53A-518 TRANSIENT DIGITIZER SUBSYSTEM

OPERATING MANUAL

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53A-518 TRANSIENT DIGITIZER SUBSYSTEM

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DESCRIPTION

The 53A-518 Transient Digitizer Subsystem (TDS) consists of two interconnected printed circuit board assemblies for use in a CDS 53/63 Series System. The TDS can digitize a single channel of data at a rate of 500,000 readings per second, producing 12-bit samples which are stored in a 1,048,576 word circular buffer memory. The 1M memory can store 524,288 12-bit samples. In addition, the TDS can be programmed to collect 8-bit samples. In this case, the circular buffer memory will store 1,048,576 samples. Since the TDS has built-in memory, it can collect data while the system controller (calculator or computer) is free to do other tasks.

The TDS has the ability to program a trigger event and a measurement count, which must be satisfied before the TDS will stop sampling input data. The trigger event may be either a specified input signal level or an externally supplied digital pulse. This facility allows the user to sample known amounts of data, both before and after a critical event. The user could, for example, program the card to start loading data into its circular memory, later trigger on a voltage above 3 V, and then take an additional 9000 measurements. When the measurement sequence was completed, the TDS would have stored in memory 1,039,576 measurements before the trigger event and 9000 measurements after the trigger event.

Once a measurement sequence is completed, the system controller can request that each measurement taken be returned, or it can instruct the TDS to first preprocess the measurements. Preprocessing commands are available for such functions as: Average, Standard Deviation, Peak and Minimum Measurement Values, etc.

The input voltage ranges of the TDS ($\pm$9.995 V, $\pm$.9995 V, $\pm$.09995 V) and the measurement sampling rate are programmable. If the user wishes, an external sampling rate generator may be used.

The TDS has Built-In Test Equipment (BITE) for self-testing all of the memory (RAM and EPROM), and indicator LEDs for displaying the operating status of the TDS.

The TDS consists of the following cards:

53A-518-1 A/D Card.
53A-518-2 Microprocessor/Memory Card.

CONTROLS AND INDICATORS

The following controls and indicators are provided to select and display the functions of the 53A-518 Card's operating environment.

53A-518-1 A/D Card

Power LED
The Power LED being lit is simply an indication that all required dc power (+5 V, ±15 V) is being supplied to the Card.

Trigger LED
The "T" LED will be lit when the trigger event, as defined by the Trigger Command, has occurred. The "T" LED will extinguish when the next Trigger Command is issued.

Measurement Complete LED
The "MC" LED will be lit when a sampling sequence, as defined by a Trigger Command, is completed. It will extinguish when the next Trigger Command is issued.

Inhibit LED
The "INH" LED will be lit when the inhibit input is low.

Internal Sample Rate LED
The "ISR" LED will be lit whenever the internal sample rate generator is enabled.

53A-518-2 Microprocessor And Control Card

Address Select Switch

When the system controller (calculator or computer) transfers data to or from the TDS, all communication is with the 53A-518-2 Card. For this reason, the 53A-518-2 Card is the only TDS Card that has an Address Select Switch.

The Address Select Switch is a miniature 10-position switch labeled "ADDRESS" that selects the 53A System's address (0-9) for the TDS. The switch's cover opens to allow the address to be reselected. A screwdriver with a narrow, flat blade should be used to turn the cam-action wiper to the desired address position.

Halt Switch

This two-position slide switch is located near the card's backplane edge connector. It selects the state of the 53A-518-2 Card after an @XH (Halt) or STOP command is received by the 53/63 Series System.

a. If the Halt Switch is in the ON position, then the 53A-518-2 Card is reset to its power-up state, all parameters are reset to their default values, and the Power LED is lit.

b. If the Halt Switch is in the OFF position, then the 53A-518-2 Card becomes unaddressed, the Power LED is lit, and any programmed parameters of the card remain unchanged.

Power LED

This LED provides a valuable diagnostic tool by giving the system programmer a visual indication of the action that the system is currently taking. Whenever the 53A-518-2 Card is addressed by the system controller, the Power LED goes out. The LED remains out until another System Card is addressed. Since only one System Card can be addressed at a time, an unlit Power LED indicates the System Card with which the controller is currently communicating. The Power LED being lit not only indicates that the 53A-518-2 Card is unaddressed, but that all required dc power (+5 V) is being supplied.

Range LEDs

The top three LEDs labeled H, M, and L indicate the programmed input range of the TDS. H indicates the ±9.995 V, or High-Range, M the ±0.9995 V, or Mid-Range, and L the ±0.09995 V Low-Range. In the calibration mode (See RANGE Command), two of these LEDs will be lit simultaneously and the extinguished LED indicates the selected range.

Extend LED

The "EXT" LED will be lit whenever 12-bit sampling is in effect. It will be extinguished whenever 8-bit sampling is in effect.

AC LED

The "AC" LED will be lit whenever the input has been programmed for ac coupling. It will be extinguished whenever dc coupling has been programmed.

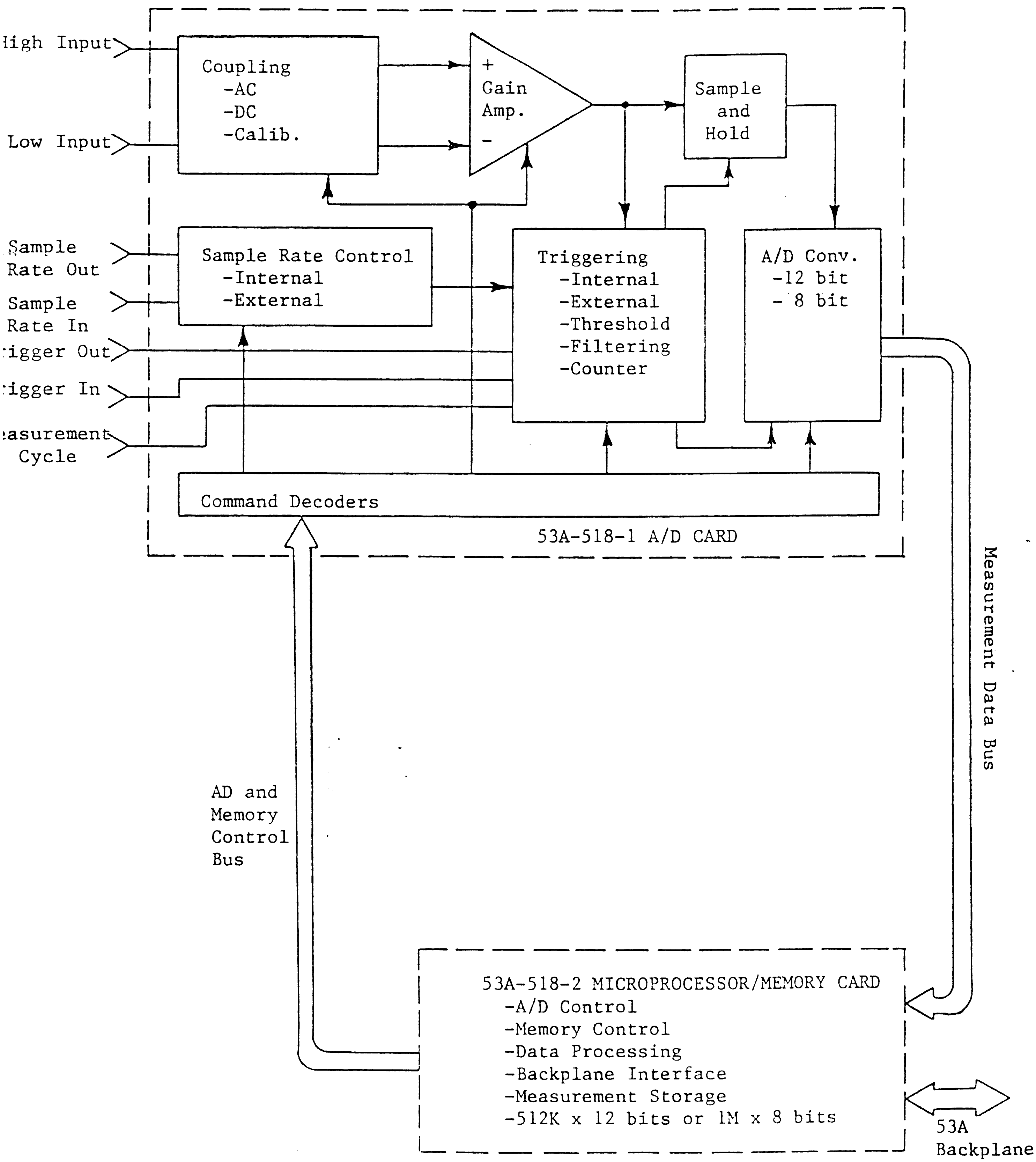
Preprocess LED

The LED marked "P" will be lit whenever the TDS is performing a data preprocessing function.

Measurement In Process LED
The "MIP" LED will be lit whenever the TDS is digitizing and storing data into the TDS memory.

Error LED
The "ERR" LED will be lit whenever the TDS detects an incorrect command from the system controller. It will remain lit until the error is cleared with an Error command.

BLOCK DIAGRAM



SPECIFICATIONS

Ranges (programmable): ±9.995 V, ±0.9995 V, ±0.09995 V.

Input Coupling (programmable): ac coupled - 10 Hz to 250 kHz, ±0.6 dB.
dc coupled - dc to 250 kHz, ±0.5 dB.

Input Amplifier: Number of Input Channels - 1
Type Input: Differential
Input Impedance - 2 megohm ±5%, shunted by 20 pf.
Maximum Input: ac coupled, 150 V (dc + peak ac).
dc coupled, High to Low Input, ±150 V peak,
Either input to ground ±150 V peak.

Linearity/Calibration Accuracy (23 °C +2 °C):

12-Bit Measurements	Accuracy
±9.995 V Range	±2 1/2 LSBs or .06% FS
±.9995 V Range	±2 LSBs or .05% FS
±.09995 V Range	±5 LSBs or .12% FS

8-Bit Measurements	Accuracy
All Ranges	±1/2 LSBs

Noise Accuracy (23 °C +2 °C):

12-Bit Measurements	Accuracy
±9.995 V Range	±3 LSBs
±.9995 V Range	±6 LSBs
±.09995 V Range	±7 LSBs

8-Bit Measurements	Accuracy
All Ranges	±1/2 LSBs

System Accuracy Drift: Without dynamic calibration - ±400 ppm/ °C of full scale.
With dynamic calibration - N/A, drift error eliminated.

Sample and Hold: Aperture time - 18 ns max.
Aperture time uncertainty - 60 ps max.

Effective Common Mode Rejection (1K unbalance):

Range	dc to 400 Hz
±9.995 V	55 dB
±.9995 V	75 dB
±.09995 V	80 dB

Memory Storage: 32,768 12-bit measurements or 65,536 8-bit measurements standard expandable to 262,144 12-bit measurements or 524,288 8-bit measurements. (See Option 001).

Memory Organization: Circular buffer. 512K x 12 bits, or 1M x 8 bits.

Maximum Sampling Rate (8 or 12 bits): 500,000 measurements per second.

Internal Sample Rate Generator (programmable):	Time Between Samples	Step Size
	2.0 μs to 16 ms	0.5 μs
	16 ms to 32 ms	1 μs
	32 ms to 30 s	1 ms
	30 s to 9 hr	1 s

External Sample Rate Generator: Type Input - TTL, negative going edge, 1 TTL load.
Pulse Width - min, 75 ns.
Pulse Rate - 500 kHz maximum.

Triggering:

Internal: A specified number from 100 to 409,600 measurements are digitized unconditionally after the Trigger Command is received from the system controller.

Digital: The TDS begins digitizing measurements when it receives a Trigger Command and continues until a specified number of measurements have been stored after detecting a negative TTL pulse on the External Trigger Input line. Minimum pulse width, 50 ns.

Threshold Level: The TDS begins digitizing measurements when it receives a Trigger Command and continues until a specified number of measurements have been stored after detecting an input signal above (or below) a programmed dc level.

Inhibit Input: Function - when low, prevents TDS from sampling.
Type Input - TTL, low true, 1 TTL load.

External Trigger Output: Function - used to synchronize multiple TDSs for simultaneous sampling.
Type Output - TTL, negative true pulse.
Simultaneous Sampling Uncertainty - ±75 ns.

Data Output Format (programmable): Four decimal digits with sign and decimal point; 12/8 bit binary packed into 8-bit bytes or blocked into records with a checksum.

Data Transfer Rate: Greater than 60,000 bytes per second using binary transfer.

Programmed By: ASCII characters.

Calibration Cycle: Six months.

Function Card Slots Used: Two slots.

Power Requirements: The 5-volt and ±15-volt power is provided by a 53A-060 Power Supply located in the 53A-002 Card Cage.

Voltage: (+4.75 V to +5.25 V dc): 53A-518-1 1.40 A, maximum quiescent; 1.50 A, peak.

53A-518-2 1.75 A, maximum quiescent; 1.80 A, peak.

Voltage (+15 V):	53A-518-1 .100 A, maximum quiescent; 0.110 A, peak.
Voltage (-15 V):	53A-518-1 .080 A, maximum quiescent; 0.090 A, peak.
Cooling:	Provided by the fan in the 53/63 Card Cage.
Temperature:	-10 °C to +65 °C, operating (assumes ambient temperature of 55 ° and airflow to assure less than 10 °C temperature rise). -40 °C to +85 °C, storage.
Humidity:	Less than 95% R.H., noncondensing.
Dimensions:	53A-518-1, 53A-518-2, and 53A-518-3: 197 mm High, 220 mm Deep, 19 mm Wide (7.75 in X 8.66 in X 0.75 in)
Dimensions, Shipping:	When ordered with a 53/63 Card Cage, the card is installed in one of the card cage's function-card slots. When ordered alone the shipping dimensions are: 254 mm X 254 mm X 254 mm (10 in X 10 in X 10 in)
Weight:	53A-518-1: 0.46 kg (1.0 lbs). 53A-518-2: 0.23 kg (0.5 lbs).
Weight, Shipping:	When ordered with a 53/63 Card Cage, the card is installed in one of the card cage's function-card slots. When ordered alone the shipping weight is: 53A-518-1: 1.3 kg (2.8 lbs). 53A-518-2: 0.64 kg (1.4 lbs).
Mounting Position:	Any orientation.
Mounting Location:	Plugs into any two adjacent System Slots of the 53A-002 Card Cage.
A/D Input/Output Connections:	A 48-pin printed circuit-type hooded connector (53A-780), provides a connection for all A/D Input/Output connections.
Required Equipment:	53A-780 Hooded Connector.
Equipment Supplied:	1 - 53A-518-1 A/D Pacer Card. 1 - 53A-518-2 Microprocessor/Memory Card. 2 - Spare fuses (Part #42202-52001). 1 - Operating Manual (Part #00000-15180). 1 - Service Manual (Part #00000-25180).

OPERATION

Overview

The TDS is programmed and queried by ASCII characters transferred between the system controller and the 53A/63A System communications card. The TDS is connected to the communications card through the 53A-002/63A-012 Card Cage backplane. The ASCII characters used, and the actions initiated, are described in the command listings that follow. When initiating commands to the TDS, more than one command may be entered on a line by simply stringing the commands together; they are scanned and acted upon in a left-to-right order. Spaces, null characters, and colons may be inserted between commands or command arguments without affecting how the card operates. Carriage-returns, <CR>, and line-feeds, <LF>, may be optionally inserted between commands. Command arguments that have leading zeroes may be transmitted without the leading zeroes, however, the command will not be executed by the TDS until another command or a carriage-return (<CR>) is sent to the card.

Typically a programming sequence will begin with one or more commands which provide the TDS with parameters to be used when it digitizes samples.

Summary

An overview of the commands, in the order they typically would be programmed is as follows:

B The BITS command selects either 8-bit or 12-bit measurements.

R The RANGE command selects the input voltage range and either ac or dc signal coupling, it may also be used to specify dynamic offset calibration.

S The SAMPLE command selects either external or internal sample rate generators. When the internal sample rate generator is selected the sampling rate must be specified.

F The FILTER command selects signal filters used with threshold level triggering such as high-pass, low-pass, band-pass or dc filtering.

I The INTERRUPT command tells the TDS when to generate an interrupt to the system controller. Interrupts may be produced when the measurement collection the preprocessing is complete.

Once these parameters have been set up, they will remain in effect until they are changed. New analog data may now be digitized and placed in the circular memory:

T The TRIGGER command specifies triggering options and causes the TDS to begin sampling. Triggering options a count of the number of measurements to be taken after the event.

After the circular buffer memory has been loaded, the user will want to examine its contents:

A The ACCEPT command allows the system controller to examine the raw measurement data in either ASCII or binary formats.

P The PREPROCESS command allows the system controller to recover the mean, minimum, maximum, standard deviation, and true root mean square of the raw measurements.

In addition, two commands allow the system controller to determine the status of the TDS:

Q The QUERY command will inform the system controller if the TDS is busy digitizing measurements, preprocessing data, or simply waiting.

E The ERROR command will tell the system controller whether or not the TDS has been sent an invalid command, and will provide a code describing any error.

In some circumstances, it may be necessary to reset the TDS:

K The KILL command stops the TDS and returns it to its power-up state.

HALT The HALT command is a special command which may be used to reset the TDS, as well as other system cards in a 53A Mainframe.

STOP The STOP signal is really a hard-wired control line which is typically used to reset all instrumentation in a system. The TDS will respond to this signal by returning to its power-up state.

Card Commands

Detailed descriptions of these commands, in the same order as listed above, are given on the following pages.

Command	Description
B	The BITS command is used to select either 8-bit or 12-bit data sampling.

Syntax: Bz

B The "B" character identifies this as a BITS command.

z z is a number specifying the number of bits to digitize in each sample. The only allowable options are:

8 for 8-bit measurements
12 for 12-bit measurements

This parameter in no way affects the maximum sampling rate of the TDS, which is 2.0 ms. However, 8-bit measurements require only half as much buffer memory as 12-bit measurements.

On power-up the TDS will automatically be set for 12-bit measurements.

Example:

The command sequence:
@01B8
will program the TDS for 8-bit measurements.

NOTE: In this, and all following examples, it is assumed that the TDS is installed in a 53A Card Cage with address "0", and that the 53A-518-2 Card has its address switch set to position 1.

Command	Description
R	The RANGE Command is used to program the input voltage range and input signal coupling options of the TDS.

Syntax: Rz_1,z_2

R The "R" character identifies this as a Range command sequence. A new Range command will replace any previously entered Range command.

z_1 z_1 is a single letter used to program the input range of the TDS. The ranges are as follows:

H----High-Range, (±9.995 V)
M----Mid-Range, (±0.9995 V)
L----Low-Range, (±0.09995 V)

On power-up, the TDS will be automatically set to the High-Range.

z_2 The z_2 parameter consists of two or three ASCII characters and specifies input signal coupling or dynamic offset calibration, as follows:

DC for dc coupling
AC for ac coupling; ac components below 10 Hz will be attenuated
CAL for dynamic offset calibration

On power-up, dc coupling will be selected.

When dynamic offset calibration is specified, the input signal is disconnected and a dead short is placed across the TDS front-end amplifier. This short may then be measured by the TDS. The reading from this is returned to the system controller, and subsequent readings are subtracted from it to compensate for errors introduced by the thermal drift. The mean value of 100 measurements, taken just before the sample data is taken, will give the most accurate offset reading for that data.

Example:

The command sequence:
@01RL,AC
will program the TDS for ac coupling on the most sensitive range, ±0.09995 V.

Command	Description
S	The SAMPLE Command is used to program either internal or external sample rate generator. If internal sample rate is chosen, then the internal sampling rate is also programmed.

Syntax: Sz

S The "S" character identifies this as a Sample Rate command.

z The "z" parameter is either the letter "E", specifying the use of an external sample rate generator, or a letter followed by a number specifying the use of the internal sample rate generator. The letter indicates in what time units the sampling rate is specified:

C for machine cycles (500 ns)
U for microseconds
M for milliseconds
S for seconds

The number determines how many time units to delay between samples. It must be a positive number in the range of from1 to 32767. It is invalid to specify a delay shorter than 2μs.

On power-up, internal sampling at 2-μs intervals is selected.

Example:

The command sequence:

@01SU60

would program the TDS for an internal sample rate generator, and a sampling rate of one sample every 60 μs.

Command	Description
F	The FILTER Command is used to select an analog filter which limits the input signal. The input signal is passed to the threshold level trigger detection circuit.

Syntax: Fz

F The "F" character identifies this as a Filter command.

z The "z" parameter is a number in the range 0 to 5 which specifies the desired filtering:

0 for dc coupling
1 for ac low pass coupling, f<50 kHz
2 for ac high pass coupling, f>10 Hz
3 for ac high pass coupling, f>1 kHz
4 for ac band pass coupling, 10 Hz<f<50 kHz
5 for ac band pass coupling, 1 kHz<f<50 kHz
f = frequencies passed by filter

On power-up dc coupling is selected.

Remember that this filtering is applied only to the signal that is passed to the threshold level trigger detection circuit. It does not affect the signal which is being digitized.

Example:

The command sequence:
@01F1
would select low-pass coupling.

Command	Description

I

The INTERRUPT Command is used to tell the TDS when it should produce an interrupt to the system controller.

Syntax: Iz_1z_2

I The "I" character identifies this as an Interrupt command.

z_1 The "z_1" parameter determines whether or not the TDS should generate an interrupt when it completes collecting a set of measurements. The parameter is specified as a single digit:

0 to disable the interrupt
1 to enable the interrupt

z_2 The "z_2" parameter determines whether or not the TDS should generate an interrupt when it completes a preprocessing command. The parameter is specified as a single digit:

0 to disable the interrupt
1 to enable the interrupt

Note that there is no comma between the z1 and the z2 parameters.

On power-up no interrupts are enabled.

Example:

The command:
@01I01
would cause the TDS to generate an interrupt when it completes a preprocessing command, but not when it finishes digitizing measurements.

A given interrupt will be armed when the appropriate I Command is issued to the TDS. Once an interrupt condition occurs, the TDS will continue to signal an interrupt condition to the 53A-171 Control Card until the interrupt status of the card cage is read and cleared.

Command	Description

T

The TRIGGER command is used to establish trigger event conditions and initiate digitization of analog measurements.

Syntax: Tz_1z_2

T The "T" character identifies this as a Trigger command.

z_1 The "z_1" parameter is used to specify trigger event conditions. The TDS begins digitizing measurements when this command is initiated and places them in the circular buffer memory until the trigger event occurs. If the trigger event has not occurred by the time the TDS has filled the buffer (1M words), then the TDS will begin overwriting the data at the beginning of the buffer. This buffer wraparound may happen any number of times. After the trigger event, the TDS will continue digitizing measurements and placing them in the buffer in the normal manner. As each measurement is stored it will also be counted. When the count of measurements after the trigger event equals the count specified by the z_2 parameter the TDS will stop and wait for further commands. Options for the z_1 parameter are as follows:

E indicates that the trigger event is a low TTL level at the External Trigger Input pin of the 53A-518-1 Card.
Note that no comma is allowed between z_1 and z_2 in this case.

>±nn,indicates that the trigger event occurs when the input signal, after being filtered, exceeds the voltage defined by ±nn. ±nn is a positive or negative value in the range 00 to 99 where the two-digit number corresponds to the two most significant digits of a measurement on the current range. For example: -45 would represent -4.5 V if the high range had been selected. With this option a comma is required before the z_2 parameter in order to separate the two numeric parameters.

<±nn,indicates that the trigger event occurs when the input signal, after being filtered, is less than the voltage defined by ±nn. The syntax is the same as for the parameter >±nn discussed above.

z_1 omitted
When z1 is not specified, one of two cases may apply. If z_2 is specified, then the trigger event is considered to coincide with the beginning of sampling. The TDS begins digitizing and counting measurements immediately. When the specified number of measurements have been taken, the TDS simply stops. If z_2 is also omitted (i.e. the Trigger command consists of the letter "T" with no parameters) then the TDS will begin digitizing measurements using the z_1 and z_2 parameters specified in the previously entered Trigger command.

z_2 The z_2 parameter specifies the number of samples to be digitized after the trigger event. It is a number in the range 0 to 4095. The actual

number of samples taken after the trigger event is 100 times this value. If a count is specified which exceeds the size of the circular buffer memory installed in the TDS, then buffer wraparound will occur and all measurements before the trigger event will be lost.
When no parameters are specified for the first Trigger command, the power-up default applies. On power-up the z_1 parameter is assumed to be omitted and the z_2 parameter is assumed to be 4095. These defaults are only used if the first Trigger command has no parameters.

Examples:

The command:
@01TE42
would cause the TDS to begin digitizing measurements. It would continue until it sees a low level on the External Trigger Input pin, and then digitize an additional 4200 measurements.

The command
@01T<-13,4095
would cause the TDS to digitize measurements until the input signal level drops below -1.3 V (on the ±9.995 V high range) and then to digitize an additional 409500 measurements.

The command
@01T5
would simply cause the TDS to digitize 500 measurements.

Command	Description
A	The ACCEPT Command is used to select a format and to initiate the return of raw measurement data from the TDS to the system controller.

Syntax: Az_1,z_2,z_3

A The "A" character identifies this as an ACCEPT Command.

z_1 The z_1 parameter is a format code which specifies the format in which raw data is returned to the system controller and the starting position within the circular buffer memory from which the first raw measurement should be taken. The parameter consists of a letter (A, B, I or R) followed by a number in the range 1 to 1048576. The letter specifies the desired format and the number indicates starting buffer position.

z_2 The z_2 parameter specifies the number of measurements per record (record size) and is only used when the format code letter is "R". It must be a number in the range 1 to 15,000.

z_3 The z_3 parameter is a number in the range of 1 through 256 which specifies the step size for both the ACCEPT and PREPROCESS commands. It must be the last field in the ACCEPT command. If the z_3 parameter is not specified, it remains unchanged. Power-up default is a step size of one. This is the same as the z_4 parameter of the PREPROCESS command, and the value set in either command is set for both.

Valid formats for the A command are:

AAn,s
ABn,s
AIn,s
ARn,r,s

where
n = number of measurements (1 1048576)
s = step size (1 256)
r = record size (1 15,000)

After the ACCEPT command is issued, the TDS will begin passing measurements to the system controller, beginning with the specified position in the buffer and continuing until the last (most recent) measurement is processed. If the system controller requests additional input after the last measurement, the action taken by the TDS will depend on the format selected.

The number following the format code specifies both the number of measurements to transfer and the starting position in the circular buffer memory. The values transferred will always be the most recently digitized measurements in the buffer. If the buffer contained 900 measurements and the ACCEPT command asked for 50 of them, the TDS would transfer measurements from buffer positions 851 through 900, in that order. If the ACCEPT command specifies a number of measurements larger than the number actually present in the circular buffer memory, then the TDS will automatically reduce the requested measurement count and start by transferring the oldest measurement in the buffer.

<u>Format Codes</u>:

A For ASCII characters representing the value of the measurement in volts. Each measurement will consist of a string of six or seven characters, beginning with a plus (+) or minus (-) sign followed by decimal digits and a correctly positioned decimal point. Each measurement will be followed by a carriage return and line feed. Any attempt to read from the TDS after the last measurement has been transferred will result in a dummy measurement being sent to the system controller whose value is +9.999. This number is larger than any valid measurement since the maximum reading on the high range is +9.995.

The record size parameter is never used with the A format.

B For a binary representation of the voltage. For 12-bit measurements each reading is presented as two 8-bit bytes. The first byte contains the eight most significant bits; and the second byte contains the four least significant bits in its four most significant bit positions. The four least significant bit positions of the second byte are undefined. Use the following formula to convert the binary representation of the voltage to its decimal equivalent:

$$\frac{C \times (2048-16H-L)}{R}$$

where:

- C is a constant 4.8828125
- H is the value of the first measurement byte, regarded is a binary number in the range 0 to 255
- L is the quotient which results from division of the binary equivalent of the second measurement byte by 16. The remainder is discarded.
- R Is determined by the range on which the measurement is taken; R=1,000 for the High-Range, R=10,000 for the Mid-Range, and R=100,000 for the Low-Range.

For 8-bit measurements, each reading is presented as a single 8-bit byte. The following formula yields the measurement value in volts:

$$\frac{C \times (2048-16H)}{R}$$

where:

H is the binary equivalent of the single measurement byte and all other parameters are as defined above.

Any attempt to read from the TDS after the last measurement has been transferred will result in undefined data being sent to the system controller. The system controller must count measurements when using the B format. This is the fastest means of recovering raw measurement data from the TDS. With a sufficiently fast system controller, the TDS can sustain transfer speeds in excess of 60K bytes per second.

The record size parameter is never used with the B format.

I For a binary integer representation of 12-bit voltage measurements. Each reading is presented as two 8-bit bytes. The first byte contains the four most significant bits in its four least significant bit positions; and the second byte contains the eight least significant bits. The four most significant bit positions of the first byte are filled with zeros.

Use the following formula to convert the binary representation of the voltage to its decimal equivalent:

$$\frac{C \times (2048-256H-L)}{R}$$

where:

- C is a constant 4.8828125
- H is the value of the first measurement byte, regarded as a binary number in the range 0 to 255
- L is the value of the second measurement byte, regarded as a binary number in the range 0 to 255
- R Is determined by the range on which the measurement is taken; R=1,000 for the High-Range, R=10,000 for the Mid-Range, and R=100,000 for the Low-Range.

Any attempt to read from the TDS after the last measurement has been transferred will result in undefined data being sent to the system controller. The system controller must count measurements when using the I format. The transfer rate for the I format is slightly slower than the B format. However, since the data requires little or no data conversion by the system controller, it is often faster from a system standpoint. With a sufficiently fast system controller, the TDS can sustain transfer speeds of 54K bytes per second.

The record size parameter is never used with the B format.

R For a binary representation of the voltage, blocked into records with a checksum appended. Each measurement is presented as two 8-bit bytes. For 12-bit measurements, the first byte contains the six most significant bits of the measurement in its six least significant bit positions. The second byte contains the six least significant bits of the measurement in its six least significant bit positions. The two most significant bit positions of each byte are undefined. Measurements of eight bits are provided in the same format, but the four least significant bits of the second measurement byte will always be zero.

Use the following formula to convert the binary representation of the voltage to its decimal equivalent:

$$\frac{C \times ((64H) + (L-2048))}{R}$$

where:

C is a constant 4.8828125

H is the value of the six least significant bits of the first measurement byte, regarded as a binary number in the range 0 to 63.

L is the corresponding value of the six least significant bits of the second measurement byte, and all other parameters are as defined above for the B format option.

R Is determined by the range on which the measurement is taken; R=1,000 for the High-Range, R=10,000 for the Mid-Range, and R=100,000 for the Low-Range.

Each record will consist of the number of 2-byte measurements (record size) specified by the z_2 parameter, followed by a 2-byte checksum, then Carriage-Return and Line-Feed. The checksum is presented exactly like any other measurement and is formed by taking the bitwise exclusive-OR logic of all of the measurements in the record. The two high order bits of each measurement byte do not participate in this operation and are undefined in the checksum, just as they are undefined in the measurement data.

Any attempt to read data from the TDS after the last measurement value has been transferred will result in the TDS sending a special dummy measurement consisting of two bytes with the following bit pattern: 10101111 10101111. Notice that in this one instance the two most significant bits (the initial 10) of each byte are significant. The TDS will never produce this exact bit pattern for any valid measurement data. If the last valid measurement should occur in the middle of a record, then the remaining positions in the record will be filled with dummy measurements and the checksum will be calculated using the bits of the dummy measurements in the normal fashion.

Examples:

The command

@01AA423

would cause the TDS to transfer the most recent 423 measurements in ASCII format.

The command

@01AR320,16

would cause the TDS to transfer a total of 320 measurements in 20 records of 16 measurements each; these measurements would be coded in binary format and each record would end with a two-byte checksum.

The command

@01AA320,32

would cause the TDS to transfer ten measurements in ASCII format with a step size of 32. The first measurement, number 320 (counted backwards from the end of the buffer), would be followed by measurement numbers 288, 256, 224, 192, 160, 128, 96, 64, and 32. If 32 channels were scanned in sequence, this would correspond to the last ten measurements on one of the channels. The last ten measurements on the next channel in the scan sequence would be read out with the command @01AA319,32.

Command	Description

P

The Preprocess Command is used to do data reduction of measurement data stored in the TDS circular buffer memory.

Syntax: Pz_1,z_2,z_3,z_4

P The "P" character identifies this as a PREPROCESS command.

z_1 The z_1 parameter consists of a single letter which specifies the preprocessing function to be performed:

- S to compute the standard deviation of all measurements.
- T to compute the true Root Mean Square (true RMS) of all measurements.
- V to compute the valley or minimum value of all measurements.
- P to compute the peak or maximum value of all measurements.
- M to compute the mean or average of all measurements stored in TDS buffer memory.

Once the preprocessing function is complete, the system controller may obtain the result by requesting a single line of input from the TDS. This line will contain the preprocessed result in the form of a plus (+) or minus (-) sign followed by ASCII digits with a correctly placed decimal point. The line will end with a Carriage-Return and Line-Feed. If more than one preprocessing command is applied to the same buffer of data, some time can be saved by using intermediate results from earlier functions in evaluating later ones. In order to take advantage of this capability of the TDS, the system controller should specify its preprocessing options in the following order:

S,T,V,P,M

The system controller does not have to wait for preprocessing to complete before requesting input. If the system controller does not wait, the input request will simply be processed when the preprocessing calculations have been completed. The disadvantage of this approach is that the system controller will be unable to do any other work while the TDS is preprocessing. If this is not acceptable, the system operator may use the QUERY or INTERRUPT commands to let the system controller know when the TDS is through.

Typical preprocessing times for 32K measurements are as follows:

CMD	Time (sec) 8-Bit Data	12-Bit Data
M	0.6	0.7
P	1	2
V	1	2
T	5	6
S	5	6

z_2 The z_2 parameter is optional and can be used to specify the starting measurement in the circular data buffer from which to begin preprocessing data. z_2 can be a negative number of up to 7 digits in the range from 0 to -1048576 specifying the offset in measurements from the end of the circular data buffer. Alternately, z_2 can be specified as an offset from the trigger point measurement in the form 'T+n', 'T-n' or just 'T'. The z_2 parameter must be preceded by a comma. If only the comma is used (or if z_2 is greater than the number of measurements in the buffer), the power-up default of starting with the first measurement in the buffer will apply.

z_3 The z_3 parameter is optional and can be used to specify the ending measurement in the circular data buffer through which to preprocess data. The format is the same as the z_2 parameter. If the z_2 parameter is given and the z_3 parameter is not given (or if z_3 is greater than zero), z_3 will default to zero, the power-up default. If z_2 specifies a measurement in the buffer after z_3, then the power-up default of all measurements will apply. If z_2 and z_3 are not specified, they remain unchanged.

z_4 The z_4 parameter is the same as the z_3 parameter of the A command, and sets the step size for both the PREPROCESS and ACCEPT commands. See the ACCEPT command description for details on the use of the step size parameter.

Examples:
The command

@01PS

would cause the TDS to compute the standard deviation of all data in its memory.

The command

@01PM, T-10, T+10

would cause the TDS to compute the mean of the 21 readings starting ten before the trigger through ten after the trigger.

Command	Description
Q	The QUERY Command allows the system controller to determine if the TDS is busy digitizing measurements or preprocessing data.

Syntax: Q

The "Q" character identifies this as a QUERY command.

After receiving a QUERY command, the TDS will provide the system controller with a single line of input consisting of an ASCII digit, 0 or 1, followed by a Carriage-Return and Line-Feed:

0 indicates that the TDS is busy
1 indicates that the TDS is free

NOTE: The QUERY command and response are handled in a special way by the TDS. While it is digitizing measurements, any command other than QUERY will cause measurement sampling to stop, regardless of whether a trigger event has occurred or the count has expired. While it is preprocessing, the QUERY command and the KILL command are the only commands recognized by the TDS. Other commands are deferred until the preprocessing is done.

Example:
The command
@01Q
would request activity status from the TDS.

Command	Description
E	The ERROR Command allows the system controller to determine if a syntax error has been detected in a previous command. Only the first error detected is returned.

Syntax: E

The "E" character identifies this command as an ERROR command.

After receiving an ERROR command the TDS will provide the system controller with a single line of input consisting of two ASCII digits, followed by Carriage-Return and Line-Feed:

00 for no errors
01 for unrecognizable command
02 for invalid Sample Command
03 for invalid Range Command
04 for invalid Bits Command
05 for invalid Interrupt Command
06 for invalid Query Command
07 for invalid Filter Command
08 for invalid Error Command
09 for unexpected input request
10 for invalid Trigger Command
11 for invalid Accept Command
12 for invalid Preprocess Command
13 for no measurements in buffer
14 for memory error

The ERROR command also extinguishes the ERR LED.

Example:
The command
@01E
would request error status from the TDS.

Command	Description
K	The KILL command is used to stop all TDS activity and return it to its power-up state.

Syntax: K

The "K" character identifies this command as a KILL command.

The KILL command immediately returns the TDS to its power-up conditions:

12-bit measurements
High Range (±9.995 V)
dc coupling
No dynamic calibration
Internal sample rate generation
2-us sampling
dc coupling for threshold level trigger
Measurement complete interrupt disabled
Preprocessing complete interrupt disabled
No trigger delays
Trigger count of 409500 measurements
Preprocess all of the captured data.

Example:

The command
@01K
would return the TDS to its power-up state.

INSTALLATION

The 53A-518-1 and 53A-518-2 Cards are System Cards and are, therefore, plugged into the blue slots of the 53A-002 Card Cage.

Before plugging any cards into the 53A-002 Card Cage, connect the CDS supplied ribbon cable to the rectangular connector located at the rear of the 53A-518-1 Card. The end of the cable with the white arrow-shaped polarity marking should be permanently attached to the rectangular connector located at the front of the 53A-518-2 Card.

Viewing the Card Cage from the front, plug the 53A-518-2 Card into the rightmost available System Card slot reserved for the TDS.

Install the 53A-518-1 Card in the leftmost slot reserved for the TDS.

CAUTION:

To avoid plugging the card in backwards, observe the following:

a. Match the keyed slot on the card to the key in the backplane connector. The component side should be to the right for a 53 Series Chassis and to the top for a 63 Series Chassis.

b. There are two ejectors on the card. Make sure the ejector marked "53A-XXX" is at the top for a 53 Series Chassis and to the left for a 63 Series Chassis.

CAUTION:

Each card is a piece of electronic equipment and therefore has some susceptibility to electrostatic damage (ESD). ESD precautions must be taken whenever the module is handled.

APPENDIX A

53A/63A SYSTEM COMMANDS

Command	Description
@XY	The @XY (Address) command addresses a function card in the 53A/63A System. @ is a delimiter used by the 53A/63A System. X is a mainframe address (0-9) defined by the address-select switch on the 53A-171 Control Card in the addressed mainframe. Y is a function card address (0-9) defined by the address-select switch on the function card. Once a mainframe and function-card combination is addressed, it remains addressed until the 53A/63A System detects a new @ character.
@XS	The @XS (Status) command provides the interrupt status of all function cards within the mainframe defined by X. The interrupt status of all function cards in the addressed mainframe is latched into the 53A-171 Control Card when the @XS command is issued. All function cards in all mainframes become unaddressed after the @XS command is issued. The @XS command allows the interrupt status of the 53A-518 Card to be read as programmed by the I (Interrupt) command (see the Card Commands subsection in the OPERATION section of this manual for details of the I command). The 53A-171 Control Card Operating Manual describes the @XS command in detail.
@XH	The @XH (Halt) command Halts all function cards within the mainframe defined by X. This command does not affect function cards in other mainframes. How a function card reacts to the @XH command depends on the particular card. The 53A-518 Card returns to its power-up state when it is issued an @XH command. In all cases, an addressed function card (Power LED out) becomes unaddressed (Power LED lit).
STOP	The STOP command is not a string of ASCII characters. This command is hard-wired from the system controller (calculator or computer) to the 53A/63A System's communications card in each mainframe. When the system controller issues a STOP command, each function card, (including the 53A-518 Card) reacts as if it received the @XH command described above. How the system controller executes the STOP command depends on the communications card used. For example, when using the 53A-128 IEEE-488 Communications Card, a STOP command is executed whenever the system controller asserts the IEEE-488 bus line IFC (Interface Clear) true.

APPENDIX B

INPUT/OUTPUT CONNECTIONS

All input signals to the TDS are via the Edge Connector on the 53A-518-1 A/D Card.

PIN	
2	High Input to be digitized
3	Low Input to be digitized
10	Inhibit Input, TTL, low true. When this line is brought to a TTL low, the TDS will be inhibited from digitizing data.
11	External Trigger Input, TTL, low true. The function of this input is defined by the TRIGGER Command.
12	Trigger Output, TTL, low true. This line will be brought to a TTL low after the Trigger Event, as defined by the Trigger Command has occurred. This line will go high at the beginning of the next measurement sequence.
13	External Sample Rate Input, TTL.
14	Sample Rate Output. A positive going TTL pulse will occur at this out-put each time the TDS digitizes a measurement.
15	Measurement Complete Output, TTL. This line will go to a TTL low when a measurement sequence is complete. The line will return high at the beginning of the next measurement sequence.
A, B, C and D	+5 Volts dc
E through BB	Ground

APPENDIX C

CALIBRATION

CDS recommends that the 53A-518 Card be calibrated every six months in order for the card to meet its published accuracy specifications. Calibrate the card in an environment where the temperature is between 21°C and 25°C.

Test Equipment Required:

- A 4-digit integrating dc voltmeter with 1-μv resolution.
- A stable voltage source capable of supplying dc voltages in the range -10 V to ±10 V in 0.01 V increments with an accuracy of ±0.008% (a less accurate source may be used if used in conjunction with an integrating dc voltmeter with 0.008% accuracy).
- A 53A-850 Extender Card
- A 53A-780 Hooded Connector
- A 50-ohm BNC-compatible in-line terminator

In addition, if the optional ac balance adjustments are to be performed, the following will be needed (see 53A-518 Card Service Manual for the component layout):

- A signal generator capable of providing sine wave output from 1 kHz to 250 kHz with an amplitude of at least 2 V peak-to-peak.
- An oscilloscope with at least 10 MHz bandwidth.
- A 16-pin IC clip and a cliplead.

Procedure:

1. Install the TDS in a 53A Card Cage as described in the Installation Section of this manual, with the 53A-518-1 A/D Card installed outside the cabinet on a 53A-850 Extender Card, in order to gain access to the calibration points of the TDS. Install only the connector portion of a 53A-780 Hooded Connector on the front edge of the 53A-518-1 Card. Allow 30 minutes warm-up time.

2. Short Pins 2 and 3 and Pins 3 and E of the edge connector.

   Note: No adjustments are necessary for the Low-Range dc calibration. The Mid-Range dc calibration Mid-Range Calibration procedures ensure that the Low-Range dc is calibrated.

3. Program the TDS to the Mid-Range with the "RM" command.

4. Connect a dc voltmeter to measure the voltage between edge connector Pin E and the test point labeled TP3 on the component layout. Record the voltage at TP3.

5. Connect the dc voltmeter to measure the voltage between edge connector Pin E and the test point labeled TP4. Adjust the "Front End Offset" potentiometer until the voltmeter reading matches the reading recorded in Step 4, ±5 µv.

CAUTION:
Make sure that your external voltage source is isolated from the 53A/63A System ground. To verify this, power both the voltage source and 53A/63A System off momentarily. Verify that there is no continuity between the voltage source low and front edge Pin E before connecting the voltage source to the 53A-518-1 Card.

6. Remove the short between Pins 2 and 3 of the front edge connector. Connect Pin 2 to the high output of the voltage source, and connect Pin 3 to the common or low output of the voltage source. Connect the dc voltmeter to measure the voltage between front edge Pin E and the test point labeled TP1.

<u>High-Range Calibration</u>:

7. Program the TDS to the High-Range with the "RH" command, and adjust the external voltage source to deliver +9.990 V.

8. Adjust the "Front End Gain" potentiometer until the dc voltmeter reads -4.995 V ±500 µv.

9. Disconnect the voltmeter from TP1 and edge connector Pin E.

<u>Voltmeter Program</u>:

10. Due to the very short aperture time of the TDS Sample and Hold circuit, it is possible for noise generated by the calibration equipment to be measured by the TDS. A simple approach to solve this problem is to program the TDS to digitize and then to average a large number of samples, thus making it into an integrating dc voltmeter for purposes of dc calibration.

    To write such a program for your system controller include the following steps:

    - program the TDS to use the Mid-Range using the "RM" command
    - program the TDS to take 30,000 samples using the "T300" command
    - program the TDS to wait approximately 200 ms
    - program the TDS to average the samples taken using the "PM" command
    - program the TDS to read and display the resulting average value
    - repeat the above steps as rapidly as possible while performing calibration Steps 11 thru 15.

11. Set the external voltage source to deliver +0.8500 V.

12. Adjust the "Plus Full Scale" potentiometer until the system controller display reads +0.8500 V ±0.0003 V.

13. Set the external voltage source to deliver -0.8500 V.

14. Adjust the "Minus Full Scale" potentiometer until the system controller reads -0.8500 V ±0.0003 V.

15. Repeat Steps 11 through 14 until no further adjustment is needed on the dc voltage.

16. Set the "Trigger Level" potentiometer fully counter-clockwise, set the external voltage source to +0.9500 V and program the TDS to the Mid-Range with the "RM" command.

17. Program the TDS to take measurements until the input signal exceeds a level of .95 V with the "T>95,0" command.

18. Turn the "Trigger Level" potentiometer slowly clockwise until the "T" LED on the 53A-518-1 Card lights.

19. Back the "Trigger Level" potentiometer off slightly and repeat Steps 17 and 18 as needed to ensure an accurate setting of the "Trigger Level" potentiometer.

<u>AC Calibration Check</u>:

20. The remaining steps adjust the ac balance of the front-end amplifiers. This adjustment is performed at the factory prior to initial shipment and normally does not need to be repeated during the life of the instrument. If you suspect that the ac response is out of specification, first perform the ac calibration check without making any adjustments. Do not remove the gold-colored electrostatic shields unless the ac calibration check fails. (See AC Calibration step 40.)

<u>High-Range AC Calibration Check</u>:

21. Program the TDS to the High-Range with the "RH" command.

    CAUTION:
    To avoid equipment damage the isolation caution discussed in Step 6 should be observed.

22. Remove the dc voltage source from edge Pins 2 and 3 and connect the signal generator in its place. Be sure that the common or ground return lead is connected to Pin 3 and that a cliplead connects Pin 3 to Pin E. Adjust the signal generator to produce a sine wave of 4 V amplitude peak-to-peak.

<u>Frequency Response Check Program</u>:

Since the frequency response check is an iterative procedure, it is easier, if your signal generator is programmable, to write a program for the procedure on your system controller.

Include steps 23 through 32, setting up the program so that the calculation results in lines 30 and 32 are continuously displayed.

23. Adjust the signal generator to produce a 1 kHz sine wave. Use a 50-ohm in-line termination to load the signal generator properly.

24. Set the sample interval of the TDS to 1024 us using the command SU1024.

25. Trigger the TDS with the command "T10".

26. Check to see if the TDS is finished by sending a "Q" command and then reading the status. Repeat this step until the response is not "0".

27. Read the true root-mean-square voltage by sending the command "PT" and then record the voltage.

28. Adjust the frequency of the signal generator to 96 kHz.

29. Change the sample interval of the TDS to 2 us using the command "SU2".

30. Repeat steps 25-27 and record the voltage as V_{96kHz}. Record whether or not $20\log(V_{96kHz}/V_{1kHz})$dB is less than ±0.5 dB.

31. Adjust the frequency of the signal generator to 256 kHz.

32. Repeat steps 25-27 and record the voltage as V_{256kHz}. Record whether or not $20\log(V_{256}/V_{1kHz})$dB is less than ±0.5 dB.

Mid-Range AC Calibration Check:

33. Adjust the signal generator to produce a sine wave of 400 mV amplitude peak-to-peak.

34. Program the TDS to Mid-Range using the "RM,DC" command.

35. Repeat steps 23 through 32.

Low-Range AC Calibration Check:

36. Adjust the signal generator to produce a sine wave of 40 mV amplitude peak-to-peak.

37. Program the TDS to Low-Range using the "RL,DC" command.

38. Repeat steps 23 through 32.

39. If the ac calibration check in steps 22 through 38 passes, then the calibration is complete.

AC Calibration:

40. Proceed with this calibration only if the ac calibration check above failed. Remove the gold-colored electrostatic shields.

41. **CAUTION:**
Equipment damage may result if Pin 2 and Pin 3 are improperly connected.

Disconnect the signal generator leads from the edge connector and remove the cliplead between Pins 3 and E. Connect the cliplead between Pins 2 and E and then reconnect the signal generator by reversing the leads going from Pin 2 to Pin 3. The High Input to the TDS (Pin 2) now is connected to 53A/63A System ground.

42. If the ac calibration check passed the Low-, and Mid-Range test, then proceed to step 63 for the High-Range calibration.

43. If the ac calibration check passed the Low Range test, then proceed to step 55 for the Mid-Range and High-Range calibration.

Low-Range AC Calibration:

44. If the Low-Range ac calibration check fails, then connect a cliplead between R233 pin 15 and R233 Pin 9 using a 16-pin IC clip and a cliplead.

45. Program the TDS for Low-Range using the "RL,DC" command. Adjust the signal generator to produce a sine wave of 40 mV amplitude peak-to- peak.

46. Adjust R332 and C33 while performing steps 23 through 32 until the readings at 96 kHz and 256 kHz, relative to the reading at 1 kHz, are as close to 0 dB as possible.

47. Attach an oscilloscope probe to TP1 and attach its ground clip to edge Pin F. Set the horizontal sweep to 5 us per division.

48. Program the TDS using the "RL,CAL" command.

49. Set the signal generator to 96 kHz.

50. Adjust R232 and C232 for minimum signal on TP1.

51. Repeat steps 45 through 50 until no further adjustments are necessary.

52. Remove the IC clip and jumper from R233.

53. Program the TDS using the "RL,DC" command.

54. Repeat steps 23-27.

Mid-Range AC Calibration:

55. Program the TDS to Mid Range with the "RM,DC" command.

56. Set the signal generator to produce a sine wave of 400 mV amplitude peak-to-peak.

57. Adjust R331 while performing steps 23 through 32 until the readings at 96 kHz and 256 kHz, relative to the reading at 1 kHz, are as close to 0 dB as possible.

58. Program the TDS with the "RM,CAL" command.

59. Set the signal generator to 96 kHz.

60. Adjust R231 for minimum signal on TP1.

61. Program the TDS with the "RM,DC" command.

62. Repeat steps 23-27.

High-Range AC Calibration:

63. Program the TDS with the "RH,DC" command.

64. Set the signal generator to produce a sine wave of 4 V amplitude peak- to-peak.

65. Adjust R322 and C32 while performing steps 23 through 32 until the readings at 96 kHz and at 256 kHz, relative to the reading at 1 kHz, are as close to 0 dB as possible.

66. Disconnect the signal generator leads from the edge connector and remove the cliplead between Pins 2 and E. Connect the cliplead between Pins 3 and E and then reconnect the signal generator, but reverse the leads going to Pins 2 and 3 again. The common or ground return lead should be connected to Pin 3, the TDS Low Input, which is connected through the cliplead to 53A/63A System ground. The precaution discussed in step 6 should be observed.

67. Set the signal generator to produce a sine wave of 4 V amplitude peak- to-peak.

68. Adjust R223 and C122 while performing steps 23 through 32 until the readings at 96 kHz and at 256 kHz, relative to the reading at 1 kHz, are as close to 0 dB as possible.

69. Repeat step 41 and then 64 through 68 until no further adjustments are necessary. This procedure calibrates the 53A-518-1 Card for maximum ac common mode rejection.

70. Replace the electrostatic shields.

71. Go back to step 21 to verify that the ac calibration check now passes.