position, the 10.000 MHz internal timebase will be appear as a 1V p-p square wave at the rear panel BNC. This output is capable of driving a 50Ω load, and may be used to provide the same timebase to several DG535's.

An external reference may be applied to the DG535 by placing the switch in the EXT position. A 10.0 MHz, ±1%, reference with a 1 Vp-p amplitude must be applied to the rear panel BNC which now serves as a reference input. If the external reference has insufficient amplitude, or is more than a few percent off the nominal 10.0 MHz, then the message "Ext Clk Error" will appear on the LCD until the problem
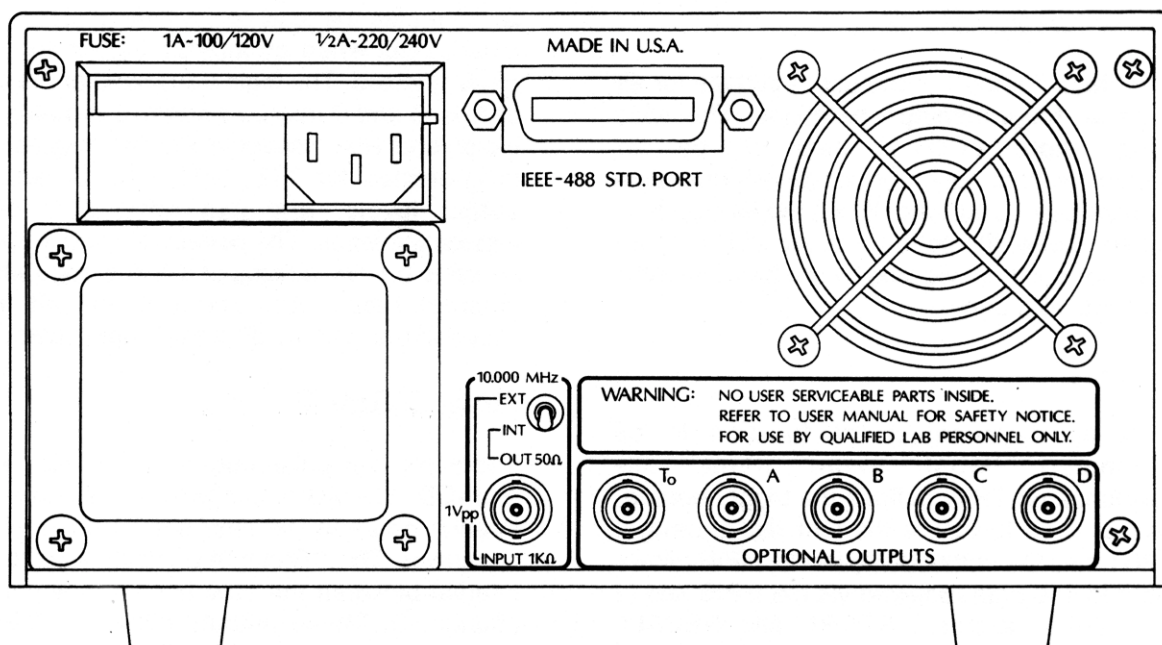

Figure - 1 DG535 Rear Panel

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is remedied.

To use the timebase in one DG535 as the timebase for several DG535's, set the switch on the "master unit" to the INT position. Use coax cables to daisychain the 10.000 MHz output from the "master unit" to the other DG535's whose switches are all set to the EXT position. Use a 50Ω terminator to terminate the 50Ω line at the last unit on the daisychain.

OPTION 02 - ±32 Volt Rear Panel Outputs

If the DG535 was ordered with the option 02, there will be five rear panel BNC's to provide amplified outputs for T0, A, B, C and D. These outputs have nominal adjustable output amplitudes from -32 to +32 Volts. The pulse width is approximately 1 µs, and the leading edge has a transition time of 2 to 3 ns. The outputs are designed to drive 50Ω loads, however, if the cable is terminated into a high impedance load, the pulse amplitude will double (up to 64 Volts) for a duration equal to the round trip cable delay. The amplitude of the output pulse is reduced by 2 Volts per mA of average output current: the average output current is only 0.7 mA for a 32 Volt output into 50Ω at a 1 kHz repetition rate. For high impedance terminations, charging and discharging of the cable capacitance may be the most important current factor. In this case, the average current is given by:

$$I = 2Vtf / Z$$

where, V is the pulse step size, t is the length of the cable in time (5 ns/meter for RG-58), f is the pulse repetition rate, and Z is the cable's characteristic impedance (50Ω for RG-58).

FRONT PANEL PROGRAMMING

Pressing a new menu key will take you to the "top" menu for that item. Each successive press of the same menu key will take you to the "next" submenu for that item. The power-up menu will be the same menu that was displayed when the unit was last turned off.

The Keypad mode (cursor or numeric) will be the same as it was the last time the menu item was accessed. Some menu items only allow one type of keypad mode, for example, the GPIB address may only be entered in the numeric mode.

In the cursor mode, only the keys with arrows are active. The keys with the green arrows are used to modify the displayed value (up/down) or to move the cursor (left/right). The two keys with grey arrows are used to adjust the LCD display contrast.
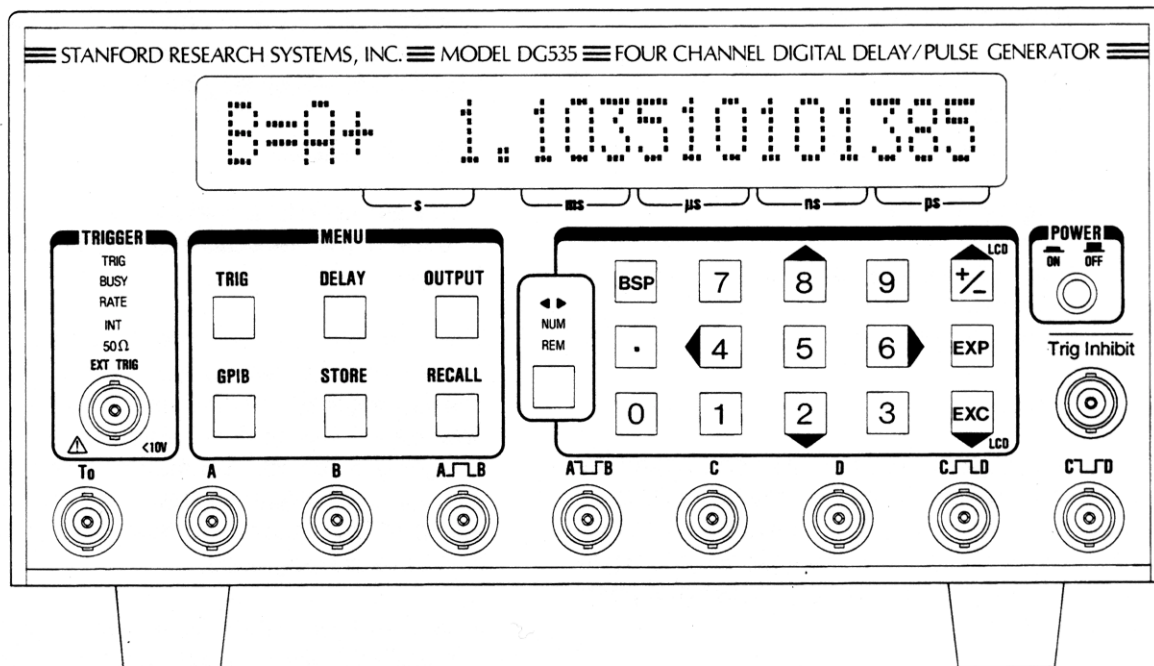

Figure - 2 DG535 Front Panel

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In the numeric mode, the entire keypad is active. Data may be entered as a floating point number or in exponential notation. Entered data may be edited by using the BSP (backspace) key. Backspacing past the left edge of the screen will cancel the command. The entered data is actually used when the EXC (Execute) key is pressed. Selecting another menu item will have the same affect as pressing the EXC key.

Error messages will appear on the LCD to indicate improper commands. For example, an attempt to decrement a delay below zero will generate the error message "Delay Range Error". The error message may be cleared from the LCD by pressing any key.

TRIGGER MENU

The "top" line on the trigger menu is:

   Int Ext SS Bur Line

The cursor, underlines one of the five modes in the list to indicate Internal, External, Single-Shot, Burst, or Line trigger. The left and right cursor keys may be used to change the mode. Subsequent menus, which are different for each trigger mode, are selected by pressing the TRIG menu key again.

TRIGGER SUBMENUS

Mode	Menu Example
Int	Rate =10000.000Hz
Ext	Threshold =+1.00V Slope($\pm$) = + Trigger Term = HighZ
SS	Single-Shot (Exc)
Bur	Rate =10000.000Hz Pulses/Burst 10 Periods/Burst 20
Line	(No submenu)

The Internal trigger mode has only one submenu to set the trigger rate. The rate may be entered in the numeric mode or modified in the cursor mode. Only four digits of precision are allowed,

and digits more than three places beyond the decimal point will be truncated.

The External trigger mode has three submenus to specify the threshold, slope and termination impedance of the external trigger input. Each submenu is selected by pressing the TRIG key. The Threshold may be entered as a floating point number or may be modified in the cursor mode. The Slope may be selected by using the cursor (up/down) keys, as can the Trigger termination impedance. The threshold, slope, and termination impedance shown in the example menus would be appropriate for triggering on the rising edge of a TTL Pulse.

The Single-Shot trigger mode has only one submenu. If SS is selected by the cursor, pressing the TRIG menu key will display "Single Shot (EXC)." Now each press of the execute key will trigger the timing cycle.

The Burst mode has three submenus to specify trigger rate, number of pulses per burst, and number of periods between the start of each burst of pulses. All of the items may be entered in the numeric mode, or modified in the cursor mode. The Rate may be entered in floating point or exponential notation, and may be specified to four digits of precision. For the entries shown in the above menu example, there would be 10 pulses per burst, each pulse separated by 100 µs, and a new burst of pulses would start every 20 periods, i.e. every 2 ms.

The Line trigger mode has no submenus. The unit will be triggered on a zero crossing of the power line at the line frequency. The line trigger is also synchronized to the internal 80 MHz timebase, so that the timing jitter of the delay outputs in this trigger mode will be very low (typically 25 ps rms).

TRIGGER TRICKS

There are several techniques that may be used to extend the versatility of the DG535's trigger modes.

The Jitter of the delay outputs will be reduced by about a factor of two (to less than 25 ps rms) if the unit is triggered synchronously with the 10 MHz time base. This is done automatically if the Line Trigger is selected. You may also want to arrange your external trigger so that it is synchronous with the 10 MHz output on the rear panel (if the internal time base is being used).

It is often desirable to trigger the unit at a sub-multiple of the trigger source. Suppose you wish to trigger a laser at 10 Hz synchronously with the zero crossing of the power line. In this case you would select the Line Trigger, and set channel D's delay to 95 ms. Once triggered, the DG535 will ignore other triggers until all channels have timed out, hence every sixth Line trigger (at 60 Hz) will cause a new timing cycle. The RATE error LED on the front panel will be illuminated to indicate that triggers occurred while the unit was busy.   Trigger rates up to 100 MHz can be used, with the unit ignoring all triggers until all channels have timed out, as in the above case.

DELAY MENUS

There are four delay menus to specify the delays for channels A, B, C and D. Each delay may be entered in floating point or exponential notation or may be modified in the keypad cursor mode. The maximum time delay is 999.999,999,999,995 seconds, which may be set with a resolution of 5 ps.

Example Delay Menus

    A=T0+0.123456789125
    B=A+0.001000000000
    C=T0+123.456789123455
    D=C+0.000000010000

Any delay channel may be "linked" to another channel. Two examples of this are shown in the above sample menus. While A is referenced to T0, channel B's delay is set to A's delay plus 0.001 seconds. Linking provides a convenient method to specify a pulse output (AB) as a pulse start time and width rather than start and stop times. Now, if channel A's delay is modified, B's delay moves with it, so that the pulse width stays at 0.001 seconds. With the above settings, the CD output will produce a very accurate 10 ns pulse despite the very long delay which is specified for channel C.

To change the linkage, the cursor is positioned beneath the character just to the right of the equal sign, and the cursor up/down keys are used to select from the available links. Not all links are available, for example, in the above menus linking channel A to channel B is not allowed, as B is linked to channel A in the second menu.

Delay can be scrolled by first selecting the delay menu, positioning the cursor under the digit to be incremented. Depress the #5 and either the up or down keys simultaneously. The step rate will be approximately 4 Hz, and may vary during a scan.

OUTPUT MENUS

The output menus are used to specify the load impedances, pulse output amplitudes, offsets, and polarities for each of the front panel BNC's. The cursor (left/right) keys are used in the "top" line of the OUTPUT menu to select which output is to be programmed. Successive presses of the OUTPUT key will access each menu line for the selected output, finally returning to the "top" line.

The menu items for the T0, A, B, C and D output are virtually identical. An example of these menus is given here for channel A's output:

A:load= High Z
A:TTL NIM ECL VAR
A:Inverted Normal (if TTL, NIM or ECL is selected)
A:Amplitude = +1.00V (if VARiable is selected)
A:Offset = 0.50V (if VARiable is selected)

The first line in this submenu specifies the load impedance. The cursor (up/down) keys are used to select between High Z and 50Ω loads. This is a very important step in setting up the output: the wrong choice will cause the output to have half the expected amplitude, or to misbehave entirely.

The cursor (left/right) keys are used in the second submenu to select either standard logic levels for the output, or continuously variable offsets and amplitudes. If either the TTL, NIM or ECL logic levels are selected, the next submenu is used to specify the polarity of the output pulse: the "Normal" polarity will provide a rising edge at the output at the set time: "Inverted" polarity will provide a falling edge.

If VAR (variable) is selected in the second submenu, then subsequent submenus allow the pulse amplitude and offset to be set. Both numbers may be entered as floating point numbers or may be modified by the cursor keys. The minimum

amplitude is 100 mV, the maximum amplitude is 4.00 VDC, and outputs outside the range of -3 to +4 VDC are not allowed.

AB and CD OUTPUTS

The menus for the AB and CD outputs are similar to the other outputs. Example menus for the AB output are shown on the following page:

AB&-AB Loads = High Z
AB: TTL NIM ECL VAR
AB:Amplitude = +1.00V (if VARiable is selected)
AB:Offset= +0.50V (if VARiable is selected)

The cursor (up/down) keys select the load impedance for both the AB and -AB outputs. It is very important that if a 50Ω load is specified, that a 50Ω load be present on BOTH the AB and the -AB output BNC's.

The cursor (left/right) keys select the logic levels for the AB and -AB outputs. If TTL, NIM or ECL is selected, then no further submenus are needed to specify the outputs: both the "Normal" and "Inverted" logic levels are available at separate front panel BNC's. If VAR is selected, then the next two submenus are used to set the amplitude and offset of the outputs.

GPIB MENUS

There are three menus which are accessed by the GPIB key. They are:

 Data:_____
GPIB Address: 15
Service RQST: (EXC)

The first menu displays the last 15 characters of data that have been received over the GPIB. 256 characters are retained in memory and may be viewed by scrolling the display window with the cursor keys. Spaces and control codes will not be displayed, however special characters for carriage returns and line feeds will be displayed. This feature is very useful when debugging computer programs that control the DG535.

The GPIB address may be set in the second menu. The keypad is automatically placed in the numeric mode for this menu item. Any address from 1 to 30 may be entered: the default address for this instrument is 15.

The third menu allows the user to generate a service request by pressing the EXC button (lower right on the front panel). A service request is used to attract the attention of the GPIB controller.
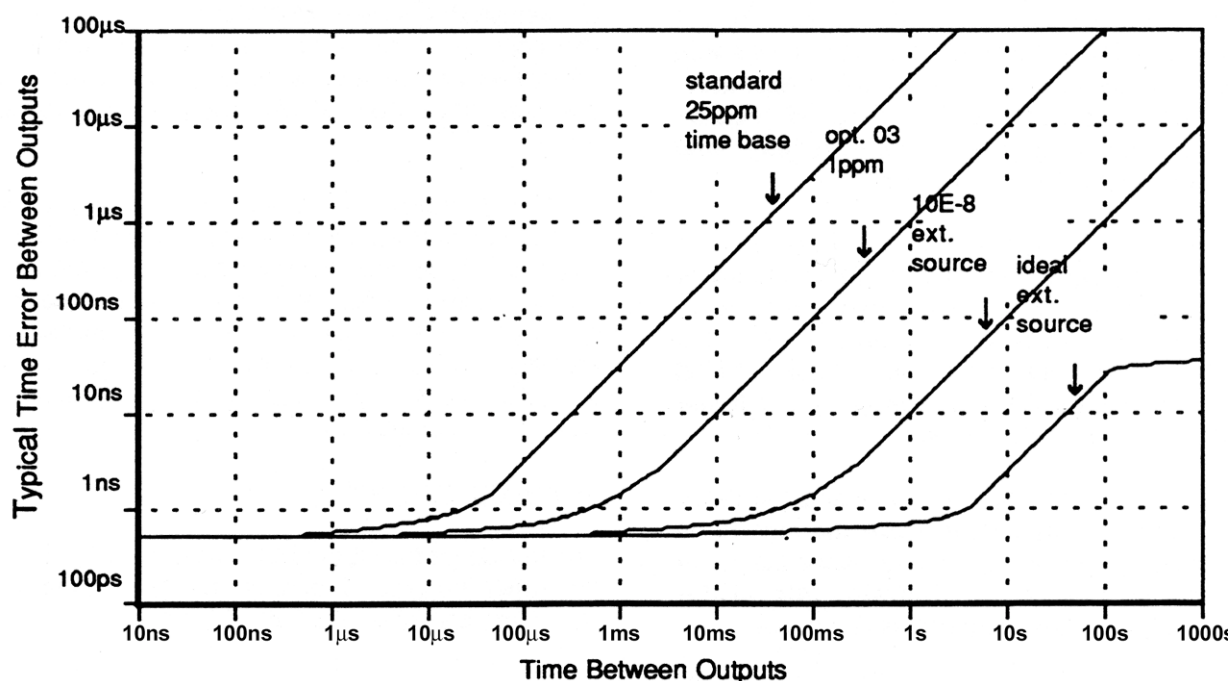

Figure - 3 Maximum Error vs. Time Delay

STORE and RECALL MENUS

There are ten storage locations from which setup data may be recalled. One of these locations, number 0, contains default setup data, the other nine locations contain setup information that was stored by the user. Because the information is stored in nonvolatile RAM, it will be available for recall even if the instrument is turned off.

All of the instrument's settings are stored, even those which are not currently active: for example, the external trigger threshold is saved even though the instrument is operating on internal trigger.

Operating data is stored by pressing the STORE key, one digit (1-9) to specify the storage location, and the EXC (execute) key. Mistakes may be edited with the BSP (backspace) key.

Instrument settings are recalled from storage by pressing the RECALL key, one digit (0-9), and the EXC (execute) key. If the stored data has been corrupted since it was saved, the error message "Recall Error" will be displayed. The error message can be removed by pressing any key. A defective Lithium battery or very noisy ac line voltages will cause "Recall Errors".

ACCURACY, DRIFT, AND JITTER

Each of the delay channels, A, B, C and D, may be programmed to time out from 0 to 1000 seconds with a resolution of 5 ps. The factors, which detract from this ideal performance, are discussed here.

ACCURACY

The error in the time delay between any two outputs is less than (1500 ps [500 ps typical] + Timebase error x Time between Outputs). (This specification is exclusive of time shifts due to slew rates at the outputs, i.e., it should be measured with both outputs set for the same logic levels driving the same loads). The timebase error depends on the timebase being used:

Standard	<25 ppm	0-50 °C
Option 03	<1 ppm	0-50 °C
External	Source spec + 0.0002ppm	

Using the typical error figure, for a time delay of 1.0 ms, this table implies an absolute error of ±25 ns, ±1.5 ns and ±0.5 ns respectively for the standard, optional and external timebases (assuming a 0.01 ppm external source specification). If A=100.000µs and B=100.01µs, the error with respect to T0 will be ±2.6 ns with the standard timebase, however the accuracy of A with respect to B will be ±500 ps.

A graph showing the maximum time error as a function time delay is shown in Figure 3. The four curves show the time error for the standard, optional, 0.01 ppm external, and ideal external timebases. The excess error for time delays longer than 1 second on the "ideal external source " curve is due to drift in the analog jitter compensation circuits.
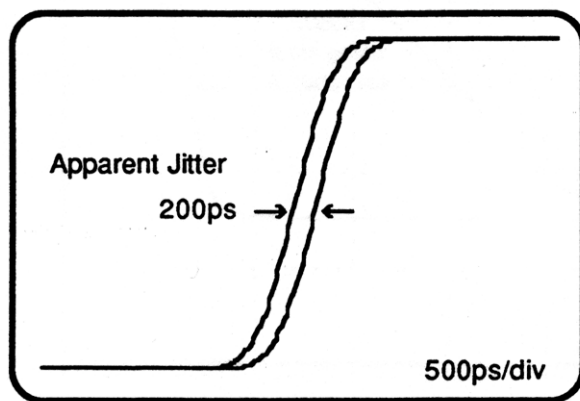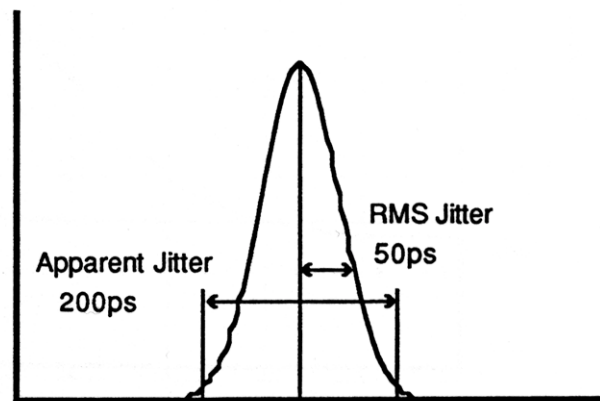
Figure -4 Apparent (Peak To Peak) Jitter and RMS Jitter

7

TIMEBASE DRIFT

The drift of the timebase over several hours is substantially less (x10 to x100 less) than the absolute timebase error. The major factor in the timebase drift is the instrument's temperature: after the instrument has warmed up, the timebase drift is about 0.5 ppm/°C for the standard timebase, and about 0.05 ppm/°C for the optional timebase. The drift between several DG535's which are used in the same experiment may be eliminated by daisychaining the reference output from one DG535 to the reference input on the other DG535's.

JITTER

Various noise sources in the DG535 modulate the time delay for the outputs causing "jitter". Some of these noise sources are common to all of the channels, others are independent. The distribution of the pulses around the desired time can be approximated by a Gaussian (or "normal") distribution:

$$p(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(t-T)^2/2\sigma^2}$$

where,
  $p(t)$ = probability of pulse occurring at time t
  T = set time for the output (mean value)
  σ = standard deviation of the distribution

Figure 4 shows the shape of the Gaussian distribution and the relations between the rms jitter and the peak-to-peak jitter.

The rms jitter, σ, is a function of the delay setting. The jitter is about 50 ps rms for delays less than100 µs. For short delays, the peak-to-peak jitter measured on an oscilloscope is about four times the rms jitter. For long delays, the observed jitter measured on an oscilloscope is

primarily due to the jitter of the oscilloscope's horizontal (timebase) deflection circuits. For a good 300 MHz oscilloscope, the rms jitter is typically (25 ps + 10 ppm of the time base).

The rms jitterm, as a function of time delay, is shown in Figure 5 for a Tektronix 2465 oscilloscope, the DG535 using an internal timebase, and for a DG535 with an ideal external source. The jitter for time delays longer than 10 seconds, using the ideal external source, is due to the drift of the analog jitter compensation circuits in the DG535. It can be seen from this figure that the Tek 2465 scope would show an apparent jitter of 1 ns rms at 100 µs even though the DG535's jitter is only 50 ps rms.

CHANNEL to CHANNEL INTERACTION

There is a small interaction (pulling) between channels A and B and between channels C and D when these channels are set within 10 ns of each
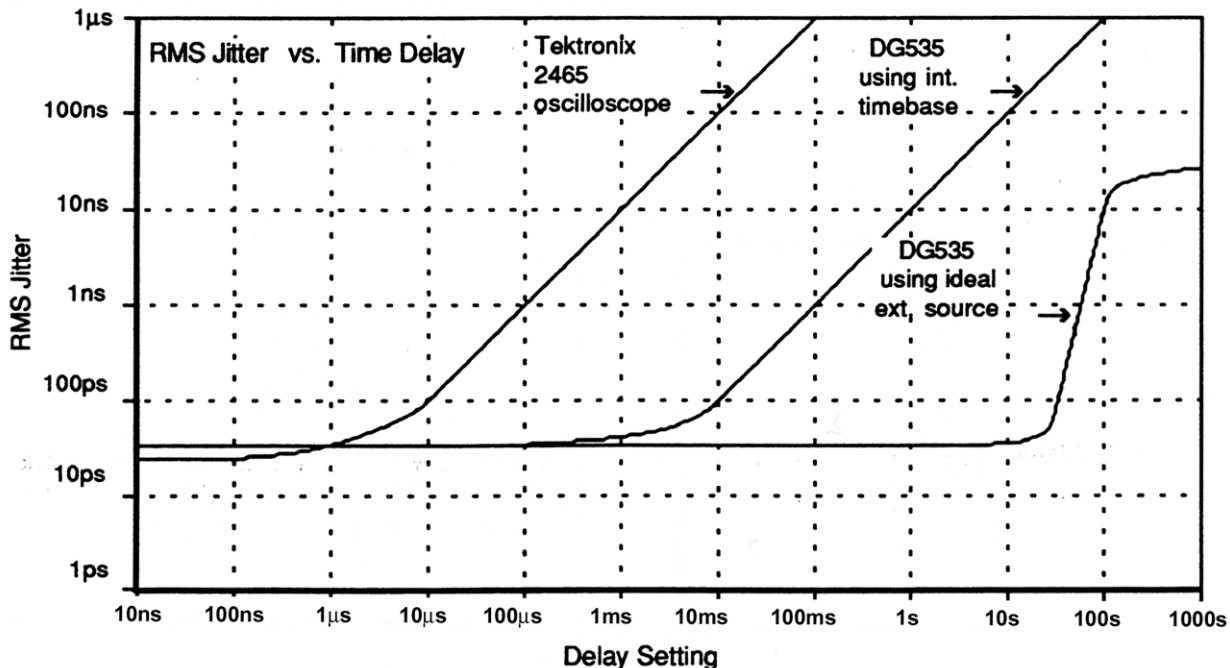

Figure - 5 RMS Jitter

other. The pulling of one channel by the other is typically less than 100 ps.

TIME DELAY vs REPETITION RATE

The time delay for any channel may change by 200 ps as the pulse repetition rate is changed from single shot to the maximum rate of $1/(1\ \mu s$ + longest delay). The burst mode of triggering is, effectively, a rapid change of the pulse repetition rate.

GPIB PROGRAMMING

DETAILED COMMAND LIST

In all of the commands listed here, i, j and k are integer values and f, t and v may be integer, floating point or exponential notation. Optional parameters are enclosed in curly brackets. In general, if optional parameters are omitted then the current value of those parameters will be sent back to the GPIB controller. For example, the command "TM 3" sets the Trigger Mode to mode 3 while the command "TM" will return the response "3".

Command errors will be reported in the Error Status Byte. The controller should verify that the Error Status Byte is zero after each command is sent: a nonzero value indicates a programming problem. When an error is detected, all of the pending commands in the communication buffer are cancelled.

Also, blanks are ignored, case is ignored, multiple commands may be sent on one line if separated by semicolons. All responses are terminated by a carriage return and line feed. The line feed is sent with an EOI.

INITIALIZATION COMMANDS

CL
Clear instrument. The communication buffers are cleared and the default settings are recalled. The instrument default settings are:

Trig:	Trigger mode set to Single-Shot (ie. triggers are off)
Internal:	The default trigger rate is 10,000 Hz
Burst Mode:	Trigger rate = 10,000Hz, 10 pulses per burst and 20 periods per burst.
External:	+1VDC, positive slope, high impedance termination.
Delays:	All delays, A, B, C and D are linked to T0 and set to zero.
Outputs:	All outputs are set to drive high impedance loads to TTL levels.

GPIB:	The GPIB address is not affected, but the terminator is returned to its default value of a carriage return and a line feed with an EOI.

GT{i}{,j}{,k}
Specify one to three ASCII codes, which will terminate each response from the DG535. The default terminator for any response from the DG535 is a carriage return and a line feed. The line feed is accompanied by an EOI. Example: to change the terminator to line feed only, the command would be "GT 10" (the ASCII code for line feed is 10 decimal). The EOI is always sent with the last character of the terminator sequence.

STATUS COMMANDS

ES
Returns the Error Status byte. The error status byte definition is given below. Example: if a command was sent to the DG535 with too many parameters, bit 1 would be set. If the ES command is used to read the error status, and no other errors had occurred, the value "2" would be returned. All bits in the Error Status byte are latched and so will remain set until the "ES" command is executed. All bits are reset to zero after the "ES" command is executed.

ES i
Returns bit i of the Error Status Byte. Example: the command "ES 5" can be used to check for a delay range error. If a delay range error had occurred since the last ES or ES 5 commands had been sent, then a "1" would be returned, otherwise the value "0" would be returned. This command also resets the error bit that is being checked.

ERROR STATUS BYTE DEFINITION

Bit	Description
7	Always zero
6	Recalled data was corrupt
5	Delay range error
4	Delay linkage error
3	Wrong mode for the command
2	Value is outside allowed range
1	Wrong number of parameters
0	Unrecognized command

Bit 6: This bit is set if the RC (recall stored settings) command finds that the stored values have been corrupted. A checksum is done on the settings when they are stored, and if the computed checksum on recall does not match, then the command is aborted and this error bit is set.

Bit 5: This bit is set if an attempt is made to set a delay to a value below zero or above 999.999,999,999,995 seconds. Because the delay channels may be linked to each other, changing a delay to an allowed value may cause another delay to exceed the allowed range of values.

Bit 4: This bit is set if an attempt is made to link delays in an illogical fashion. For example A=B+1.000 and B=A+2.000 is a condition which clearly cannot be satisfied.

Bit 3: This bit is set if the instrument is not in the correct mode for the command that was sent. For example, if the instrument set to trigger on the internal rate generator, the SS (single shot) command will be ignored and cause bit 3 to be set.

Bit 2: This bit is set if the value of a parameter exceeds the allowed range for that parameter. For example, if the command "TL 20.0" is sent, the command will be ignored and bit 2 will be set (because the trigger level may only be set between ±2.56VDC).

Bit 1: This bit is set if too many or too few parameters are sent with a command.

Bit 0: This bit is set if the command is completely unrecognized.

IS
Returns the Instrument Status byte. The definition of the instrument status byte is given below. Example: if the trigger rate to the DG535 is too high, bit 4 of the instrument status byte will be set. Sending the command "IS" will return the value "16" (if no other bits have been set). All of the bits in the instrument status byte, except for the BUSY bit, are latched, ie., if a trigger rate error is detected at any time, that bit will stay set until the "IS" command is sent. All bits, except the BUSY bit, will be reset to 0 after the "IS" command is executed. (See the IS i

command to test one bit of the Instrument Status byte.)

IS i
Returns bit i of the Instrument Status Byte. Example: the command "IS 4" will test bit 4, the "trigger rate too high" bit. The value "1" will be returned if a trigger rate error occurred since the last time the "IS" or "IS 4" command was sent. If no error had occurred, then the value "0" will be returned.

INSTRUMENT STATUS BYTE DEFINITION

Bit Description

7   Memory contents corrupted
6   Service request
5   Always zero
4   Trigger rate too high
3   80MHz PLL is unlocked
2   Trigger has occurred
1   Busy with timing cycle
0   Command error detected

Bit 7: This bit is set if the instrument settings were corrupted since the last time power was removed. The processor computes a checksum of RAM contents, which contain the instrument settings, when a power supply dropout is detected. The checksum is again computed on power-up. If the checksums do not match, then the default settings are used (see CL command for default settings) and the message "Memory Failure" is displayed. A defective Lithium battery or very noisy ac line voltages may cause "Memory Failures" to occur.

Bit 6: This bit is set if the unit is currently requesting service of the GPIB controller. A service request may be generated by a variety of conditions as specified by the service request mask. This bit allows the controller to see if this instrument was the one that asserted the service request line on the GPIB.

Bit 4: This bit is set if the trigger rate is too fast. The instrument requires one microsecond after the last delay has finished to reset all the delay channels. If a trigger comes during this time, then the front panel RATE LED will be turned on and bit 4 will be set.

Bit 3: This bit is set if a gross error is detected in the 80MHz PLL. This can happen if the rear panel switch is set to EXT reference, and the applied

10.0MHz reference is too small or more than a fewpercent off the nominal 10.0MHz. If this occurs, the LCD will display the message "Ext Clk Error".

Bit 2: This bit is set whenever a trigger occurs that starts a delay cycle. Triggers, which occur during a delay cycle, do not set this bit, rather they will set bit 4, the rate error bit.

Bit 1: This bit is set if the unit is currently busy with a timing cycle. Unlike all of the other status bits, it is not latched (rather it reflects the current status of the unit) and it is not reset when read by the IS command (it is reset when the unit finishes the current timing cycle.)

Bit 0: This bit is set if a command error is detected. If this bit is set, the controller should read the Error Status Byte to determine the exact nature of the command error. Command errors can originate from either the GPIB or from front panel interactions.

SM {i}
Set Status Mask for service request to i. The service request status mask is used to specify which Instrument Status bits will generate a GPIB service request. For example, if the command "SM 16" is sent, then a service request will be generated if the "trigger rate too high" bit is set. When a service request is generated, the corresponding bit in the Service Request Mask is turned off. This will prevent an uncontrolled stream of service requests from being generated by the DG535. To re-enable the service request, the controller must again set the service request mask with the "SM i" command.

CS {i}
Set Cursor Mode (i=0) or Number mode (i=1). The unit must be in the cursor mode (CS 0) for the SC, MC, or IC commands to work. Note that certain menu items allow only one type of cursor mode. For example, there is no numeric mode for the menu item, which selects between TTL, NIM, ECL and VAR outputs, and there is no cursor mode in the STORE and RECALL Menus. Selecting an

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DISPLAY CONTROL COMMAND

DL {i, j, k}
Select Display to show menu i, submenu j, line k. The menu, submenu, and line number designations are given in the table below:

DISPLAY LINE SELECT TABLE

i j k	Display Example	Comment
0 0 0	Int Ext Ss Bur Line	Trigger Mode Menu
0 1 0	Rate =1234000.123Hz	Internal Trigger Rate
0 2 0	Threshold = +1.23V	External Trigger Menu
0 2 1	Slope($\pm$) = +	
0 2 2	Trigger Term = 50Ω	
0 3 0	Single Shot (EXC)	Single Shot Trigger
0 4 0	Rate =1234000.000Hz	Burst Trigger Menu
0 4 1	Pulses/Burst 12345	
0 4 2	Periods/Burst 12345	
1 0 0	A = T+123.456789123450	Delay Menus
1 0 1	B = A- 0.123456789125	
1 0 2	C = B+ 23.456789123455	
1 0 3	D = T+ 0.000000000005	

i j k	Display Example	Comment
2 0 0	T0 A B AB C D CD	Output Menu Select
2 1 0	T0: Load = 50Ω	T0 Output Control Menus
2 1 1	T0: TTL NIM ECL VAR	
2 1 2	T0: Amplitude = +1.23	(Only if VAR selected)
2 1 3	T0: Offset = -2.00	(Only if VAR selected)
2 1 4	T0: Inverted Normal	(For TTL, NIM, and ECL)
2 2 0	A: Load = 50Ω	A Output Control Menus
2 2 1	A: TTL NIM ECL VAR	
2 2 2	A: Amplitude = +1.23	(Only if VAR selected)
2 2 3	A: Offset = -2.00	(Only if VAR selected)
2 2 4	A: Inverted Normal	(For TTL, NIM, and ECL)
2 3 0	B: Load = 50Ω	B Output Control Menus
2 3 1	B: TTL NIM ECL VAR	
2 3 2	B: Amplitude =+1.23	(Only if VAR selected)
2 3 3	B: Offset = -2.00	(Only if VAR selected)
2 3 4	B: Inverted Normal	(For TTL, NIM, and ECL)
2 4 0	AB & -AB Loads = 50Ω	AB output control menu
2 4 1	AB: TTL NIM ECL VAR	
2 4 2	AB: Amplitude = +1.23	
2 4 3	AB: Offset = -2.43	
2 5 0	C: Load = 50Ω	C Output Control Menus
2 5 1	C: TTL NIM ECL VAR	
2 5 2	C: Amplitude = +1.23	(Only if VAR selected)
2 5 3	C: Offset = -2.00	(Only if VAR selected)
2 5 4	C: Inverted Normal	(For TTL, NIM, and ECL)
2 6 0	D: Load = 50Ω	D Output Control Menus
2 6 1	D: TTL NIM ECL VAR	
2 6 2	D: Amplitude = +1.23	(Only if VAR selected)
2 6 3	D: Offset = -2.00	(Only if VAR selected)
2 6 4	D: Inverted Normal	(For TTL, NIM, and ECL)
2 7 0	CD & -CD Loads = 50Ω	CD output control menu
2 7 1	CD: TTL NIM ECL VAR	
2 7 2	CD: Amplitude = +1.23	
2 7 3	CD: Offset = -2.43	
3 0 0	Data: GPIB Strings	GPIB Menu
3 0 1	GPIB Address = 15	
3 0 2	Service RQST (EXC)	
4 0 0	Store	Store Menu
5 0 0	Recall	Recall Menu

incorrect cursor mode will have no effect: the error will not be reported in the error status byte.

SC {i}

Move cursor to column i= 0 to 19. This command allows the controller to position the cursor under a particular digit (usually in a DELAY menu) so that the digit may be incremented or decremented by the "IC" command. A request to position the cursor in a non-allowed location (for example, under the decimal point in a time delay menu) will result in a "value outside of allowed range" error, setting bit 2 in the Error Status byte.

MC i

Move cursor left (i=0) or right (i=1). This command allows the cursor to be moved relative to its present position.

IC i

Increment (i=1) or decrement (i=0) the digit at the current cursor location. This command is used to change a displayed parameter in a manner analogous to operating a thumbwheel switch.

DS string

Display a string of 1 to 20 characters. This command allows the controller to display a message on the DG535's liquid crystal display. As with all data that is sent to the DG535, spaces will be stripped from the transmitted data, so the program should use the underline character to_separate_words. Also, do not use semicolons, as they are reserved characters which allow several characters to be sent on the same line.

If the "DS" command is sent without a string, then the display will be cleared and the menu item which was displayed before the "DS string" command was used will be displayed.

DELAY AND OUTPUT COMMANDS

The Delay and Output commands use integer codes, which are assigned to each front panel BNC. The table for these assignment is given below.

Integer	Assignment
0	Trigger Input
1	T0 Output
2	A Output
3	B Output
4	AB and -AB Outputs
5	C Output
6	D Output
7	CD and -CD Outputs

DELAYS

DT i{,j,t}

Delay Time of channel i is set to t seconds relative to channel j. Example: DT 3,2,1.2E-6 will set B=A+0.000,001,200,000 seconds. The command DT 2,1,10.5 will set A=T0+10.500000000000 seconds. Setting delays shorter than 0 or longer than 999.999,999,999,995 seconds will set bit 2 of the Error Status Byte.

A "Delay Linkage Error", bit 4 of the Error Status Byte, is caused by an attempt to totally disconnect a time reference from T0. For example the commands DT 2,3,1.5 ; DT 3,2,2.5 attempt to reference A to B and B to A so that neither is referenced to T0. This command sequence would generate a "Delay Linkage Error".

An efficient method to change a delay is to position the cursor under a digit (using the SC command) and then increment/decrement the digit (using the IC command).

OUTPUT CONTROL

TZ i{,j}

Set the Termination Impedance. Output i is configured to drive a 50Ω load (j=0) or a high-Z load (j=1). (If i=0, this command is used to set the impedance of the external trigger input: see the Trigger control section). Example: "TZ 4,1" will configure both the AB and -AB outputs to drive high impedance loads. The command "TZ 4" will then return the response "1", indicating that the AB and -AB outputs are configured to drive high impedance loads.

OM i{,j}

Set Output i to Mode j where j=0-3 for TTL, NIM, ECL, or VARiable. This command sets the logic level of the front panel outputs. If TTL, NIM or

ECL is selected, the polarity of the logic output is specified by the "OP" command. If the VARiable output mode is selected, then the output amplitude and offsets may be set with the "OA" and "OO" commands. Example: the command "OM 6,0" selects TTL levels (0 to 4VDC) for the D output.

OA i{,v}
Amplitude of output i is set to v Volts if in the VARiable mode. This command is used to set the amplitude, i.e. the size of the step, at an output BNC. The maximum step size is limited to ±4 Volts: the minimum step size is ±0.1VDC. The specified step size must not cause the output level (including the programmed offset) to exceed +4V or -3V. Example: the command sequence "OM 5,3; OO 5,0 ; OA 5,4.0" will select the VARiable mode for output C, zero its offset (see below) and set its amplitude to 4.0VDC. Note the importance of setting the offset: if the offset was set to a level greater than zero, the command "OA 5,4.0" would generate an error because the programmed offset plus amplitude would exceed the +4VDC maximum.

OO i{,v}
Output Offset of output i is set to v Volts if in the VARiable mode. This command is used to set the offset of an output when in the VARiable mode. For pulses which have a rising edge output, the offset is the voltage between the lowest output level and ground, and so a TTL signal has zero offset and +4VDC amplitude, while an ECL signal has -1.8VDC offset and a +1VDC amplitude. To invert the polarity of the pulse, i.e. for a falling edge output, a TTL output is described as a +4VDC offset an a -4VDC amplitude pulse, and an inverted ECL pulse is described by a -0.8VDC offset with a -1.0VDC amplitude.

OP i{,j}
Output Polarity of channel i is inverted (j=0) or normal (j=1) for TTL, ECL or NIM outputs. This command sets the polarity of logic pulses at the BNC outputs. In all cases, normal polarity means that the output will provide a rising edge at the specified time. Example: the command sequence "OM 5,2; OP 5,0" will set the C output for an inverted ECL output, i.e., the output goes from -0.8VDC to -1.8VDC when the channel times out.

TRIGGER COMMANDS

TM {i}
Set Trigger Mode to Int, Ext, SS or Bur (i=0,1,2,3). This command selects between Internal, External, Single-Shot, or Burst trigger modes. Other trigger commands are then used to completely specify the trigger conditions: TR will set the internal trigger rate, TL and TS set the trigger level and trigger slope for external triggers, SS is used to execute a single shot if in the SS mode, and BC and BP set the burst count and burst period for the burst mode. The TR, TL, TS, BC, and BP commands may be executed at any time, regardless of the trigger mode. Example: The command "TM 0" selects the internal rate generator as the trigger source.

TR i{,f}
Set Internal Trigger Rate (i=0) or Burst Trigger Rate (i=1) to f Hz. The frequency may be any value between 0.001 Hz and 1.000MHz. The precision is 0.001Hz below 10Hz, or 4 digits if above 10Hz. Other digits will be truncated. The internal rate generator will settle to the programmed value within 2 seconds after the command is executed: significant departures from the programmed value may be expected during the 2 second settling period. (A simple way to disable triggers during this settling time is to select the single-shot trigger mode, i.e. "TM 2".) Example: the commands "TM 0; TR 0,100.2" will select the internal trigger mode and set the trigger frequency to 100.2Hz.

TL {v}
Set External Trigger Level to v Volts. This command sets the threshold voltage for external triggers. To completely specify the external trigger, the TS (trigger slope) command must also be used. Example: "TM 1; TL 1.00; TS 1" specify the external trigger mode, with the trigger level at 1.00VDC, with a positive slope. These values would be appropriate for triggering on the rising edge of a TTL logic pulse. (Also see the TZ 0{,j} command which sets the input impedance for external triggers.)

TS {i}
Trigger Slope set to falling (i=0) or Rising Edge (i=1). This command selects the slope condition for external triggers. It is used with the TM, TL and TZ commands to specify the conditions for an external trigger. Example: the command "TM 1; TL -1.2; TS 1; TZ 0,0" specify the external trigger mode, a trigger level of -1.2VDC, a positive trigger slope,

and a trigger input impedance of 50Ω to ground. These trigger conditions would be appropriate for triggering on the rising edge of an ECL logic pulse (if it is able to drive a 50Ω load to ground.)

TZ 0{,j}
Set the input impedance of the external trigger input to 50Ω (j=0) or high impedance (j=1). Example: the command "TZ 0,1" will set the input impedance to 1 MΩ, the command "TZ 0,0" will set the input impedance to 50Ω.

SS
Single-Shot trigger if Trigger Mode = 2. Each time this command is issued, a new delay cycle will be initiated (if one is not already in progress) provided that the single shot trigger mode has been selected. Example: the commands "TM 2; SS; SS; SS" will place the instrument in the single-shot mode and trigger it three times.

BC {i}
Burst Count of i (2 to 32766) pulses per burst. This command is used to specify the number of pulses, which will be in each burst of pulses when in the burst mode. The Trigger Rate and Burst Period commands are also used to completely specify the burst mode of operation. Example: the command sequence "TM 3; TR 1,1000; BC 4; BP 10" selects the burst mode, sets the trigger rate to 1000Hz, and specifies 4 pulses per burst. Each burst is separated by 10 triggers, so that a new burst will start every 10ms.

BP {i}
Burst Period of i (4 to 32766) triggers per burst. This command specifies the number of triggers between the start of each burst of pulses when in the burst mode. The burst period must always be at least one larger than the Burst Count. Example: the command "TM 3; TR 1,1E5; BC 100; BP 101" sets the burst mode of operation with a trigger rate of 100KHz. There will be 100 pulses in each burst, one trigger will be skipped, and a new burst of pulses will start.

STORE and RECALL COMMANDS

ST i
Store all instrument settings to location i=1 to 9. This command allows nine complete setups to be stored in the instrument's nonvolatile RAM. All of the instrument's settings are stored, even those that are not currently active: for example, the trigger level for external triggers will be stored even though the instrument may be operating on internal trigger. Example: the command "ST 3" will save all the instrument settings to the third storage location.

RC i
Recall all settings from location i=1 to 9. Default settings may be recalled from location 0. (See the CL command for the values of the default settings that are recalled from location 0.) Example: the command "RC 3" will recall all of the instrument settings which were last stored by the ST command to location 3. The display will show the menu item that was active when the ST 3 command was executed. It is possible that the memory contents of the stored settings were corrupted between the time they were stored and when they were recalled. If this happens, the message "Recall Error" will be displayed on the LCD and bit 6 of the Error Status byte will be set. Example: The command sequence "RC 3; ES 6" would recall location 3 and check bit 6 of the Error Status byte. If a "1" is returned by the "ES 6" command, then the stored values were found to be corrupted, and so the instrument setting will not be changed. Memory contents may be lost if the Lithium battery is defective or if large line transients occur.

TROUBLESHOOTING

To start, make sure that the power entry module on the rear panel is set for ac line voltage in your area, and that the correct fuse is installed. The programmed voltage may be seen through a window when the power entry module is viewed from the bottom of the unit. Verify that the line cord is plugged all the way into the power entry module, and that the power button on the front panel is pressed "in".

When the ac power is applied, you should be able to hear the fan: the unit will not function properly if the fan is not operating or if the side or bottom vent holes are blocked.

Set the rear panel switch "down" to select the INT timebase. If this switch is "up", and a reference is not applied, then the error message "Ext Clk Error" will appear on the LCD.

LCD CONTRAST

If there are no characters on the LCD, or the contrast is very poor, adjust the contrast with the two right most keys (the ones with the gray up/down arrows). The up arrow will increase the contrast, the down arrow will decrease the contrast when the keypad is in the cursor mode.

COLD BOOT

If the instrument turns on, but is completely unresponsive to the keyboard, then the RAM contents may have been corrupted causing the instrument to "hang". To remedy this situation, turn the unit off, then hold down the BSP (backspace) key down and turn the unit back on again. This procedure initializes the RAM. User calibration parameters will be overwritten by the factory calibration parameters and GPIB address will be set to 15.

QUICK TEST

Unplug all cables from the unit and recall the "default" settings by pressing the "RECALL" menu key, the "0" key, and the "EXC" key in sequence. The trigger menu will appear on the LCD with the cursor under "Ss" for single shot. Press "TRIG" to select this mode. To trigger the unit once, press the "EXC" key. The TRIG and BUSY LED's on the left side of the instrument will blink once each time the "EXC" key is pressed. Now press the left arrow key (the "4" key) twice to select the Internal trigger source. The default trigger rate is 10 kHz, so the TRIG and BUSY LED's will now glow steadily. Trigger an oscilloscope on the rising edge of the T0 output, and use the scope to look at the output from channel A on the 1µs per division scale.

The default time delays are all zero. Press the DELAY Menu Key to show the A delay setting. Use the left/right cursor keys to position the cursor beneath the 1µs digit (seventh from the right). Use the up cursor key to increment the delay in 1µs increments. The rising edge of the A output will move 1µs later each time the "up" cursor key is pressed. The RATE error LED will come on if the delay setting exceeds 99µs, as the trigger period is 100µs (10kHz) and 1µs is required for the reset cycle. If channel A is set for a longer delay than any of the other channels, its pulse will have a constant pulse width of about 800ns.

OUTPUT LEVELS

If an output has only half of the programmed amplitude, then it is very likely that a high impedance load was specified in the OUTPUT Menu, but a 50Ω load is attached. If an output behaves very erratically, then it is very likely that a 50Ω load was specified, but a high impedance load is attached. The pulse outputs, AB and CD, will misbehave if a 50Ω load is specified for these outputs, but a 50Ω load is attached to only one side of the pair (i.e., to the AB output but not to the -AB output).

JITTER

The most common causes of excess jitter are (1) incorrect external trigger threshold setting, (2) noise or amplitude fluctuations on the trigger input, (3) insufficient or excessive trigger amplitude, (4) blocked or stalled cooling fan, or (5) triggering at too high a rate. The instrument is specified to have a jitter of 50ps + 0.01ppm of the delay (rms). The peak-to-peak jitter, as seen on an oscilloscope, is approximately four times the rms jitter, hence one would expect to see about 200ps peak-to-peak on an oscilloscope for short delays.

GPIB PROBLEMS

The first requirement for GPIB operation is to properly attach GPIB cable and to specify the correct address for the instrument. The default GPIB address is 15, but any address between 1 and 30 may be set from the front panel. To check the GPIB address, press the GPIB menu key twice. A new GPIB address may be entered by keying in the number and pressing the EXC key.

The DG535 will respond to commands only if it is addressed and the Remote Enable line (REN) is asserted. When this happens, the front panel goes to the REMote state, which disables all of the keys except the keyboard mode key, which allows the user to leave the REMote state.

The program can prevent users from using the keyboard by asserting the Local-Lockout state (LLO).

Different GPIB controllers expect different "string terminators" to finish each response from an instrument. The default GPIB terminator for the DG535 is a carriage return and a linefeed with an EOI. The "GT" command may be used to change the GPIB terminator if your controller requires a different one.

CALIBRATION

There are hundreds of bytes of calibration data in ROM which are determined when the instrument is calibrated at the factory. Most of these calibration bytes will never need to be adjusted: they correct for unit-to-unit variations, which will not change with aging. Other calibration bytes may need to be adjusted to re-calibrate the instrument.

All of the calibration bytes are stored in ROM, however, those which may need to be adjusted are also stored in nonvolatile RAM. The RAM bytes are the values that are used in the operation of the instrument. These bytes are transferred from ROM to RAM when (1) the unit is first calibrated, (2) if the RAM data is found to be corrupted, or (3) by a request to "Recall Factory Cal" in the calibration menu. Only the bytes that are stored in RAM may be modified by the end user in the calibration procedure.

The procedure for the adjustment of these calibration bytes is detailed here. The calibration bytes are used to minimize jitter, adjust the full-scale analog delays to 12.50ns, adjust the offsets and amplitudes of the output drivers, adjust the trigger threshold offset, and to set the optional TCXO time base to exactly 10MHz.

Any part, or all, of the calibration procedure may be done. If only an adjustment of the timebase is desired there is no need to do the entire calibration procedure. If your calibration attempt only makes things worse, you have the option of recalling the factory calibration constants to restore the RAM values to their factory settings.

REQUIRED EQUIPMENT

A 300MHz scope with 500ps/div timescale such as a Tektronix 2465. A frequency counter with a timebase better than 0.1ppm such as an HP 5384A with option 004 (ovenize timebase) to calibrate the optional 1ppm TCXO. A pulse generator to provide adjustable amplitude fast risetime (less than 5ns) pulses such as an SRS DG535. You will also need several 50Ω coax cables and about ten 50Ω terminators.

CALIBRATION PROCEDURE

Start by setting the instrument to the default settings with a RECALL 0 EXC. This will set the trigger mode to Single shot, the delays to zero, the output levels to TTL, normal polarity, and configure the output drivers for high impedance loads.

You should recall the factory calibration values. If you are going to do only a partial calibration you may wish to write down calibration values that have been recently entered so that they may reentered without redoing the calibration. To recall the factory calibration values hold down the BSP key and press the RECALL key. The message "Rcl Fact Cal (EXC)" will appear. Now press the EXC button to recall the factory calibration parameters.

Trigger Threshold Calibration

The trigger threshold calibration is required only if the Ext Trigger input was damaged, and the input JFET transistor, Q114, has been replaced. This calibration adjusts the input offset for the trigger input to cancel variations in the gate-to-source voltage between JFETs.

___ Recall default instrument settings by RECALL 0 EXC.

___ Select Ext trigger and set the Trigger Input to 50 Ω (leave the Threshold = +1.00 VDC, Slope = +)

___ Apply a 10 KHz 0 to +1.00 VDC pulse to the Ext Trigger Input.

___ Adjust the Trig Threshold value (the last item in the BSP-GPIB Menu) so that the TRIG LED blinks intermittently.

Optional 1 ppm Internal Timebase Calibration

This procedure should be done only if the /03 optional 1ppm TCXO oscillator is installed (refer to the rear panel serial number tag). There is no adjustment for the standard 25ppm time base.

___ Set the rear panel 10.000 MHz source switch to the INT position.

___ Attach a frequency counter to the 10.0 MHz reference output BNC. This output can provide a 1V p-p output into a 50Ω load.

___ Press the STORE Menu Key and adjust the value to set the reference frequency to 10.000000 MHz ± 1Hz. This calibrates the internal time base to 0.1ppm.

CALIBRATION MENUS

To access the calibration menus you must hold down the BSP key then press a menu key. Each menu key is used to access a different calibration factor per the following table:

Menu Key	Name	Function
TRIG	Jitter Cal	Minimize jitter from Ext Trig to A
DELAY	Delay T0	Set T0's full scale analog delay
	Delay A	Set A's full scale analog delay (do not alter this value)
	Delay B	Set B's full scale analog delay
	Delay C	Set C's full scale analog delay
	Delay D	Set D's full scale analog delay
GPIB	Amplitude T0	Adjust T0's amplitude
	Amplitude A	Adjust A's amplitude
	Amplitude B	Adjust B's amplitude
	Amplitude AB	Adjust AB's amplitude
	Amplitude C	Adjust C's amplitude
	Amplitude D	Adjust D's amplitude
	Amplitude CD	Adjust CD's amplitude
	Trigger Thres	Calibrate Ext Trig Input threshold
OUTPUT	Offset T0	Adjust T0's output offset
	Offset A	Adjust A's output offset
	Offset B	Adjust B's output offset
	Offset AB	Adjust AB's output offset
	Offset -AB	Adjust -AB's output offset
	Offset C	Adjust C's output offset
	Offset D	Adjust D's output offset
	Offset CD	Adjust CD's output offset
	Offset -CD	Adjust -CD's output offset
STORE	Freq Cal	Set optional TCXO to 10.000000 MHz
RECALL	Rcl Fact Cal	Press EXC to recall factory calibration

Output Amplitude Calibration

This procedure is used to calibrate the amplitude of the front panel output drivers. You will adjust calibration values to get a -0.800 VDC pulse into a high impedance load on the T0, A, B, C, D, AB and the CD outputs.

___ Recall default settings: RECALL 0 EXC

___ Use the TRIG Menu key to select Int trigger. Press TRIG again to set the rate to 100 KHz.

___ Use the DELAY Menu key to set the delays for channel B and channel D to 5 µs.

___ Use the OUTPUT Menu key to set all the outputs for High-Z loads, NIM logic levels. (between 0 and -0.8 VDC.) Do this for T0, A, B, AB, C, D and CD outputs.

For each of the outputs T0, A, B, AB, C, D and CD:

___ Connect the output to the oscilloscope input (1 MΩ input, 200 mV/div sensitivity).

___ Hold down the BSP key and press the GPIB key to access the amplitude calibration factor for the corresponding channel.

___ Use the Up/Down cursor keys to adjust the amplitude of the output to -0.800 VDC.

Output Offset Calibration

This procedure is used to calibrate the offset of the front panel output drivers. You will adjust calibration values to get zero offset into a high impedance load on the T0, A, B, AB, -AB, C, D, CD and the -CD outputs.

___ Recall default settings: RECALL 0 EXC

___ Use the TRIG Menu key to select Int trigger. Press TRIG again to set the rate to 100 KHz.

___ Use the DELAY Menu key to set the delays for channel B and channel D to 5 μs.

___ Use the OUTPUT Menu key to set all the outputs for High-Z loads, NIM logic levels (between 0 and -0.8 VDC). Do this for T0, A, B, AB, C, D and CD outputs.

For each of the outputs T0, A, B, AB, -AB, C, D, CD and -CD:

___ Connect the output to the oscilloscope input (1 MΩ input, 200 mV/div sensitivity).

___ Hold down the BSP key and press the OUTPUT key to access the Offset calibration value for the corresponding channel.

___ Use the Up/Down cursor keys to adjust the offset of the output (i.e. the top of the -0.800 V pulse) to zero.

Jitter Calibration

This procedure is used to minimize the timing jitter of all the outputs with respect to an external trigger. Apply a fast risetime (<3 ns) +2 V pulse with a 10 KHz repetition rate to External Trigger input of the DG535 under test. The same pulse should also go to the CH 1 input of the oscilloscope. A good way to do this is to use the T0 output from another DG535, which has been set to drive a 50 Ω load to TTL levels. Place a tee directly on this output, with one cable to the DG535 under test, and the other cable to the oscilloscope. Both cables should be terminated into 50 Ω. With this arrangement the T0 output sees a 25 Ω load, and so the pulse amplitude will be 2 V.

The jitter from the External Trigger input to any output (T0, A, B, C or D) should be less than 50 ps rms. On a non-intensified fast oscilloscope triggered at 10 KHz, a 50 ps rms jitter will appear as about 200 ps peak-to-peak jitter. Careful attention to trigger levels and termination impedances is required to observe this small jitter.

DG535 settings:

___ Recall default settings with RECALL 0 EXC

___ Select Ext trigger: +1.00 V threshold, + slope, 50 Ω Term

___ Set Delay A = 100 ns, B, C, D to 1 μs

___ Connect the A output to the oscilloscope's CH 2 input

Scope settings:

___ CH 1 and CH 2 inputs both terminated into 50 Ω

___ Trigger on CH 1 with trigger threshold set to +1.00 V

___ 500 mV/div sensitivity on both channels.

___ Main timebase set for 50 ns/div

___ Delayed timebase set for 5 ns/div

___ Center CH 2 trace and horizontal expand x10 to 500 ps/div

___ Change CH 2 sensitivity to 200 mV/div

Jitter Cal Factor

___ Hold down the BSP key and press the TRIG key to access the Jitter Cal factor.

___ Adjust the Jitter Cal factor to minimize the jitter from the External trigger to the A delay output.

Delay Cal Factors

For each of the channels T0, B, C and D (not A):

___ Set the delay for the selected channel to 100 ns, all other delays to 1 μs. (Skip this step for T0)

___ Connect the selected delay to the CH 2 input of the oscilloscope.

___ Hold down the BSP key and press the DELAY key to access the delay factor for the corresponding delay output.

___ Adjust the delay factor to minimize the jitter between the External trigger and the delay output