TR3412 / TR2412 HIGH SPEED TRANSIENT RECORDERS

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1 TR3412 GENERAL DESCRIPTION

The TR3412 High Speed Transient Recorder is a high performance four channel transient waveform digitizing instrument designed in a single station CAMAC module and capable of digitizing to 12 bits at rates up to 25 MHz on all four channels. Each channel includes an independent analog front end and analog-to-digital converter providing superior interchannel isolation and full bandwidth availability on all channels. The TR3412 segmented memory architecture and internal timer allow multiple sequential events to be captured and time stamped without the need to read data between events. A full one million sample static memory is provided on each channel and is divisible into smaller data segments.

The TR3412 analog inputs have selectable 2, 10, 20, and 100 volt full scale ranges. A full scale input offset adjustment is also available. The sample rate is adjustable in 1, 2, 5 steps from 40 ns (25 MHz) to 10 µs (100 KHz). An external sample clock from 100 KHz to 20 MHz may also be selected. Multiple modules may be synchronized using the front panel sample clock output.

The store operations respond to front panel trigger events and CAMAC generated triggers. A trigger event starts the recording of a given number of samples (pre-trigger) or stops the continuous recording of a circular buffer of samples after a given number (post-trigger). The sample rate is set independently for samples taken before and after the trigger.

Four front panel TTL level digital status inputs are recorded along with the analog sample data. Another internal binary status recorded with the data indicates whether the sample was taken before or after the trigger. This simplifies reconstruction of waveforms recorded in the circular buffer used in post-trigger operation. An internal timer is used to record a count with each trigger event which can be used to determine the relative time of multiple trigger events. These time stamps are saved in a first-in-first-out (FIFO) memory which may be read on a Q-stop basis to determine how many triggers events are present in the sample memory and when they occurred with respect to each other.

The TR3412 requires no ongoing calibration effort. Periodic calibration procedures are described in Appendix B. For system calibration, the TR3412 includes a *Watch Mode* which allows the analog input channels to be read directly to the CAMAC dataway. By looping on this reading, input signal levels and offsets are easily verified and adjusted or the TR3412 analog offset can be adjusted for system requirements. The *Watch Mode* also makes available the internal timer and the digital status inputs making the TR3412 usable as a simple data acquisition system in this mode.

Important Note: The TR2412 transient recorder is in all respects the same as the TR3412 except that it does not support sample rates above 10 MHz. The effect of any such difference is noted where appropriate in this manual. If not noted otherwise, the function for the TR2412 should be considered identical. The included software is built around the TR3412 specification but will work with a TR2412 except in the noted aspects.

1.1 Specifications Summary

General

Dataway Interface
IEEE 583-1975

Power Requirements
+6 V @ 1.5 A
-6 V @ 1.0 A

Ambient Temperature Range
0 To 50 Degrees C

Package Size
Single Width CAMAC Module

Features

Sample Rate
100 KHz To 25 MHz All Channels
External Clock Up To 20 MHz
50 MHz Bandwidth

Memory Size
1M Sample Per Channel
4096 Sample Minimum Block Size
Configurable Memory Segmenting

Input Channel Architecture
4 Independent Analog Signal Inputs
4 Independent Digital Status Inputs
1 Common Trigger Input

Input Sensitivity
12-Bit Resolution
2-100 Volts Full Scale In Four Ranges
1% Accuracy (40 LSB)
80 dB Minimum Interchannel Isolation

Analog Input Characteristics
Single Ended DC Coupled
Full Scale Offset 15-Bit Resolution
1 MΩ And 10 pF
50 Ω Termination Available

Input Withstand Rating
Analog ±300 VDC
Digital 0 To +6 VDC

Trigger Input
Single Ended DC Or AC Coupled
10 KΩ And 20 pF

Trigger Input Threshold
-10V To +10V 16-Bit Resolution
Rising Edge Or Falling Edge
AC or DC Coupling

Digital Input Signals

Digital Status (TTL)	2.5V	470 Ω
Clock Input (TTL)	2.5 V	470 Ω

Data Readout
Up To 3 MB/s (Full CAMAC Rate)

Digital Outputs

Record Clock Output (TTL)	2.5 V	470 Ω

Clock Input To Output Delay
50 ns Maximum

1.2 Setup and Installation

The TR3412 is a single width CAMAC module using only the standard CAMAC dataway card edge connection to the CAMAC crate and controller module. The TR3412 complies entirely with the IEEE 583-1975 CAMAC standard and can be installed at any CAMAC I/O station.

CAMAC modules should be inserted in the CAMAC crate only after turning off the power to the crate. Otherwise, damage to the module is possible due to momentary misalignment of pins on the card edge connector.

To insert the TR3412 in the CAMAC crate, choose a convenient I/O station and slide the module into the crate with its top and bottom metal rails mated to the guide rails of the crate. Be sure that the module is properly aligned with the card edge connector at the back of the crate. Push the module toward the back of the crate with gentle pressure, but do not insert entirely. Start the threading of the front panel jack screw. Press the TR3412 into the crate completely with firm pressure on the top and bottom of the front panel. Complete the threading of the front panel jack screw.

It is recommended that the TR3412 module and CAMAC controller be installed alone in the crate until the user is familiar with TR3412 operation enough to integrate it with other modules in a CAMAC instrumentation system. Software is included with the TR3412 for operation in a Data Design SCSICrate™ integrated CAMAC crate and controller. If a SCSICrate™ is to be used in the instrumentation system, this software provides an easy way to review TR3412 features and to get the module up and running quickly. The TR3412, SCSICrate™, and included software can also be used as a complete transient recorder system or component subsystem in many bench top instrumentation applications.

2 TR3412 CONTROLS AND INTERFACES

The TR3412 is a single width CAMAC module designed for access to all of its measurement interfaces through front panel connectors. To fit in a minimum of panel space, these connections are made on miniature female Lemo coaxial connectors. In all cases the center conductor of the connector caries the signal and the outer shield conductor is connected to an appropriate CAMAC analog grounding path. These connections and front panel status indicators are described in this section.

2.1 Front Panel Connections

2.1.1 Analog Inputs (Channel 1 to Channel 4)

These inputs are used to connect the measured signal to the analog input circuits of each channel. Each channel includes an independent ground plane and return to CAMAC ground for maximum noise immunity and interchannel isolation. The analog signals are DC coupled to the preamplifier circuitry and see an impedance of 1 MΩ and 10 pF to CAMAC ground. Shorting the posts of the jumper block adjacent to each channel connector on the board will terminate the associated input through a 50 ohm resistor to CAMAC ground.

2.1.2 Digital Status Inputs (DS1 to DS4)

These inputs are TTL level compatible inputs each of which is stored along with data from the corresponding analog channel. There is no other relationship between these inputs and the analog inputs. The signals see a 470Ω impedance to CAMAC ground.

2.1.3 Sample Clock Output

This output is a TTL level signal sourced from 470Ω on the connector labeled *Rec Clock Out*. The signal follows the sample clock used for recording with no more than 50 ns delay. This signal can be connected to the external sample clock input of other modules to synchronize the sample clocks of multiple TR3412 modules or other apparatus. Samples are taken on the rising edge of this clock.

2.1.4 Sample Clock Input

This input is a TTL level signal to the connector labeled *Ext Rec Clock* which sees 470Ω to CAMAC ground. If selected as the sample clock within the TR3412, this signal is used in recording samples during store operations. This input can be used to synchronize multiple TR3412 modules or other apparatus. The minimum input frequency is 100 KHz. The maximum input frequency is 20 MHz (10 MHz for the TR2412).

2.1.5 Trigger Input

This input is a an analog signal used to generate trigger events from the front panel. The input signal sees an impedance of 10 KΩ and 20 pF. When the signal crosses the programmable threshold in the specified direction, a trigger event is recognized. The threshold can be set from -10 volts to +10 volts and can be DC or AC coupled. See section 3.3.4 for more information on trigger threshold and trigger events.

2.2 Front Panel Indicators

Five LED lamps at the bottom of the TR3412 front panel are used to indicate various module status. The following is a description of each.

1) *Rec Pre* indicates that the TR3412 is in *Pre-trigger Store Mode*.

2) *Rec Post* indicates that the TR3412 is in *Post-trigger Store Mode*.

3) *Watch* indicates that the TR3412 is in the *Watch Mode*.

4) *Read* indicates that the TR3412 is in the *Readout Mode* and ready to read data from the sample memory to the CAMAC dataway.

5) *LAM* indicates that a CAMAC LAM would be generated if the LAM was enabled. A LAM is generated internally to the TR3412 when the sample memory has been filled with data.

3 TR3412 CAMAC OPERATION

The TR3412 must be interfaced to an external host computer through the CAMAC dataway and installed controller. The CAMAC interface is used to reset, configure, and read data from the TR3412. This section discusses operation of the TR3412 through the CAMAC interface including the function of global CAMAC signals, module specific setup and operational commands, and TR3412 operating modes. Descriptions of the CAMAC commands contain general operation information and specifics required for invoking features of the TR3412. This information should be reviewed in order to obtain an understanding of required steps for configuration and operation.

3.1 CAMAC Global Signals

3.1.1 CAMAC Status Lines

Q - The Q signal is active in *Readout Mode* when reading data from the timer FIFO to indicate that there are more time points to be read. Q is also active as a response to the *Request Status* command if the internal LAM signal is active whether or not CAMAC LAM is enabled.

X - The X signal is active as a response to every command, indicating that the module is present.

L - The LAM signal is generated internally when the sample memory is full. It may be enabled and disabled by command. By default and after reset, LAM is disabled. In either case, its actual internal state may be read on Q with the *Request Status* function code and in the returned status data.

3.1.2 CAMAC Control Lines

I - The CAMAC inhibit line is used to effectively shut off the module to trigger events. As soon as the inhibit line is deasserted, the module will respond to triggers.

C - The CAMAC C cycle clears all user parameters to their defaults. The internal LAM will be cleared and the TR3412 will be set to the *Readout Mode*.

Z - No function of Z is implemented.

3.2 CAMAC Command Summary

Table 3.1 is a summary of the CAMAC function codes, subaddresses and data ranges which make up the dataway command interface. This table is meant to be a quick reference. Each of the commands is described in detail in section 3.3 below.

COMMAND	FUNCTION	SUBADDRESS	DATA
Read Data	F<0>	A<1> = Channel 1 A<2> = Channel 2 A<3> = Channel 3 A<4> = Channel 4	R1-R16 = Channel Data (See 3.3.6)
Read Timer	F<1>	A<0> = Read Timer FIFO A<2> = Read Latched Lower A<3> = Latch Timer, Read Upper	R1-R16 = Timer Data (See 3.3.8) R1-R16 = Latched Timer Lower Word R1-R16 = Latched Timer Upper Word
Read ID Code	F<2>		R1-R12 = 3412 or 2412
Read Status	F<8>		R1-R16 = Status (See 3.3.7)
Reset Module	F<9>		
Clear LAM	F<10>		
Software Trigger	F<11>		
Set Readout Mode	F<12>		
Set Pre Trigger Store Mode	F<13>		
Set Post Trigger Store Mode	F<14>		
Set Watch Mode	F<15>		
Operating Parameters	F<16>	A<0> = Blocks Per Segment A<1> = Post Trigger Samples Low A<2> = Post Trigger Samples High A<3> = Pre Trigger Sample Rate A<4> = Post Trigger Sample Rate A<5> = Address Preset A<6> = Address Clear A<7> = Timer Resolution	W1-W4 = 0 to 8 (Exponent Of 2) W1-W12 = Samples Taken After Trigger LSB W1-W12 = Samples Taken After Trigger MSB W1-W4 = 0 - 8 (See Table 3.2) W1-W4 = 0 - 8 (See Table 3.2) W1-W8 = 0 - 255 (Block 0 To 255) W1-W4 = 0 - 8 (See Table 3.2)
Analog Input Sensitivity	F<17>	A<1> = Channel 1 A<2> = Channel 2 A<3> = Channel 3 A<4> = Channel 4	W1-W2 = 0 - 3 (See Table 3.3) W1-W2 = 0 - 3 (See Table 3.3) W1-W2 = 0 - 3 (See Table 3.3) W1-W2 = 0 - 3 (See Table 3.3)
Analog Input Offset	F<18>	A<1> = Channel 1 A<2> = Channel 2 A<3> = Channel 3 A<4> = Channel 4	W2-W16 = 16 Bits Offset Binary ±FS/2 W2-W16 = 16 Bits Offset Binary ±FS/2 W2-W16 = 16 Bits Offset Binary ±FS/2 W2-W16 = 16 Bits Offset Binary ±FS/2
Trigger Parameters	F<19>	A<0> = Trigger Threshold A<1> = Reserved A<2> = Trigger Slope A<3> = Trigger Coupling	W1-W16 = 16 Bits Offset Binary ±10V W1 = 0 For Positive, 1 for Negative W1 = 0 for DC, 1 for AC
Clear Timer	F<23>		
Disable LAM	F<24>		
Enable LAM	F<26>		

Notes: 1) FS = Full scale range set by Analog Input Sensitivity command
2) Never issue commands shown as reserved to this module
3) Reset and clear sets all values to zero

Table 3.1 TR3412 CAMAC Command Summary

3.3 CAMAC Command Descriptions

This section describes the TR3412 CAMAC command set in detail and how each command is applied to operation the TR3412. The commands are not described in function code order as they appear in the Table 3.1 above, but instead are described in the order in which they are likely to be applied when configuring and operating the TR3412. Therefore, this section can to some extent be used as a step by step guide to preparing for a transient measurement.

3.3.1 Operating Parameters (F<16>)

The general global operating parameters of the TR3412 are all established by subaddresses of the F<16> command. These parameters include such things as sample rate, timer configuration, and memory allocation. The function of each subaddress is described below.

A<0> = Blocks Per Segment

Each channel is allocated a 1M sample memory which is logically divided into 256 *blocks* of 4096 samples each. To enable the TR3412 to store data from multiple trigger events between readout cycles, the memory may be divided into *segments* each of which is a number of *blocks*. The definitions of the terms *block* and *segment* are important to understanding the operation of the TR3412 sample memory. The A<0> parameter specifies the number of blocks per segment as an exponent of two. That is, the memory may be divided into segments of 1,2,4,8,...,128,256 blocks each. The TR3412 also maintains an internal sample memory pointer which contains the absolute memory address and is linear across the entire memory. The operation of the sample memory pointer is important during data readout. This TR3412 memory architecture concept is diagramed in Figure 3.1 below.

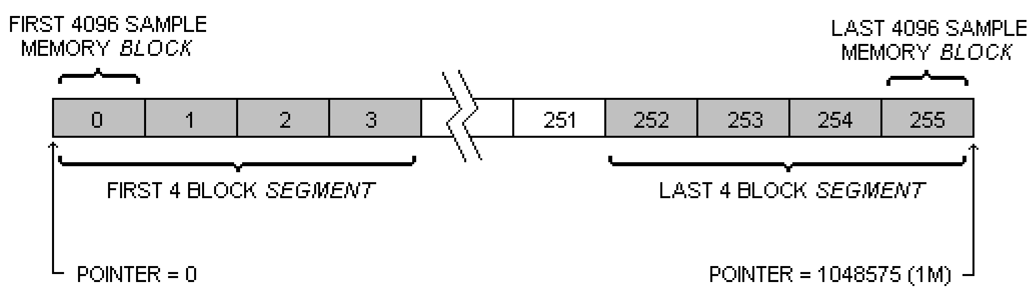


Figure 3.1 Concept of Sample Memory *Blocks* and *Segments*

The example in Figure 3.1 shows the layout of each channel of sample memory for the case where the A<0> parameter is 2 specifying the number of blocks per segment as 4. This would be established by the command F<16>A<0>W<2>. The value can be any number from 0 to 8, specifying from 1 to 256 blocks per segment.

When a store mode is entered, the TR3412 resets the sample memory pointer to zero and begins using the memory of the first defined segment to record data associated with the first trigger event. When all data from the first trigger event are recorded, the TR3412 will move the sample memory pointer to the first location of the next defined segment and record data associated with the next trigger event. This process is repeated causing each subsequent segment to contain sample data associated with subsequent trigger events. When all segments of memory are filled, further storage of data will be inhibited until the memory pointer is reset by reentering the store mode, generally after a readout cycle.

A<2>:A<1> = Samples After Trigger

These subaddresses are used to specify the number of samples to be taken in the *Post-trigger Store Mode* after the trigger event and before recording stops for that event. This parameter applies only to *Post-trigger Store Mode* since in *Pre-trigger Store Mode* the number of samples stored after the trigger is defined by the sample memory segment size. The number specified by this parameter is 24 bits in length but is written to the TR3412 in two 12-bit words with A<2> specifying the higher order 12 bits and A<1> specifying the lower order 12 bits.

In all modes, after recording is complete for one trigger event, the TR3412 moves the recording process to the next sample memory segment. After recording stops for the current trigger event in *Post-trigger Store Mode*, the TR3412 will begin recording pre-trigger samples in the next sample memory segment. In order to properly discern when the trigger occurred, the number of samples to be recorded after the trigger as specified here must be less that the number of samples in the segment. Post-trigger sampling will record at all locations in the sample memory segment returning to the beginning of the sample memory segment from the end as required until the specified number of samples after the trigger are recorded. When the samples are read to the host, the a post trigger indicator bit will be true for samples following the trigger. See section 3.4.3 below for more information about the *Post-trigger Store Mode.*

A<3> = Pre-trigger Sample Rate
A<4> = Post-trigger Sample Rate

These parameters set the two sample rates of the TR3412. The post-trigger rate applies in both store modes and is the rate at which samples are taken and stored after a trigger is received. In *Post-trigger Store Mode* the pre-trigger sample rate is the rate at which samples are recorded before a trigger is received. It is often desirable to store data at a substantially slower rate before the trigger event to conserve memory while recording slow moving pre-trigger signal level information such as background light or offset voltage measurements.

The internally generated sample rate is selected through a 1, 2, 5 step factoring of the minimum sample time through 8 possible settings. An external clock of up to 20 MHz can also be selected with the W<8> setting. These settings are defined in Table 3.2 below.

W	Sample Time	Sample Rate
0	40 ns	25 MHz
1	100 ns	10 MHz
2	200 ns	5 MHz
3	500 ns	2 MHz
4	1 µs	1 MHz
5	2 µs	500 KHz
6	5 µs	200 KHz
7	10 µs	100 KHz
8	External Clock	External Clock

Notes: 1) TR3412 external clock must be <20 MHz
2) TR2412 external clock must be <10 MHz, setting 0 is not defined

Table 3.2 TR3412 Sample Rate Settings

Note that as soon as the trigger is received the TR3412 will begin recording samples at the post-trigger sample rate. Therefore, if the pre-trigger sample rate is different than the post-trigger sample rate, there will be an inherent ambiguity in time between the trigger and the sample taken before the trigger. The typical case of slower pre-trigger rate is shown in Figure 3.2 below. Thus, if the timing of pre-trigger samples versus the trigger time is important, the sample rates must be the same.

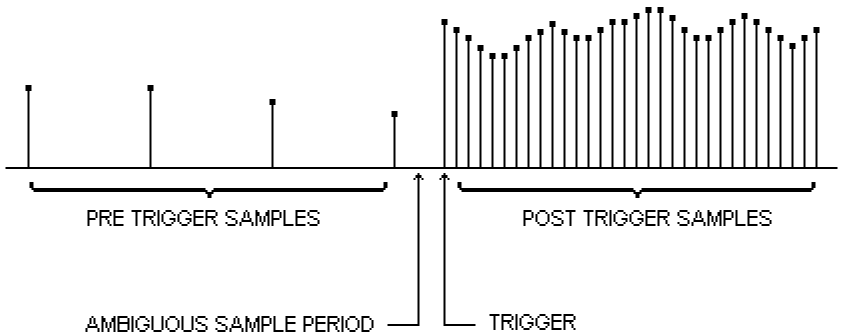


Figure 3.2 Potential Ambiguity of Sample Time Prior to Trigger

A<5> = Address Preset
A<6> = Address Clear

The TR3412 sample memory pointer is used for writing and reading data in the sample memory. The same pointer applies to the sample memory of all four channels. When a store mode is entered, this pointer is reset to the beginning of sample memory. During readout it may be desirable to allow the CAMAC host to define what data is to be read. The A<6> subaddress is used during readout to set the pointer to the beginning of sample memory. The A<5> subaddress is used to set the pointer to the beginning of a specific block of sample memory. Generally, to read a specific sample memory segment, the CAMAC host will set the pointer to the beginning of the first block of the segment of interest and issue a read command for each sample in that segment. Each read command will increment the sample memory pointer to the next sample in memory even beyond the end of a block or segment. Refer to section 3.4.5 below for more information on *Readout Mode* operations.

A<7> = Timer Resolution

The TR3412 includes a 32-bit timer which can be programmed to count at a frequency determined by the W data value issued with this command. The available settings correspond to those available for sample rates as shown in Table 3.2 above except that the external source is not available.

The timer is automatically reset when the TR3412 enters a store mode and begins counting continuously from there. The rate at which the timer counts will determine how long it can run before overflowing as well as the available resolution. This time varies from 172 seconds to 11.9 hours with internal timebase settings.

Each time a trigger event occurs while a store mode is active, the timer count is stored in a first-in-first-out (FIFO) memory. After entering *Readout Mode*, the FIFO can be read to determine how many triggers occurred, and where they are in time with respect to each other. The number of trigger points which exist in the FIFO will also indicate how may segments of sample memory contain valid data. See section of 3.3.8 on the *Read Timer* command for more information.

3.3.2 Analog Input Sensitivity (F<17>)

This command sets the full scale voltage range of each analog channel. The channel affected is specified in the subaddress. The setting can specify 2, 10, 20, or 100 volts full scale using the W data range 0 to 3. Since these ranges are bipolar, they can also be referred to as 1, 5, 10, and 50 volt sensitivity settings. Table 3.3 shows this relationship for easy reference.

W	Full Scale Voltage (FS)	Sensitivity
0	100 V	-50.0V to +50.0V
1	20 V	-10.0V to +10.0V
2	10 V	-5.00V to +5.00V
3	2 V	-1.00V to +1.00V

Table 3.3 TR3412 Analog Input Sensitivity Settings

3.3.3 Analog Input Offset (F<18>)

This command sets the offset of each analog channel. The setting is a 16-bit inverse offset binary number representing an analog offset on the input channel specified in the subaddress nominally from +FS/2 to -FS/2. For example, a setting of 32768 would imply an offset of 0 volts, a setting of 0 will imply an offset of FS/2 volts (i.e. 50 volts for 100 volts full scale range). It is important to note that these are not absolute or calibrated numbers. While 32768 can be expected to provide close to zero offset, it is not necessarily exact. Moreover, the offset generally will not reach FS/2 on either side of zero though it will be close. The intention of this control is to allow the user to empirically determine a number which counteracts a DC offset on the input signal to bring the input signal within the range required for reading. This will typically be done in *Watch Mode* where the user can adjust the offset until the data from the channel are no longer saturated at one extreme or the another.

3.3.4 Trigger Parameters (F<19>)

This command sets the characteristics of the trigger input to determine under what conditions a trigger event will be generated. The front panel trigger input is an analog input with an absolute voltage range of -10 volts to +10 volts. This command is used to set trigger threshold and slope conditions on which a trigger event will occur.

A<0> = Trigger Threshold

This subaddress establishes the voltage threshold through which the trigger signal must pass to cause a trigger event. The direction in which it must pass this threshold is determined by the trigger slope set with the A<2> subaddress as described below. The threshold setting is a 16-bit offset binary number representing a threshold voltage in the range -10 volts to +10 volts. For example, 0 represents a -10 volt threshold, 32768 represents a 0 volt threshold, and 65535 represents a +10 volt threshold.

A<2> = Trigger Slope

This parameter determines the direction in which the trigger threshold must be passed in order for a trigger event to be detected. The command F<19>A<2>W<0> sets the slope to positive while F<19>A<2>W<1> sets the slope to negative. With a positive slope, the trigger input voltage must increase through the threshold for a trigger event to be detected. For a subsequent trigger to be detected, the trigger input voltage must return below the threshold before crossing the threshold again in the positive direction. With a negative slope, the same logic is true except that the trigger event is detected when the trigger voltage decreases through the threshold.

A<3> = Trigger Coupling

This parameter determines if the trigger is AC or DC coupled to the trigger detection circuits. The command F<19>A<3>W<0> sets the trigger input to be DC coupled while the W<1> argument would cause the trigger input to be AC coupled. With DC coupling set, the trigger input is sensitive to absolute voltages in the range of -10 volts to +10 volts. With AC coupling set, the trigger input is sensitive only to changes of this magnitude regardless of the absolute DC voltage applied to the trigger input. In this case any DC voltage at the trigger input would correspond to a 0 volt input to the trigger detection circuit.

3.3.5 Operating Mode Settings (F<12> F<13> F<14> F<15>)

Four function codes are used to set the operating mode of the TR3412. Once an operating mode is set, the TR3412 will remain in that mode until another mode is set through the use of one of these commands. However, upon reset the TR3412 will revert to the *Readout Mode*. The commands are F<12> to F<15> as shown in Table 3.1 above. Refer to section 3.4 below for detailed information about each operating mode.

3.3.6 Read Data (F<0>)

This command is generally used to read data from the sample data memory of the channel specified in the subaddress while the TR3412 is in *Readout Mode*. It can also be used to read data directly from the analog-to-digital converter of the specified channel in *Watch Mode*. The data will appear on the CAMAC dataway in R1 to R16 with R1 as the least significant bit (LSB) and will have the following format.

R16				R12		R1
PT	DS	R1	R0	MSB	Analog Sample Data	LSB

The analog sample data is a 12-bit offset binary number meaning that a value of 0 represents the minimum voltage in the range (-FS/2), 2048 represents 0 volts, and 4096 represents the maximum voltage in the range (+FS/2). The R0 and R1 bits represent the analog sensitivity currently in use with a two bit binary number corresponding to values in Table 3.3 above. The DS bit represents the value of the digital status bit for the corresponding channel. That is, the status of the DS1 input is read with channel 1 sample data. The PT bit is 1 if the sample was recorded after the trigger event for the current sample memory segment. The same data format will be used when reading channel data in *Watch Mode*.

The TR3412 uses a high speed pipeline analog-to-digital converter. The pipeline is seven samples deep. Each sample stored in memory contains the current state of the PT and DS bits and the analog sample data currently emerging from the pipeline. This means that the analog data will represent the voltage at the input seven samples prior to the current sample time. In many applications this delay is immaterial. However, time correlation of analog data with digital status and trigger time is more often than not an important part of the measurement. In this case, part of the data processing required by host software will be shifting of analog sample data from seven samples ahead. This would imply that the first seven (time order) analog samples in a segment of sample memory are not useful and the last seven digital status samples in a segment of memory are not useful. In effect, the resulting array of samples from host software will be shortened by seven.

3.3.7 Read Status (F<8>)

This command is used to identify the operating status of the TR3412 and may be read in any mode. The status is returned in a 16-bit bitwise number on R1 to R16 which has the following format.

R16	R15	R14	R13	R12	R11	R10	R9		R1
LAM	REC	TOF	RO	R	R	R	MSB	Number Of Events	LSB

Where:
Number Of Events = Trigger events captured since store mode entered
R = Reserved bits (read as 0)

And where a 1 indicates:
LAM = Internal LAM signal active (memory full)
REC = TR3412 is in a store mode
TOF = The timer has overflowed
RO = TR3412 is in *Readout Mode*

This status information is typically used to determine the condition of a the TR3412 during store operations. This command will set the CAMAC Q signal if the internal LAM flag is active. The function of this command is not affected by the status of the CAMAC LAM signal enable. The internal LAM flag indicates that the memory has been filled since the beginning of a store operation or since the last time the internal LAM flag was otherwise reset.

3.3.8 Read Timer (F<1>)

A<0> = Read Timer FIFO

This command is used to read data from the timer first-in-first-out (FIFO) memory to determine how many triggers occurred during a store mode operation and when they occurred relative to each other. When either store mode is entered, the timer is reset and begins counting at a rate selectable by the F<16>A<7> operating parameter. Upon the occurrence of a trigger the timer count is written to the timer FIFO.

When the TR3412 is set to *Readout Mode*, the timer FIFO may be read with the F<1>A<0> command. The FIFO may not be read in any other mode. If there are data in the FIFO to be read, the CAMAC Q signal will be set true when the read is executed. When there are no more counts in the FIFO, the Q signal will be set false. In this way, the host can read the FIFO repetitively and stop on Q false. The timer data will be a 16-bit number received on R1 to R16, every two of which represent a 32-bit timer count at the time of a trigger event. The low order 16-bits are returned first in each count. The total number of 16-bit words returned will be twice the number of trigger events received during the prior store mode operation. Generally, the FIFO will be emptied after every store operation and before data readout to determine how many sample memory segments contain useful data and where the trigger events occurred in time with respect to each other. The FIFO is cleared when a store mode is first entered.

A<3>:A<2> = Read Timer Value

When the TR3412 is in any mode other than *Readout Mode*, the *Read Timer* F<1>A<3> command will latch the current 32-bit count in a static register and return the high order 16 bits on the R1 to R16. The F<1>A<2> command can then be used to read the previously latched value of the low order 16 bits on R1 to R16. This sequence of commands allows the actual value of the timer to be read. In this way, the TR3412 timer can be used independently. For example, in the *Watch Mode* the *Clear Timer* command F<23> can be used to clear the timer while subsequent reads can be used to measure a time since the last clear.

In the *Readout Mode*, these commands can be used to read the FIFO one word at a time. While the A<0> method will read the FIFO sequentially, a manual operation with A<0> can be confusing since the output of high or low word will depend on how many words have been read. A<3> will always advance the FIFO and retrieve the high 16-bit word. A<2> would then be issued to retrieve the low word at the same location in the FIFO.

3.3.9 Miscellaneous Commands

Read ID Code (F<2>)

This command returns the number 3412 on the R bus. It can be used to identify a TR3412 in a crate full of modules for automatic software setup.

Reset Module (F<9>)

This command allows the addressed TR3412 module to be reset without resetting other modules in the CAMAC crate. The affect on the module is the same as a CAMAC C cycle.

Clear LAM (F<10>)

This command will clear the TR3412 internal LAM signal. If enabled and active, the CAMAC LAM signal for this module will also change to inactive.

Software Trigger (F<11>)

This command is used when a store mode is active to cause the TR3412 to perform data storage exactly as if a front panel trigger event was received. This is useful in setup and test or in the viewing of repetitive waveforms.

Clear Timer (F<23>)

This command can be used to reset the internal timer from the CAMAC dataway without resetting an other process. This may be useful when the timer is expected to overflow or when a specific timing measurement is of interest.

Disable LAM (F<24>)
Enable LAM (F<26>)

The TR3412 maintains an internal LAM signal which indicates that the sample memory has been filled. This internal LAM signal will not activate the CAMAC LAM signal unless enabled by the *Enable LAM* command. The use of the CAMAC LAM signal can be discontinued with the *Disable LAM* command. The internal LAM will always be generated and can be read using the *Read Status* command as described in section 3.3.7 above.

3.4 TR3412 Operating Modes

This section describes each of the operating modes, specifically as it applies to how data are stored and retrieved. The user should be familiar with the module operating parameters set by each of the commands described in section 3.3 above.

3.4.1 Watch Mode

The *Watch Mode* is entered by issuing the F<15> command which sets the TR3412 to act as a four channel analog-to-digital converter. In this mode, the *Read Data* command (F<0>) can be issued to read the current analog data from the channel specified in the subaddress. The data read will include the status of the front panel digital status input along with the data from the analog input measurement. The format will be as specified in section 3.3.6 above.

The *Watch Mode* is typically used for setup and calibration of the measurement system and can be used for such things as setting appropriate ranges and internal or external offsets. Readings are typically taken and displayed at the host computer in a loop while other parameters are adjusted. Moreover, in this mode the TR3412 can also be used as a simple data acquisition instrument. The *Watch Mode* provides direct access to four 12-bit analog inputs, four digital inputs, and one 32-bit timer.

3.4.2 Pre-trigger Store Mode

The *Pre-trigger Store Mode* is entered by issuing the F<13> command. Entering this mode causes the TR3412 to set the sample memory pointer to the beginning of sample memory and wait for a trigger event. The timer is cleared, the timer overflow status flag (TOF) is cleared, the internal LAM flag (LAM) is cleared, and the timer FIFO is cleared. The timer increments continuously from zero from this point forward.

When a trigger event occurs, the TR3412 will record the timer count in the timer FIFO and begin recording samples on all channels to the first segment of sample memory at the post-trigger sample rate. Samples are recorded until the end of the first segment of sample memory is reached. At that point the sample memory pointer is moved to the beginning of the next segment of sample memory, and the TR3412 begins waiting for the next trigger event. This implies that the minimum time between trigger events is the time required to fill the segment at the post-trigger sample rate. Sample data will continue to be recorded on the occurrence of subsequent trigger events until all sample memory segments are full or another operating mode is selected. When all sample memory segments are full, the internal LAM flag will be set, no more data will be recorded, and the TR3412 will automatically enter the *Readout Mode*.

3.4.3 Post-trigger Store Mode

The *Post-trigger Store Mode* is entered by issuing the F<14> command. Entering this mode causes the TR3412 to set the sample memory pointer to the beginning of sample memory. It will also clear the timer, the timer overflow status flag (TOF), the internal LAM flag (LAM), and the timer FIFO. The timer increments continuously from zero from this point forward.

The TR3412 then begins recording data samples at the pre-trigger sample rate to the first segment of the sample memory for each channel. When the last sample in the current segment of sample memory is reached, the sample memory pointer is returned to the beginning of the same segment and the process continues by overwriting the oldest data. This process will continue until a trigger event is detected. At that point the TR3412 will write the timer count to the timer FIFO and begin recording data samples at the post-trigger sample rate. These samples will be recorded in the same circular buffer as the pre-trigger samples but the process will continue only until the specified number of post-trigger samples are recorded. The sample memory pointer is then moved to the beginning of the next segment of sample memory where the TR3412 again begins to record data samples at the pre-trigger sample rate. In this manner the circular buffer moves from one segment to the next after the recording of each trigger event until all segments of the sample memory are full or another operating mode is entered. When all sample memory segments are full, the internal LAM will be set, no more data will be recorded, and the TR3412 will automatically enter the *Readout Mode*.

Trigger events will be ignored until all samples in a segment have been written with pre-trigger samples at least one time. A trigger occurring after this delay will cause the writing of the requested number of post-trigger samples. Therefore, the minimum time between detected trigger events in this mode is defined as follows.

T = (pre-trigger sample period)*(samples per segment) + (post-trigger sample period)*(requested post-trigger samples)

In order to make it easier to determine which samples are recorded before and after the trigger in the circular buffer, the post-trigger status bit (PT) is included with each sample in the segment. Sample data will generally be read from the first sample in the memory segment. Because the segment forms a circular buffer, this data may not be the oldest data. Figure 3.3 shows some possible synarios.

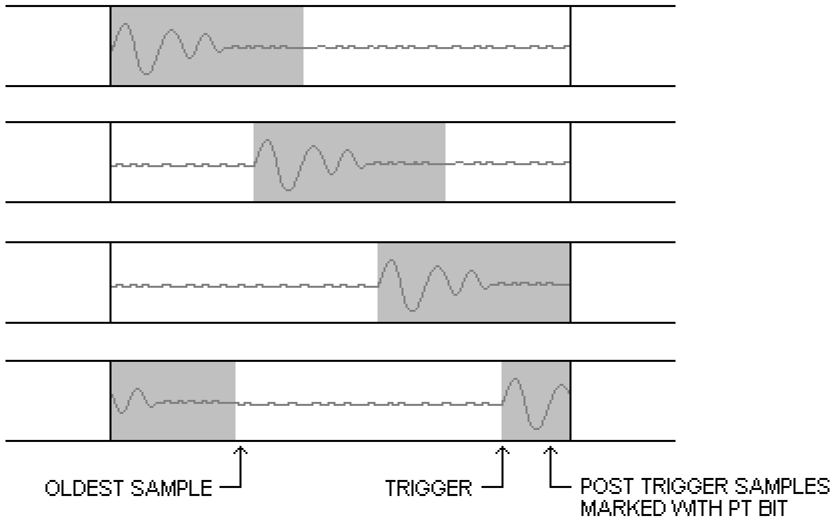


Figure 3.3 *Post-trigger Store Mode Circular Buffering*

Since the data are read from the beginning of the sample memory segment, software must sort out which sample is the oldest to reconstruct the data time line. The data could be read into a circular buffer in the host, the oldest sample found, and the data copied in time order into a linear buffer. Alternatively, the oldest sample could be found in the circular buffer formed by the sample memory segment in the module, after which time data could be read in time order with a read operation which respects this offset.

To find the oldest sample, the segment data are read from the beginning of the circular buffer until a sample is found in which the PT bit is not set and for which the previous sample did have the PT bit set. This process must recognize the memory as a circular buffer. That is, the first sample in the segment is the sample after the last sample in the segment.

With the oldest sample found in the circular buffer, the trigger point is the first sample with the PT bit set which occurs in time after the oldest sample. This time linearized buffer can be used to graph a trace of the recorded data. Finally, the data presentation and analysis should account for the fact that the sample rates can be different before and after the trigger point.

3.4.5 Readout Mode

The *Readout Mode* is set by issuing the F<12> command. Entering this mode causes the TR3412 to set the sample memory pointer to the beginning of sample memory. Sample data can then be read from sample memory using the *Read Data* command (F<0>). Each time the *Read Data* command is issued the current sample is read on the CAMAC data R lines in the format shown in section 3.3.6 above and the sample memory pointer is incremented so that the next sequential sample may be read. The sample memory pointer may be adjusted to the beginning of any block of sample memory using the *Address Preset* command as described in section 3.3.1 above.

Generally, the host application will be aware of how the TR3412 sample memory was divided and, therefore, the location of the segment boundaries will be known. Each segment can be located and read independently by adjusting the sample memory pointer to the beginning of the first block of a segment and reading the appropriate number of samples. The host application can also determine the number and relative time of sample memory segments which contain valid data by reading the timer FIFO. This process is described in section 3.3.8 above. Taken together with data available to the host application about how the TR3412 was configured, there is sufficient information to read and reconstruct a sequence of events.

4 TR3412 SCSICrate SOFTWARE

The *TR3412 Control Panel* is a fully integrated software package for PC compatible computers providing access to a TR3412 transient recorder installed in a Data Design SCSICrate bench top CAMAC crate with integral controller. The SCSICrate provides a fast and efficient interface to up to eleven CAMAC modules for small instrumentation systems. The control panel software is designed on a channel basis and allows a TR3412 channel located at any station in the SCSICrate to be configured and read. The graphical user interface design takes full advantage of the speed of the SCSI connection providing powerful data acquisition features, full data preview, and graphical as well as raw data storage options. The control panel and SCSICrate can be used to complete a turn key stand alone transient recorder system with the TR3412 with no programming required. It can also serve as an excellent starting point to understanding the features of the TR3412 as a part of preparing the design of a multiple module custom instrumentation system. Finally, the software is friendly to other applications also using the SCSICrate, thereby allowing the control panel to become a component in the overall instrumentation system software design.

4.1 Setup and Installation

The *TR3412 Control Panel* is a standard Windows GUI application compatible with 32-bit Microsoft Windows operating systems such as Windows 95 and NT. Before installing the control panel it is important to complete all installation and setup procedures for the SCSICrate. The control panel software itself is distributed on the SCSICrate compact disc (CD) and has a familiar Windows installation procedure. If an older SCSICrate is to be used, the version of the control panel which came with the TR3412 should be installed. This version may include some updates to the SCSICrate drivers. From the Windows command prompt or explorer run the program \TR3412\SETUP.EXE on the CD and follow the on screen instructions.

The control panel installation prepares a directory with two executables and deposits special purpose drivers in the \WINNT\SYSTEM32 or equivalent directory. These programs communicate with the TR3412 through the SCSICrate drivers. The two executables are identified as the TR3412.EXE and TR3412W.EXE files. The installation creates a menu item for the TR3412 program which when executed identifies TR3412 modules in the SCSICrate and provides an interface for channel configuration. This control panel is used to launch one copy of the TR3412W executable for each channel configured. The TR3412W control panel can not be executed by itself. Finally, it is important to note that in order to maximize speed, the control panel is designed for use in a system with only one SCSICrate. However, this SCSICrate may contain multiple TR3412 and other modules.

4.2 Control Panel Basics

Upon starting the *TR3412 Control Panel*, the main system configuration window appears as shown in Figure 4.1 below. The control panel automatically scans the SCSICrate for available TR3412 modules and lists them each as four distinct channels in the *Available Channels* box in the upper right corner. A channel can be selected for use in the configuration by clicking on it to highlight and adding it to the *Installed Channels* list by clicking the *Add* button. Multiple channels can be installed at one time. Similarly, a channel can be removed from the installed list by highlighting it and clicking the *Remove* button. Only one channel at a time can be removed. When complete, the *Installed Channels* list indicates which channels will be used in recording and displaying data.

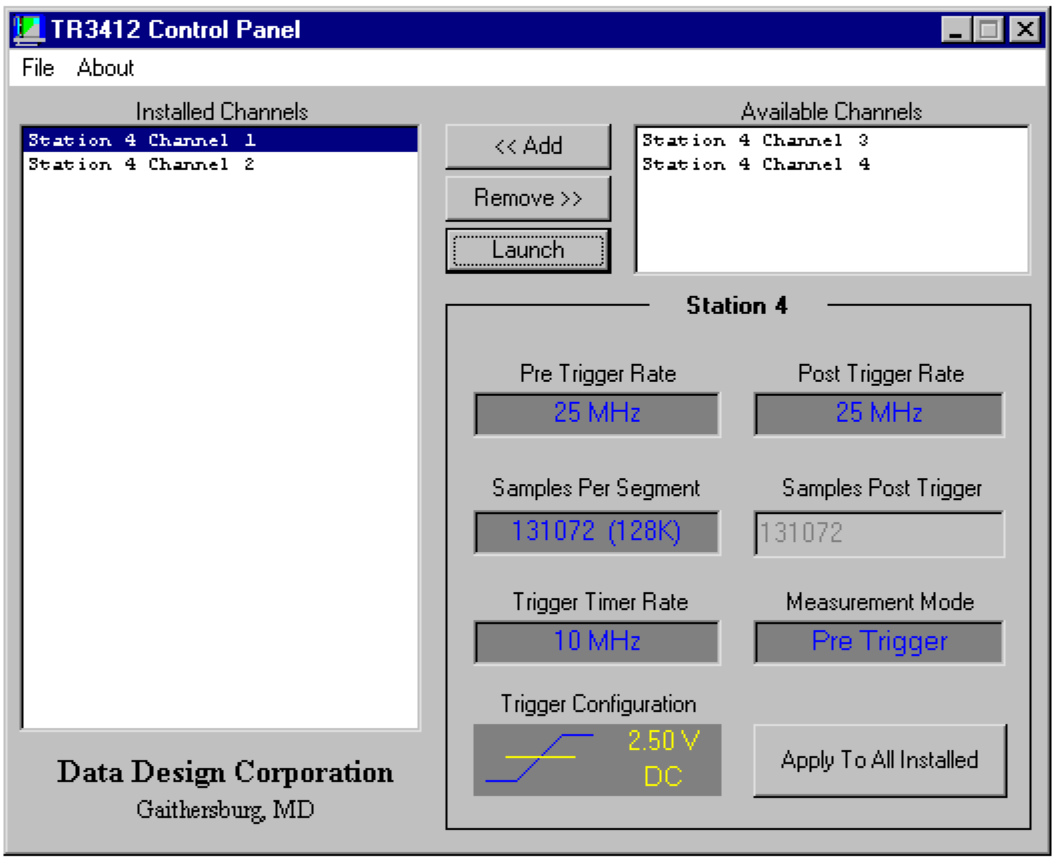


Figure 4.1 TR3412 Configuration Window

4.2.1 Configuring A TR3412 Station

As long as there are channels in the *Installed Channels* list, one such channel will be selected. Another channel can be selected by clicking on it. The station setup dialog at the right of the window will apply to the station of the channel selected in the *Installed Channels* list as indicated by the labeled frame below the *Available Channels* selection box. The parameters in the dialog correspond directly to TR3412 instrument parameters described in detail in section 3 above. Most parameters can be incremented by clicking with the left mouse button and decremented by clicking it with the right mouse button. The *Samples Post Trigger* parameter must be changed by manually entering a value. This value will be coerced to a valid number when other parameters are changed and will be fixed if the *Pre Trigger* measurement mode is selected. Of course, not all parameters apply to all measurement modes.

The *Apply To All Installed* button assigns the parameters shown in the dialog to all TR3412 modules identified in the *Installed Channels* list. It does not change parameters on modules identified in the *Available Channels* list which are not also identified in the *Installed Channels* list.

4.2.2 Configuring A TR3412 Channel

Certain TR3412 configuration parameters apply to only one channel at a time. To adjust these parameters, double click a channel in the *Installed Channels* list. The dialog box shown in Figure 4.2 below appears with the selected channel identified. The parameters have the meanings described in section 3 above. Changes are made to the settings as they are selected in the dialog.

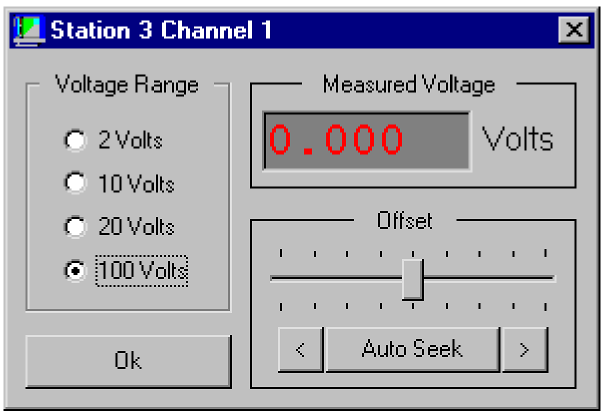


Figure 4.2 TR3412 Channel Configuration Dialog

The selected station is placed in the *Watch Mode* and readings of the analog input are periodically taken and displayed in the *Measured Input* box. In this way, the appropriate full scale voltage can be selected, the offset can be adjusted, and affects of changes on measured voltage can be viewed. With the offset set at mid range (0 volts), this screen behaves like a volt meter. The offset will in effect adjust the 0 volt baseline for the purposes of viewing waveforms similar to the offset control on an oscilloscope. That is, the V=0 baseline can be other than at the center of the display. The absolute measurement data stored to disk from the TR3412 memory will include the offset, similar to the measured voltage reading on this configuration screen.

The offset control has several useful features. The slider can be used as a course adjustment. With an input of steady state DC, the *Auto Seek* button can be used to automatically find the offset required to compensate for the DC input and make the reading appear as zero volts. The < and > buttons can be used to adjust the offset by one step in either direction.

4.2.3 Saving A TR3412 System Configuration

After a system configuration has been diligently tweaked to its optimum settings, the list of installed channels and all associated parameters can be stored to disk for retrieval in a later run of the same experiment. The menu item *File:Save Configuration* provides a standard dialog for this purpose. Configuration files will have the extension *.cfg* in the file name.

A saved configuration can be retrieved with the menu item *File:Open Configuration*. Care should be taken to ensure that the configuration identified in the saved configuration is actually still available in the system. If it is not, the control panel will not be able to properly configure the identified channels.

4.3 Performing A Measurement

The TR3412 control panel is generally configured to perform transient measurements. As such, it follows a sequence of arm, record, and readout states. After the TR3412 system is fully configured, the next step to beginning the measurement is to click the *Launch* button at the center of the configuration dialog. This will inhibit further adjustments of the instrument configuration by minimizing the control panel window and opening a small "measurement governor" dialog as shown in Figure 4.3 below.

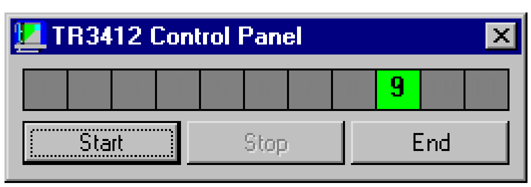


Figure 4.3 Measurement Governor Dialog

The governor dialog will indicate with green colored boxes the TR3412 stations which are active in the system. Click the *Start* button to arm the transient recorders and begin waiting for a trigger event. When the first trigger event is received at a TR3412 station, the box for that station will turn yellow. The measurement session ends when the memory fills or the user clicks the *Stop* button. When the memory fills, the indicator box turns red. A session must end before it can be restarted. When the session is restarted, the box again turns green. The *End* button terminates the session at any stage and restores the setup dialog.

When the session ends for a particular station, a waveform display window opens for each active channel in that station. Data for the first trigger event is displayed. When the session is started again by arming the transient recorder by clicking the *Start* button, the waveform display windows remain but are blanked until the session ends again.

4.4 Waveform Display Window

A separate waveform display window will exist for each active channel in the system. The basic form of this window is shown in Figure 4.4 below. The primary function of the display window is to present a static waveform image of the analog data captured during the transient record session on a gradicule display similar to an oscilloscope. The channel represented and the scale of the gradicule are indicated in the title bar of the window. The scale is derived in part from the sample rate and sensitivity settings of the module. The ADC pipeline delay is removed by the software for completely time accurate display of data.

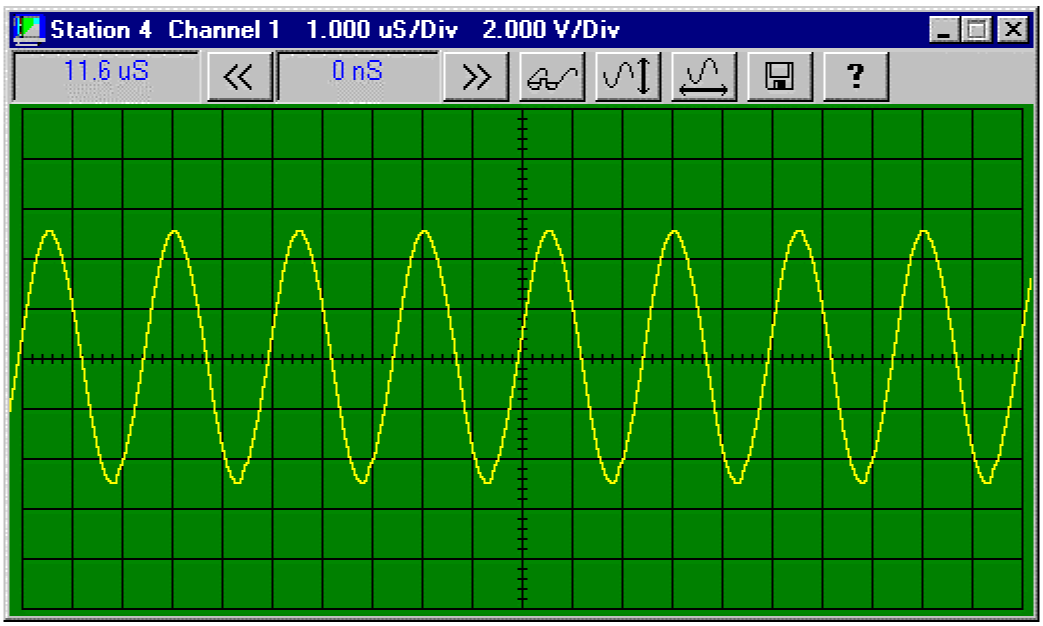
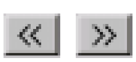
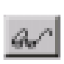
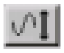


Figure 4.4 Basic TR3412 Waveform Image Window

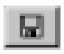
Various controls at the top of the screen allow the user to select the trigger event displayed, zoom the image in various ways, and store the waveform data to disk. These controls have the following specific functions. These functions can also be reviewed by pressing the help button at the upper right corner of the window.

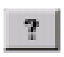
 These buttons select the trigger event to be displayed. A time value displayed between the buttons is the time from the first trigger to the current trigger. If this value is zero, the first trigger is being displayed. The resolution of the time displayed is the resolution selected by the *Trigger Timer Rate* in the configuration for the associated TR3412 station.

 This button zooms the size of the window, but not the number of points displayed. Click on this button with the left mouse button to enlarge the window and with the right mouse button to reduce the window.

 This button zooms the vertical scale of the display. Click on this button with the left mouse button to view finer waveform detail and with the right mouse button to view coarser detail. The gradicule scale indicated in the title bar will change accordingly.

 This button zooms the horizontal scale of the display. Click on this button with the left mouse button to view fewer points spread further apart on the display and with the right mouse button to view more points. The gradicule scale indicated in the title bar will change accordingly.

 This button allows channel data to be saved to a file on disk. Click this button to open a standard file save dialog box. The file type may be selected as a text file or a bitmap. If a bitmap is selected then the file saved will have the .bmp extension and will contain the current waveform image in bitmap format. This file can be directly read by other windows applications. If the text file is selected, the file saved will have the .txt extension and will contain a comma separated text file with all the data captured during the recording session. The format of this file is straight forward including basic identifying information and labeled parameters in the first few lines followed by labeled columns of data. The format is discussed in detail in Appendix A.

 This button displays a help screen with a summary of information in this section.

The waveform image can be panned in time by clicking and holding the left mouse button on the waveform display gradicule. A panning cursor will appear. The waveform can be panned by dragging the mouse. The time which appears in the upper left corner of the window indicates the time represented at the center of the screen with respect to the current trigger event. The resolution of the time displayed is the associated sample period.

4.4.1 Setting Display Preferences

The colors of the display and certain additional display functionality are user selectable through a configuration window. This window is opened by double clicking the waveform display gradicule. The configuration window is shown in Figure 4.5 below.

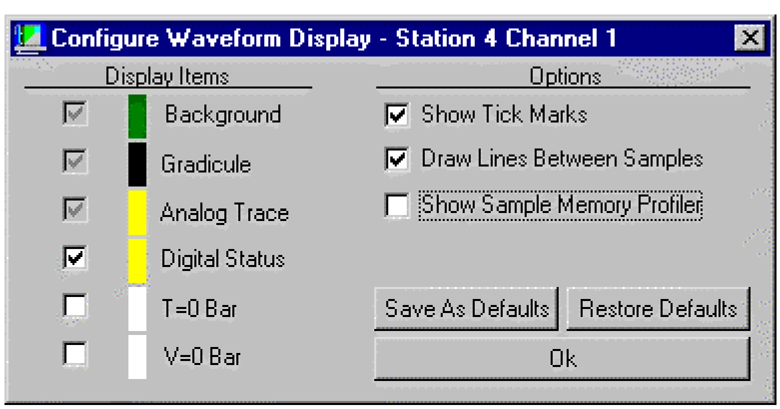


Figure 4.5 Waveform Display Configuration Window

The *Display Items* column at the left side of the configuration window allows the user to select what items are to be displayed and in what color they are to appear. Certain items are always displayed. Other items may be selected or deselected using the adjacent check box. The color may be changed by clicking on the adjacent color patch. This will open a standard color dialog window for purposes of color selection.

The selectable display items are as follows. The *Digital Status* selection will cause the data collected from the digital status input of the current channel to be displayed in a bar along the bottom of the gradicule. The bar will be the color of the gradicule at points when the input is zero and will be the selected color at points when the input is a logical one. The *T=0 Bar* selection places a vertical line of the selected color at the point of the trigger. This selection is only relevant in the display of post trigger measurements. The *V=0 Bar* selection places a horizontal line of the selected color at the level representing an absolute input value of zero volts when the offset is taken into account. This is the zero volt baseline for the displayed waveform in the analogy with the oscilloscope display. The V=0 bar will only appear if selected and the appropriate location is within the viewing area of the gradicule.

The *Options* column at the right side of the configuration window allows the user to select various optional display features. These features are as follows. The *Show Tick Marks* option determines if the gradicule should have tick marks on its vertical and horizontal center lines. The *Draw Lines Between Samples* option determines whether the analog trace should appear as a series of dots at the sample points or as line segments between sample points. The *Show Memory Profiler* option modifies the display window to include additional information about location of the viewing area within the memory. This feature is described in the following section.

As the display configuration is changed, the changes are reflected in the associated waveform display window. These changes will remain in effect as long as the waveform display window remains open. The user may continue to use the waveform display window while the configuration window is open. To make the settings the defaults to be used whenever a waveform display window opens, click the *Save As Defaults* button. This will save a configuration file to disk which will be accessed when a waveform display window is opened, regardless of what channel is represented. To load settings from this file, click the *Restore Defaults* button. If the file does not exist, the factory defaults will be loaded.

4.4.2 Sample Memory Profiler

The sample memory profiler is a selectable feature of the waveform display window which presents more detail about the location of the in memory of the samples currently being viewed. The waveform display window with the sample memory profiler enabled is shown in Figure 4.6 below.

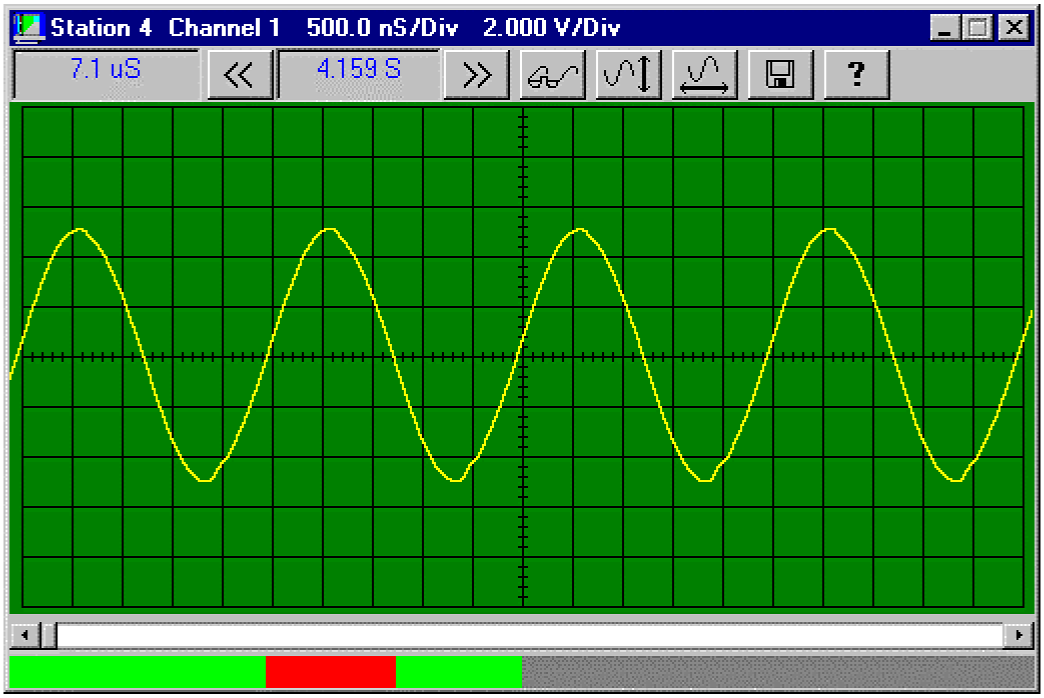


Figure 4.6 Waveform Display Window With Sample Memory Profiler

The colored bar at the bottom of the screen is a graphic representation of the entire TR3412 memory for the displayed channel. The green highlighted area represents the portion of memory which contains valid points collected during the last measurement session. In cases where the segment size is smaller than the entire memory and fewer than the maximum possible triggers were received, the green highlight may be less than the entire memory. Areas containing no data will not be displayed. The red highlight represents the memory segment corresponding to the trigger event for which data points are currently displayed.

The scroll bar above the memory profiler bar adds an additional way to pan through memory. Moreover, the size and location of the cursor in the slider provides an indication of which data points within the red highlighted segment are currently being displayed.

4.4.3 Closing A Measurement Session

A new transient measurement can be started by clicking the *Start* button in the governor dialog window. The display windows will go blank and new data will be collected. When the measurement session is ended, the data will be displayed on the display windows already present. To close the measurement session, close the governor dialog window using the *End* button. The display windows will automatically close and the main configuration window will reappear. The instrument can then be reconfigured and a new measurement session launched.

Appendix A TEXT DATA FILE FORMAT

When data recorded on a particular channel is saved to disk as a text file, a simple comma separated text file is generated which includes all of the data recorded on that channel for the displayed recording session. The ADC pipeline delay is removed by the software for a completely time accurate record of the data.

The file contains a few lines of header information to identify the file and the parameters used during the recording session. The header will appear as follows. A <CR><LF> sequence is included after each line indicated.

TR3412 Sample Data
Station, 4
Channel, 1
Pre-trigger Sample Period (SEC), 0.001
Post-trigger Sample Period (SEC), 0.0000001
Timer Resolution (SEC), 0.0000001
Full Scale Volts, 100

The following line will be a header indicating the names of the data columns in the data to follow. This header line will appear as follows and will include a <CR><LF> at its end.

Trigger Event, Sample Number, Voltage, Analog Data, Digital Status, Post Trigger, Timer Count

The data will follow in the seven columns per line indicated in the header. Each value will be presented in the format indicated below. A <CR><LF> will follow each line.

Trigger Event = Ordinal number of trigger event in the recording session starting with the first trigger event as zero. This number is used to determine with which trigger event a sample is associated.

Sample Number = The time ordinal number of the sample within the data recorded for the trigger event indicated in the first column starting with zero for the first sample.

Voltage = A floating point number indicating the absolute voltage in volts recorded at the given sample.

Analog Data = The 12-bit offset binary number recorded for the given sample presented as a fixed point positive integer.

Digital Status = A 0 or 1 indicating the status of the digital input at the time the given sample was recorded.

Post Trigger = A 0 or 1 indicating that the given sample was taken respectively before or after the current trigger event.

Timer Count = The count found in the timer when the trigger event occurred. This column will be filled only with the sample data of the first post trigger sample for each trigger event. The location of this data point therefore also indicates the beginning of post trigger data similar to the change in the post trigger flag.

Appendix B CALIBRATION PROCEDURE

The TR3412 does not require any ongoing calibration effort during normal use. Once calibrated, the module should provide accurate results within specifications for a period of at least one year. However, as with most analog measurement instrumentation, the TR3412 will require periodic calibration and verification for optimum performance.

The TR3412 analog-to-digital converters use precision semiconductor bandgap voltage references which are highly stable over temperature and age and can not be adjusted. The required calibration points compensate for aging, drift, and tolerances of analog front end components using adjustments of offset, gain, and AC compensation. The trigger level is not a precision value and does not have a calibration point.

Readings and adjustments are made with the analog front end metallic shield covers removed. These covers are removed by carefully prying the cover away from the clip fence with a small flat screw driver. All required readings are to be taken with calibrated test equipment and with respect to test point TP0 defined as the clip fence of the metallic shield of any channel. Calibration proceeds as described in the following steps.

1) Offset Adjustment

The TR3412 is designed with a single reference used as the offset voltage source for all four channels. A separate 16-bit digital-to-analog converter provides the offset adjustment on each channel. The gain in the offset voltage circuit will determine the definition of the offset values written to the module and the associated affect on full scale input range. With a calibrated 4 digit voltage meter, measure the voltage at TP5. Adjust potentiometer R22 until the voltage reads 1.500 volts +/- 0.001 volt.

2) AC Compensation

Each channel is calibrated separately starting with the AC compensation. For this step, the 50 ohm termination jumper should be installed and the channel should be set to the 20 volt full scale input setting.   Apply a 1 KHz square wave (frequency not critical) at 1.000 (tolerance not critical) volts peak to peak as measured when applied to the channel under test.

Place the probe of a calibrated oscilloscope at the test point TP1 to TP4 with the ground on TP0. Use a calibrated x10 or higher impedance probe and set the oscilloscope for DC input. Observe several cycles of the square wave for wave shape only and not for amplitude. Adjust the small variable capacitor located towards the input side in the shielded area until the waveform appears as nearly square as possible.

Expand the time scale of the oscilloscope to focus on a single rising edge. Locate the small variable capacitor near the test point TP1 to TP4. Adjust this capacitor until the leading edge appears as square as possible. Reduce the time scale of the oscilloscope again and verify that the shape of the overall waveform matches that of the input waveform.

2) Gain Adjustment

The gain of the TR3412 analog front end is adjustable on each channel. The range of adjustment is very limited and only compensates for component tolerances and aging. For this step, the 50 ohm termination jumper should be installed and the channel should be set to the 2 volt full scale input setting. Set the offset of the channel to the middle of its range with a value of 32768. Apply a 1 KHz square wave (frequency not critical) at 1.000 (+/- 0.005 volts) peak to peak as measured when applied to the channel under test.

Start CAMAC host software which can read the input voltage in a loop and capture the difference between minimum and maximum readings. Alternatively, transient recordings may be taken and data reviewed manually. Adjust the gain potentiometer (R5, R21, R35, or R46) until the detected difference is 2048 +/- 20 LSB (+/- 0.01 volts or 0.5%).

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