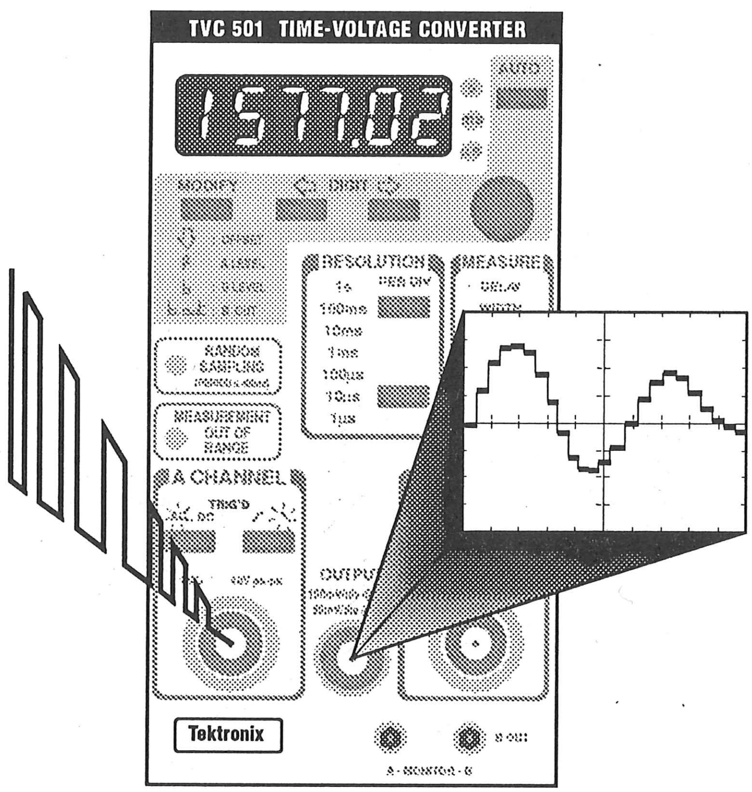
TVC 501

Time-to-Voltage Converter

Sales Guide



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TVC 501 Time-Interval to Voltage Converter **$2500 USDC**

Includes: Operator's manual (070-7991-00), Service manual (070-7992-00), two (2) 42" SMB-BNC monitor cables (012-0532-00), 42" BNC-BNC output cable (012-0057-01), P6109 10X 150 MHz probe.

There are no options. The **TVC 501** requires one slot in a TM 500 or TM 5000 power module mainframe.

Warranty: One (1) Year Standard Warranty (Limited), Tektronix Warranty #2
Export Control: ECCN 6599G. Schedule B: 9030.89.0000.9

Note to our non-U.S. readers.
Since many non-U.S. offices have marketing managers and develop independent marketing programs, I have included as much marketing background material as practical; more information is available. The **TVC 501** represents a new measurement concept. Those of you that have engineering groups might find niche opportunities for region-specific applications. Also, I apologize in advance for the liberal use of American colloquialisms.

July 1990 Vancouver, Wa., USA

Food for Thought

Turn the page for the traditional sales guide material

Oscilloscope Positioning. The battle for the mind.[1]

Engineers know that scopes satisfy certain measurement needs:

- Correlating a signal to other signals (multiple channels)
- Correlating a signal to itself (screen persistence or point accumulation)
- Viewing some aspect of a signal (triggering),
- Measuring signal dynamics (calibrated timebase)

Fancy words notwithstanding, these measurement needs are well established... and scopes fill that position in their minds. So scope suppliers do not spend too much time marketing the need for a scope. How often must you educate a potential customer that he or she needs a scope instead of a DMM? After all, both a scope and a DMM measure voltage.

Instead, given that an engineer wants a scope, the question becomes, "Who are you going to call?" Tek, being the scope leader, has created the position of Scope=Tek. Competitors see this and try to clutter the battlefield with spec, price, or semantic skirmishes.[2] This increases the noise level and it gets harder to hear, much less answer, the calls. Fewer orders come in over the transom, more must be won by knocking on customer doors or slamming doors on the competition.

So what?

Cherchez le creneau...Filling the hole.

So in the midst of the scope wars, customers are not idle. Customer applications are rapidly changing. And when their measurement needs change, holes appear in their minds. Customers struggle to fill the holes with existing solutions. After all, they have better things to do than build new instruments. The supplier must fill the holes. It's always easier to fill an open hole than to dig a hole where a competitor has a concrete barrier. So when a potential customer calls, what's the hole that needs to be filled?

Find the hole, then fill it.

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[1]Partially inspired by the book Positioning: The Battle for the Mind, by Trout and Ries.

[2]The astute reader will note that non-scope 'competitors' such as CAE suppliers position themselves as an alternative solution to the fundamental measurement needs discussed above.

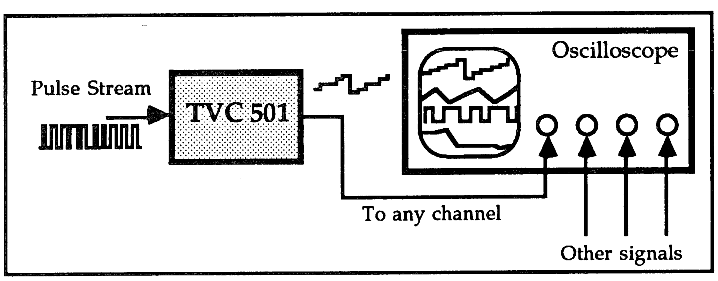
Product Overview

The **TVC 501** is a single-wide TM 500 modular instrument and can be used with any analog or digital scope, any waveform analyzer or recorder, or any logic analyzer with an analog input channel.

The Need. Debugging or verifying circuits used to mean looking at just *analog* signals. The scope was the perfect tool for viewing these voltage vs. time waveforms. Then came switching power supplies, digital telecom, digital encoders and servo controllers, and embedded processors. Signals are now sampled, pulse-coded, or pulse-width-modulated. So measuring parameters is no longer as simple as recording voltage vs. time. Information is in the varying time intervals between transitions. Failures result from timing errors instead of voltage errors.

Timing variations typically appear as confusing left-to-right motion or jitter on a scope. Timebase or holdoff adjustments may improve display stability but do not show timing dynamics. A scope can miss infrequent timing errors because of writing rate or update rate limitations. The **TVC 501** extends any scope's ability to capture, untangle, and visualize complex digital waveforms.

Same Scope, More Power. The **TVC 501** adds three measurement functions to a scope's voltage vs. time capability: time-delay vs. time, pulse-width vs. time, and period vs. time. The **TVC 501** continuously measures the selected timing parameter and instantaneously generates a voltage proportional to the measurement. The time-interval vs. time waveform can be viewed on any scope. Conversions are made pulse-to-pulse without averaging...up to 2 million timing measurements per second. Timing variations can be viewed with selectable vertical resolution from 1 µsec to 1 sec per division.



The **TVC 501** is a front-end signal converter for a scope.

Real-time. There is no resetting or re-arming. The **TVC 501** output becomes another signal that can be correlated, measured, and analyzed with waveforms on other scope channels. Since the TVC generates voltages proportional to time-intervals, a scope can be set to trigger on timing violations such as an incorrectly narrow pulse or glitch.

TVC 501 Operation- Example

The best introduction to the **TVC 501** is a visual example. The waveform in Figure 1 depicts a pulse width modulated (PWM) signal. PWM signals are found in switching power supplies where varying pulse widths control the delivery of current to the load. PWM signals are also used for communications coding such as in couch-potato TV remote controls.

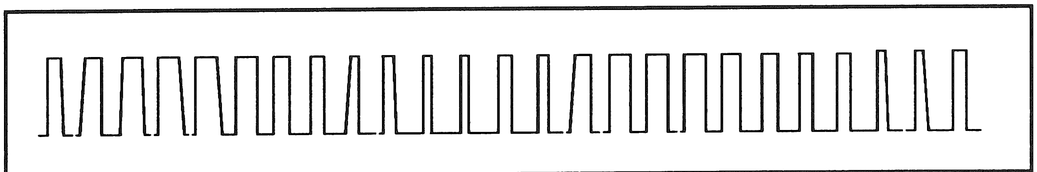


Figure 1. Pulse Width Modulated Signal. Pulse widths change from pulse-to-pulse.

Figure 2 shows three views of the PWM signal using an oscilloscope. The left display shows the timebase set to view overlapping pulses. They start at the same location because the scope is triggering on the rising edge. The falling edges smear because of the varying pulse widths. The middle display shows the results of slowing down the sweep speed. The middle display adds very little to the understanding of how the pulse widths are varying.

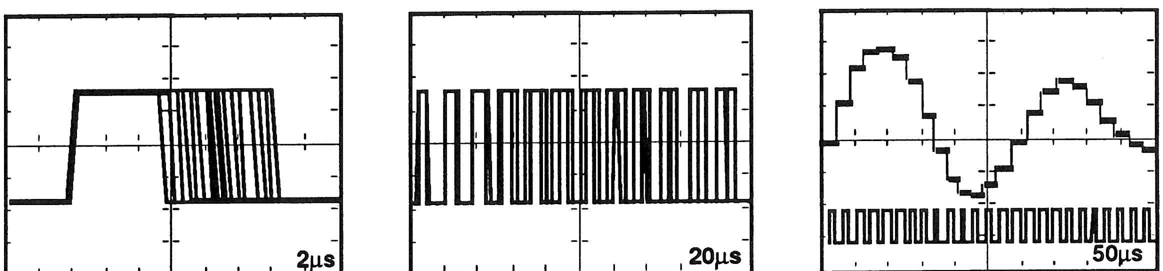


Figure 2. Three views of the PWM signal. The left view shows that pulses vary in width. At a slower timebase setting the middle view does not unveil any new information. The right view shows what's really happening. The upper trace is the **TVC 501** output signal showing Width vs. Time. The lower trace is the PWM input signal. The **TVC 501** looks like a staircase because it holds the voltage corresponding to a just completed conversion until the next timing measurement is completed.

The right view, made with the **TVC 501**, uncovers the true dynamics of the pulse width variations. The **TVC 501** measures each pulse width in sequence and without interruption. After each measurement, the **TVC 501** generates a voltage proportional to the measured time-interval. The resulting Width vs. Time waveform unveils when the pulse widths change, by how much, and in what relation to real time. Correlations can be made with other signals that are displayed on the scope.

Since the **TVC 501** generates voltages proportional to measured time-intervals, a scope can be qualified to trigger on time-intervals (that is, when a pulse is too long or too short) rather than just on voltage levels.

Product Specifications.

Instead of listing row after row of technical specifications, we will introduce the key specs by an example using the **TVC 501**'s period vs. time mode.

Spec:	In addition to pulse-to-pulse period measurements, the **TVC 501** can make uninterrupted and sequential pulse width measurements, and pulse-to-pulse delay measurements (between two signals).

Refer to the pulse stream at the top of Figure 3.

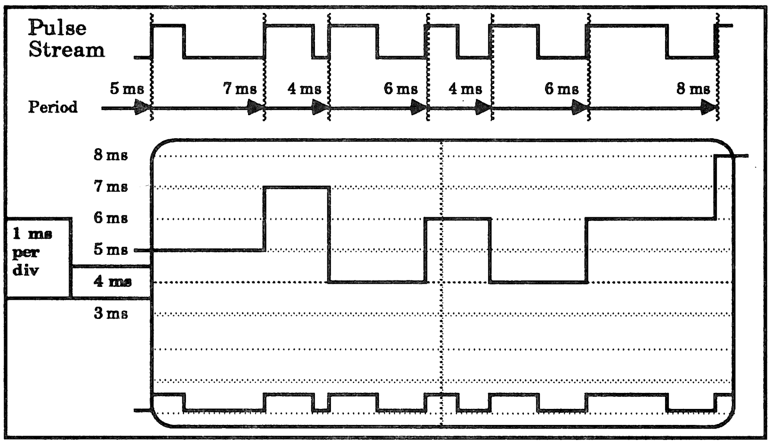


Figure 3. Period vs. time measurements...in real-time. The measured pulse stream is shown on the lower trace.

The **TVC 501**'s continuous measurement capability means that <u>each</u> period in the pulse stream is measured. After each period measurement a voltage proportional to the just measured period is generated at the **TVC 501** output. Notice that in the scope view the waveform looks like a staircase. The **TVC 501** output voltage is held until the next measurement is completed. If the input pulse stream had a constant period, then the **TVC 501** output would be a constant voltage.

Spec:	The **TVC 501** measures up to 2.5 million timing measurements per second without interruption. A voltage proportional to the measurement is generated in real-time for each measurement. If the input signal rate exceeds the uninterrupted measurement rate, a warning indicator lights on the **TVC 501** front panel.

In Figure 3 the pulse periods vary from 4 to 8 milliseconds. The scale factor at the left of the scope screen suggests a vertical scale of 1 ms/div. Where did this come from? The **TVC 501** generates a voltage proportional to time-interval measurements. The **TVC 501** is calibrated to drive a scope channel set to 100 mV/division. The vertical position of the scope channel is set to 0 volts at center-screen. The **TVC 501** generates a simple calibration waveform at power-up to assist in this set-up. Since the selected scope channel is then left at 100 mV/div, the **TVC 501** can itself alter the vertical time-interval/div scale factor.

Spec:	The **TVC 501** generates seven calibrated vertical resolution scales from 1 microsecond/div to 1 second/div. Timing measurements are made with crystal timebase accuracy using digital counters. The best digital counter resolution (at the 1 µs/div setting) is 33 nsec. This means that each vertical division is sliced up into 30 steps.

In Figure 3, a scale factor of 1 ms/div is shown. Figure 4 shows the result of changing the **TVC 501** scale factor to 10 µs/div.

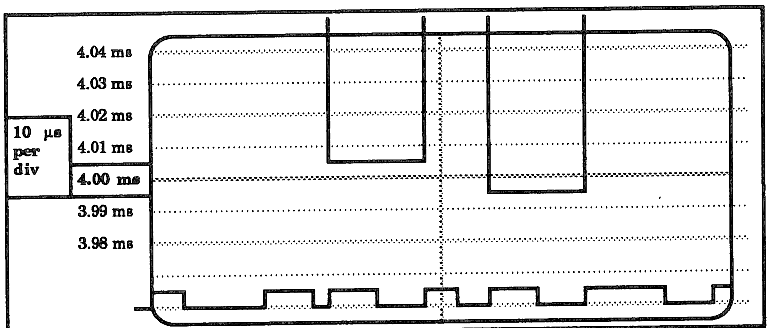


Figure 4. Changing the scale factor to 10 µs/div sends some of the measurements off the screen.

Whenever the **TVC 501** zooms in like this, it has to zoom in around some time-interval offset. In Figure 3, center-screen was 4 ms. When the vertical resolution was changed to 10 µs/div, center screen is still 4 ms. The next division up from 4 ms is now 4.01 ms instead of 5 ms. Any measurements above 4.04 ms go off the top of the screen and can't be seen. Any period measurements smaller than 3.96 ms would go off the bottom of the screen.

Spec:	The **TVC 501** output range is ±4 vertical scope divisions. Since the scope is set to 100 mV/div, this means that the output voltage range from the **TVC 501** is ±400 mV. When a measurement exceeds the ±4 division viewing range of the scope, a warning indicator lights on the **TVC 501** front panel.

How did the center-screen offset get to 4 ms? The **TVC 501** has time-interval offset capability. This means that small period or width deviations can be viewed around large average values (this is similar to viewing small voltage ripples around a large average dc voltage). The user can dial in a time-interval offset through the **TVC 501** front panel.

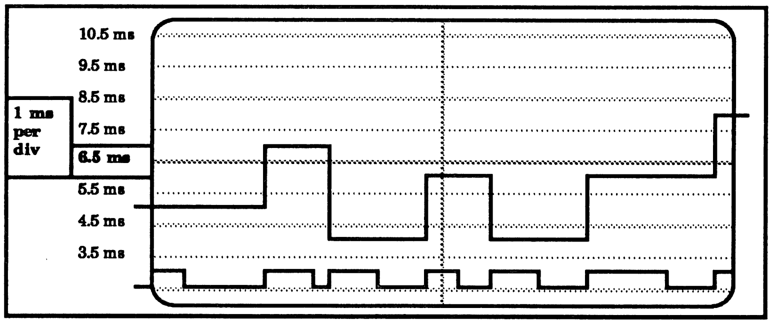


Figure 5. Offset is changed from 4 ms to 6.5 ms.

Figure 5 shows the effect of changing the center-screen offset from 4 ms (Figure 3) to 6.5 ms. The vertical resolution is still 1 ms/div; the period vs. time waveform just slides down 2.5 divisions (2.5 ms @ 1 ms/div).

Spec:	The center-screen time-interval offset can be set from 0 to 30,000 divisions in 0.1 division increments. For example, if the **TVC 501** resolution is 1 µs/div, then an offset of 30,000 µs can be set. This would be used to view microsecond deviations around time-intervals with an average value around 30,000 µs! You can think of this as the timing dynamic range.

In summary, the **TVC 501**:

- **Makes period, width, or delay timing measurements.**
- **Makes measurements on consecutive pulses up to 2.5 million/sec**
- **Converts <u>each</u> measurement to a voltage proportional to the result**
- **Converts each measurement continuously and without delay (real-time)**
- **Generates a calibrated time-interval vs. time waveform for scope viewing**
- **Generates display resolutions from 1 µs to 1 sec per vertical division**
- **Permits up to 30,000 divisions of timing offset**
- **Works with any scope or signal recording instrument**

The data sheet (#60W-7875) lists all specifications. At this point, the objective is just to understand the TVC 501 concept. No information has been given on who would use it, what they would use it for, and why they would purchase one.

Competition & Alternatives. The TVC 501 is different.

Saying that a product has no competition is either naive or extremely bold. But then reactive marketers tend to be too focused on 'the competition.' The smart money follows what customers are doing...not what the competitors are doing. After all, if there is no need for a product, then it really doesn't matter whether you have one or a hundred competitors. We have found that an effective way to further your understanding of the **TVC 501** is, in fact, to present alternative techniques for getting time-interval vs. time information. One of these alternatives might be an answer to the question, "How do they make these measurements today?"

Alternative #1. Counter-timer with controller.

Traditional counter-timers (like the TM 500 DC 50X modules) provide 8 or more digits of resolution on stable signals. But if the measured timing parameter changes more than once or twice a second, the numerical display becomes impossible to read (similar to a DMM measuring a rapidly changing signal). The next step would be to connect the counter-timer to a controller and to rapidly read the measurements over the bus. The controller can post-process (if you have software) hundreds or thousands of measurements and graph the results. Unfortunately, most counter-timers have measurement transfer rates under 100/sec. This means measurements are missed if the event rate is faster than the transfer rate. This technique also misplaces real time; even though the results are ordered in time, they are not time-stamped (see box). Unlike a DSO where voltage measurements are taken at fixed intervals, a counter-timer makes a measurement on an edge transition. The controller cannot recreate the signal on a graph with a linear time axis. This means that the measurements cannot be correlated with other waveforms.

A few vendors make PC-based (or VXI) counter-timer cards. The cards support faster transfers of successive counter results to measurement memory. Record lengths can be quite long... limited only by system memory (as opposed to instrument memory). Virtual front panels can produce arbitrarily impressive displays. But customers find this 'big-system' approach rather overwhelming for benchtop applications.

> Time-stamping means that each measurement result is stored along with <u>when</u> the measurement occurred. Since timing measurements in a pulse stream may not occur at a fixed rate (unlike a DSO's constant sampling rate), a list of consecutive measurement values is not enough information to reconstruct the original waveform. Each value in the list must be tagged or stamped with when it was made.

Fluke/Philips came out with a useful option for several of their counters. Called 'Analog Output,' it allows a counter user to select any three consecutive digits on the counter's 8 to 10 digit numerical display and have the value of those 3 digits (000...999) also drive an internal D/A converter. The voltage output proportional to the three digit value comes to a BNC. This analog monitor is like the analog bar graphs that DMM suppliers are now putting next to the digital readout. Of course the update rate of the Analog Output is quite slow (<10 Hz) since it is the same rate as the numerical readout update rate. The output is not truly real-time since the counter results must be processed before it goes to the display (and the D/A). And the counters themselves are not consecutive measurement instruments.

Summary: Using Counter-timers for time-interval vs. time measurements

+ Great timing resolution (10-100 psec) for single shot measurements
+ Low cost (typically a few thousand dollars)
- Slow measurement rate (<100/sec)
- No measurement vs. time info (measurements not time-stamped)

Alternative #2. Time-Interval Analyzers (TIAs).

Several vendors offer counter-timers specifically designed for accumulating information on a large set of timing measurements. In general, customers will use the term 'time-interval analyzer' or TIA to refer to these instruments. Statistical measurements are standard in TIAs. For example a TIA will report the min, max, mean, and standard deviation on hundreds or millions of timing measurements. Most have built in displays that show measurement distributions in the form of a histogram (Figure 6). The axes on a timing histogram are (# of events vs. time-interval value).

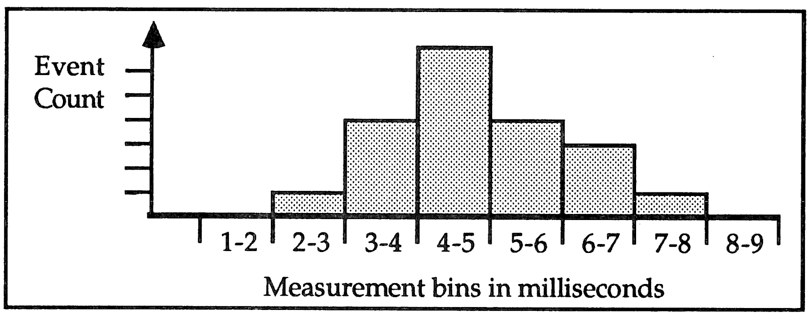


Figure 6. TIAs use histograms to show distributions of measurement results. In this case most of the measurements were between 3 and 6 msec.

Recognize that this type of analysis is a statistical (or sampling) process that is meant to correlate many values with each other. In other words it answers questions such as, "how many 1 μsec pulses were there relative to 1.2 μsec pulses?" This is different than correlating timing values to <u>when</u> they occurred (time-interval vs. time) which is the capability of the **TVC 501**. TIAs must have a fast measurement rate to produce meaningful results in a reasonable time. However, like traditional counter-timers, the measurements are not time-stamped. Those of you that sell into digital communications will recognize that the CSA 803 Analyzer and the i-Pattern software package both emulate the functions and graphical display of a TIA.

> TIAs are found in abundance at disk drive companies. In particular they are used for bit shift (jitter) measurements on data bits from the read channel. Bits come off hard disks at Mbit/sec rates and bit error rates are typically better than 1 in a million (a statistical spec). A TIA that samples hundreds or thousands of measurements per second does not provide timely information. TIAs for disk drives read channel testing must be able to sample at MHz rates.

Summary: Using Time Interval Analyzers for time-interval vs. time measurements

+	Great timing resolution (typ. 10-100 psec)
+	Great measurement rate (>1 Million/sec)
+	Great for statistical analysis (timing histograms on built-in display)
0	Spendy, ~$20K (though appropriate if you need it)
-	No measurement vs. time info (measurements not time-stamped)

Alternative #3. Modulation Domain Analyzer.

HP has been making a lot of noise about the 'modulation domain.' Their HP 5371A and 5372A are probably the most relevant alternatives to the **TVC 501**. Potential customers might query whether the **TVC 501** is like that 'new HP thing.' These units are standalone instrument with built-in bit-mapped graphic displays. In principle, these units are transitional recorders (described in Alternative #5) with built-in software to post-process the record, and built-in software to display the results. 'Analyzer' is a good name for these instruments since they offer a lot of post-processing timing analysis on a stream of pulses. They do not generate real-time displays. And while they directly show time-interval vs. time plots, these units do not have an analog input channel for voltage vs. time signals. Thus, there is no direct correlation between real-world voltage vs. time signals and the time-interval vs. time information. And since it is a post-processing architecture, the record length is necessarily finite (up to 8K consecutive timing measurements).

In all fairness, HP bundled the transitional recording, the display technology, and the right software to produce a one box solution. HP has made a lot of money selling these units into: disk drive read channels, high speed (>1 Mbit/sec) digital communications, and frequency agile (hopping or spread spectrum) synthesizers for secure RF transceivers.

Summary: Using Modulation Domain Analyzers for time-interval vs. time measurements

+	Great timing resolution (typ. 10-100 psec)
+	Great measurement rate (>1 Million/sec)
+	Great for statistical and measurement vs. time analysis
0	Spendy, ~$20K (though appropriate if you need it)
-	Measurement vs. time info is not real-time
-	Measurement vs. time has limited record length

Alternative #4. DSO or digitizer with post-processing.

A stream of pulses with a varying timing parameter (e.g., width, period) can be captured with a DSO or digitizer. Post-processing software can scan the record for edge transitions and sort out each pulse timing parameter. The resulting list of consecutive time-interval measurements can be used to create a time-interval vs. time plot. The waveform has to be captured single-shot to retain the time-ordering of the events. The record length has to be long enough to capture hundred or thousands of pulses to exhibit the timing dynamics. And the sampling rate has to be fast enough to produce the desired timing resolution on each pulse. This generally means Megabyte record lengths. And once the data is captured, the record must be transferred and processed (if you can find suitable software). This means real-time displays are impossible. Refer to the Engineering Brief EB1 in the Applications Booklet (#60W-7869) for further information on this technique.

Alternative #5. Logic Analyzer with post-processing.

A stream of pulses with a varying timing parameter (e.g., width, period) can be captured with one channel of a logic analyzer. Post-processing software can then scan the record for transitions and sort out each consecutive pulse timing parameter. The resulting measurements can be used to create a time-interval vs. time plot. This is similar to Alternative #4 with a 1-bit DSO. Some logic analyzer vendors offer 'transitional recording'[1] in which 'calendar' time (with ns resolution) is recorded when a transition occurs. Nothing is stored when the input signal is at a fixed level. Post-processing (if you can find suitable software) can uncover the time-interval vs. time information from a transition record. Of course, this method does not provide real-time displays. And most engineers loathe the thought of dragging out a logic analyzer to look at one or two signals.

Colorado Data Systems offers a VXI counter card with time-tagged memory. This card implements transitional recording and can store the transition time of up to 2K consecutive edges. Once again, post-processing software is required to sort through the data and plot a time-interval vs. time plot.

Alternative #6. By analysis

The timing analysis may have been performed on paper or by using a computer-aided simulation package. Of course simulation is just simulation. The rubber meets the road when the power switch is thrown.

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[1] For digitizer experts, this is similar to HP's Adaptive Sample Rate (ASR) techniques used on some of their digitizers. ASR 'looks' at the waveform as it is being digitized and lowers the sample rate when the signal is slowly changing; this saves record length memory.

Alternative #7. A well-trained eye

Every so often, you run into an experienced scope user with "a well-trained eye." They can look at a complex signal that is bouncing back and forth on a scope and make remarkable observations about the signal. They intuitively account for the effects of trigger holdoff, update rate, writing rate, screen persistence, trigger rejection, and so on. In other words, they understand a scope's capabilities and limitations when viewing complex signals. These individuals are very rare. They are reluctant to use 'Autoset.' Customers do not accept this alternative since the path to the "well-trained eye" is time-consuming and there are very few good teachers. Customers have better things to do than to become scope experts.

Alternative #8. Assuming, guessing, and believing

This is the most used alternative. "My scope is good enough." "I have the information I need." "I don't need to know that." "It's useful but not critical." These are all legitimate responses. This alternative simply means that the value of knowing instead of assuming has not been adequately conveyed to the targeted customers. This is a marketing responsibility, though many of you in the sales force might find value in understanding market creation dynamics.

Conclusion: **The TVC 501 is different.** It helps to understand the differences between the **TVC 501** and instrumentation alternatives. But alternatives are not necessarily competitive in a sales situation (pencil and paper are an *alternative* to a computer spreadsheet). You may find that explaining the **TVC 501** using common instrumentation alternatives is the best way to show why **the TVC 501 is in a class by itself. But if you find yourself defending the TVC 501 against one of these instrumentation alternatives, fold the tent and re-group. You're fighting the wrong battle!**

A table of product offerings is shown on the next page.

Remember:

The TVC 501 is NOT a:	Time Interval Analyzer
The TVC 501 is NOT a:	Jitter Analyzer
The TVC 501 is NOT a:	Modulation Domain Analyzer
The TVC 501 is NOT a:	Frequency-to-Voltage Converter

Characteristics of TVC 501 and Instrument Alternatives

	Form Factor	Graphical Display	Sequential Measurements	Real-time	Single-shot Resolution	Measurement Rate	Price	Introduced	Targeted Applications
Time-Voltage Converter									
Tek TVC 501	**TM 500**	**Any Scope**	**Yes**	**Yes**	**30 nsec**	**2 MHz**	**$2500**	**1990**	**Digital Control**
Counters									
Fluke/Philips opt. PM9695	Counter option	Any Scope	No	No	2 nsec	<10/sec	$425 opt.	>5 yrs ago	General Purpose
HP 5370B	Stand-alone	Controller	No	No	20 psec	8 kHz	$12K	>5 yrs ago	General Purpose
Tek DC 5010	TM 5000	Controller	No	No	3 nsec	<10/sec	$4K	>5 yrs ago	General Purpose
Stanford Research SR620	Stand-alone	X-Y scope	No	No	4 psec	2 kHz	$4500	1988	General Purpose
Tek CDS 73A-541	VXI card	Controller	Yes	No	100 nsec	10 MHz	$2400	1988	General Purpose
Guide Technology GT 200	PC card	Controller	No	No	100 psec	1.4 kHz	$1500	1989	General Purpose
Time-Interval Analyzers									
Kode/Odetics 3625 CTime	Stand-alone	Built-in	Yes	No	60 psec	20 MHz	$15K+	1990	Disk Drive
Kode/Odetics TIA 3100	Stand-alone	Built-in	No	No	100 psec	1 MHz	$23K	1987	Disk Drive
Kode/Odetics TIA 2001A	Stand-alone	Built-in	No	No	1 nsec	800 kHz	$15K	1985	Disk Drive
Schmidt Instruments 800	PC card	Controller	No	No	1.5 nsec	10 MHz	$7600	1989	Particle Physics
LeCroy 4204	CAMAC card	Controller	No	No	150 psec	1 MHz	$5000+	>5 yrs ago	Particle Physics
Modulation Domain Analyzers									
HP 5372A	Stand-alone	Built-in	Yes	No	200 psec	13 MHz	$28K	1989	Oscillators, Disk drive
HP 5371A	Stand-alone	Built-in	Yes	No	200 psec	10 MHz	$23K	1987	Oscillators, Disk drive
ITI DTA 8850	Stand-alone	Built-in	Yes	No	50 psec	10 MHz	$25K	1990	Disk Drive

If you can't sell Tek, and the customer is about to buy HP, perhaps you can still gain some points by suggesting another supplier. I have run into dozens of cases where a customer about to buy an HP product was not aware of products from the following vendors.

Guide Technology	Los Altos, Calif.	(415) 961-9259
ITI (Int'l Test Instruments)	Irvine, Calif.	(714) 770-5711
Kode/Odetics	Anaheim, Calif.	(714) 758-0400
Stanford Research Systems	Sunnyvale, Calif.	(408) 744-9040
Schmidt Instruments	Houston, Texas	(713) 529-9040

So if it's different, then what's the message?

You're on the spot and the customer says, "so what's really different about this?" The message is simple...

Real Time Output of Every Measurement...

Real Time

...means live feedback, not after-the-fact analysis. Why wait for information when you can have it now? Ask if they have every tried trimming a circuit while watching an instrument that updates only once or twice a second.

...means the timing information can be correlated to other signals. Hidden or subtle correlations or cause-effect relationships can be uncovered.

...means *right now!*

Output

...means the information can be viewed on a scope. The scope is the natural and preferred choice for graphically viewing value vs. time information. Plus everyone already has a scope.

...means the timing information can be used to trigger instrumentation. Triggers are used to look at selected portions of a signal. Now a scope's trigger selection criteria includes timing qualification, not just voltage qualification.

Every Measurement

...means that every event is measured in order. Complete information means knowing instead of guessing or assuming.

...means that the measurements never stop. Record length is meaningless to the **TVC 501**. It just goes on and on and on.

Means Discovering what is Really Happening.

Prospecting- If you know your customers by application.

The purpose of this section is to explain how the **TVC 501** fits its target application, **digital control systems**. In traditional analog systems (Figure 7), such as a linear power supply, all circuit points are analog voltage vs. time signals. The output voltage is sensed and compared to an analog reference. The controller delivers current in proportion to the error voltage between the output and the reference voltage. It makes senses to view these voltage vs. time signals with a scope.

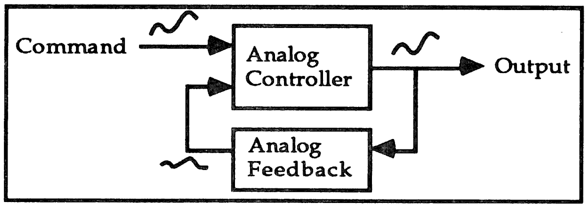


Figure 7. Analog system signals are amplitude vs. time signals that can be viewed, correlated and analyzed with a multi-channel scope.

Now digital technology brings switching power supplies, digital speed control, digital VCR frame tracking, digital radio tuning, and so on (Table 1).

Aerospace (avionics, guidance systems, control surfaces)
Automotive (ABS, speed control, engine timing)
Consumer (VCR, CD, DAT speed control, RC toys, pacemakers)
Industrial (robotics, wafer handlers, process control)
Peripherals (printer, plotter, tape drive, disk drive motor control)
Power Supplies (switch mode converters, motor power amplifiers)
Semiconductor (any vendor that supplies ICs for above applications)
Transducers (digital rotary encoders, optical encoders)

Table 1. Digital control technology is used by system integrators, and by component and module suppliers that serve these integrators.

Digital control means that somewhere in the system, digital signals are used for performance improvement (Figure 8). This means the ability to apply a microprocessor, or the ability to operate components more efficiently.[1]

[1]For example, switch mode power converters are more efficient than linear supplies since the power delivery element operates in saturation or cut-off instead of in the linear region. In some of the newer topologies, power element on-off timing is synchronized (resonant) with power line cycles.

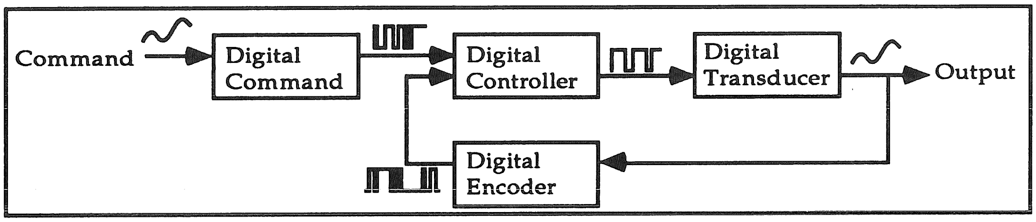


Figure 8. Digital signals are used for feedback, for command signals, and for output control. Is a traditional scope the right tool to view these digital signals?

Figure 9 shows two views of control signals. The analog views are easy to understand. There is a simple correlation between the voltage vs. time signal and what it represents. The top trace could be a drifting voltage, the second could be an unwanted output transient, the third could be the perfect power supply. The digital views are easy to understand when given the previous information. But by themselves, they are difficult to decipher. How would a scope trigger on it? What does drift in a digital control signal look like? The **TVC 501** untangles digital waveform timing and delivers a clear view.

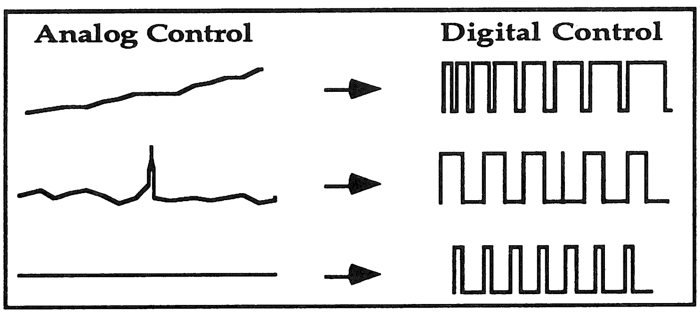


Figure 9. Alternate views of control signals. The top pair shows drift. The second pair shows a transient anomaly. The third pair shows stability.

Application: Pulse timing demodulation and fault detection in digital control

Since information is embedded in the signal timing (varying widths, periods, or pulse delays), a TVC is the logical solution. Why? A TVC converts (that is, demodulates) the timing information back to a form that can be easily visualized using a scope. The scope is the design or evaluation engineer's preferred tool for visualizing complex signals. And timing faults are converted to voltage variations that can trigger a scope.

Action. If a customer manufactures any of the products in Table 1, find the digital control design or evaluation engineer. Introduce the concept of time-interval vs. time measurements. Give them an Applications Brochure.

Application: Performance monitoring in digital systems

Engineers developing software dependent systems will also benefit from the **TVC 501**. Real-time systems depend on timely code execution and

performance evaluation requires timing measurements. Engineers design to specifications that constrain execution times for various functions, or how often a function must be performed. How long did it take to access the disk? How long did it take to connect a phone call? How many waveforms/second can be sent over the bus?
Action. If a customer manufactures any of the products in Table 1, find the firmware design engineer. Introduce the concept of time-interval vs. time measurements. If there's any interest give them an Applications Brochure and refer them to AN2 and AN3.

Application: Time qualified scope triggering

Design engineers now expect more than voltage qualified scope triggering. They need to trigger the scope when a signal parameter (such as pulse width) is too long or too short. This occurs across all disciplines and typically comes up as a directed question such as, "Can I trigger this scope on glitches?" The **TVC 501** uniquely addresses time-qualified triggering. Just as a scope provides a voltage vs. time display to support its voltage-qualified triggering, the **TVC 501** provides a time-interval vs. time display to support its time-qualified triggering. This means higher confidence in timing measurements since you can see what timing event triggered the scope. And with a DSO you can see what timing events preceded the trigger.
Action. If a customer talks about time-qualified triggering, extend that need to time-interval vs. time measurements. Give them an Applications Brochure. Refer them to AN5, Time Qualified Scope Triggering.

Application: Oscillator transient response characterization

Since digital systems depend on timing, there is always a system clock or oscillator. Traditional tools such as counters and spectrum analyzers are great for steady-state signal analysis. But the interesting problems are during start-up and shutdown, or during power transients. What happens to the system clock(s) during these intervals? The **TVC 501** has built-in ÷100 and ÷1000 prescalers that digitally divide input signals so that oscillator transients can be observed. The prescaler is conservatively spec'd at 100 MHz. With the TM 500 DP 501 external prescaler, the measurement range extends to 1.3 GHz. Refer to the Applications Brochure (AN4, AN11, EB2). Furthermore, not all systems are based on crystal oscillators. Cost constraints often force manufacturers to use ceramic resonators, or simple R-C timebases such as the popular 555 timer IC. These circuits need to be evaluated for stability and parameter susceptibility.
Action. If a customer manufactures any of the products in Table 1, find the hardware engineer working on clock generators, timing generators, synthesizers, or oscillators. Introduce the concept of time-interval vs. time measurements. If there's any interest give them an Applications Brochure.

Prospecting- If you know your customers by job title.

Perhaps all you know about a potential customer is his or her title. What kind of person would be interested in a **TVC 501?**

The Innovator

Profile: There's usually one person in every group who seems more clever or intuitive than the rest; they are first to try new approaches...the first to get the DSO while everyone else was still taking pictures...the first to use CAE tools. That person will pride him/herself in being the first to tell colleagues of this new discovery.

Action: Ask them if they're interested in seeing a new instrument concept. Of course they'll say yes. Select a few pictures or examples from the Applications Brochure that you're comfortable with. Use the "before-after" technique to illustrate the concept. The innovator may not immediately buy but will be the first to tell a colleague how their problem could be solved with a **TVC 501**. The innovator will usually suggest applications to show off his/her knowledge. Get referrals. A good investment.

The Manager

Profile: Always looking for ways to improve productivity. If the person is an equipment manager, they want to be known as having the right equipment at the right time.

Action: Point out uniqueness. Assure them that they do not have one in their inventory. Point out that the **TVC 501** was designed to support the increasing use of digital and microprocessor technology in system design. Use App. Brochure to show applications breadth. Point out low cost and that it works with any scope. Suggest that every mid-sized design group should have at least one. Admit, if necessary, that it may not be used daily; but that it's frequently the subtle circuit timing problem that brings a project to a standstill.

The Firmware Engineer

Profile: Writes embedded processor code for robots, avionics, computer peripherals, telecom switches, fire control systems, or anything electro-mechanical controlled by a processor. "Real-time" is the buzzword. Task switching, latency, kernals, and throughput are commonly heard phrases. Uses µP development systems, DSOs and generally has a bench full of general purpose instruments such as power supplies, signal generators and PROM programmers. You'll find lots of odd patch cables and old code listings.

Action: Use the phrase "real-time performance analysis." Ask whether any system timing parameter must not exceed some limit (cannot take too long). There are always timing constraints in embedded firmware. Ask if the timing parameter varies and if they would really like know what's going on. Suggest that they read AN2 and AN3 in the Applications Brochure.

The Hardware Design Engineer

Profile: Stay away from the antenna guru or the speed freak trying to get the last picosecond out of a new Gallium Arsenide gate. Lean toward people integrating components to solve higher level problems at the board or system level. Look for engineers with a wide variety of equipment (scope, generators, logic analyzers) on the bench. The more cables and interconnects the better. Complex systems tend to have timing problems and depend on clock synchronization.

Action: Probe to see if timing is a problem. Does the system perform some task every so often? How does the rate change? Are there any time constant controlled by R-C values? Is there drift? Any 555 oscillators or one-shot ICs for timing? Is there any pulse modulation? Do they have trouble triggering on and capturing complex waveforms? Do they constantly play with holdoff to stabilize the display? Do they talk about capturing the longest or the short pulse or event (time qualified triggering)? Determine if timing <u>variations</u> are measured in msec, µsec, nsec, or psec. If it's psec or a few nsec, talk 11K or high end 2400. If it's slower, you have a prospect. Talk through a few pictures in the intro article of the Applications Brochure. Point out how the **TVC 501** is an insurance tool. Point out how it uses only one channel of a scope. Suggest that it can find the 1 in a million timing glitch that is crashing the system.

The Evaluation Engineer

Profile: Evaluation engineers keep the design engineers honest. They find limits of performance. They stress circuits and look for subtle side effects. They often do not know what they will find so they need a full set of tools to look at signals in different ways.

Action: Point out how problems are more and more the result of timing errors instead of voltage errors. A digital signal that is 10% too high or too low means nothing. But if the timing is off by 10%, there is a problem. Point out how the **TVC 501** is a real-time tool that measures every event. It is not statistical. Evaluation engineers like to know that they did not miss anything. Refer to the **TVC 501** as a discovery tool that uncovers hidden correlations. Evaluators are paid to think from a different perspective.

Prospecting- If you know your customers by instrument.

Perhaps you are new to a territory...or you're looking at the order activity of an unfamiliar account. If a customer is about to buy or is using the following types of products, they are good **TVC 501** prospects. Of course, any scope user is a **TVC 501** prospect, but you were not born yesterday.

Product Clue:

- Any 2400 scope with the Word Recognizer Opt. 09.
- Any scope AND a µProcessor emulator or µProcessor Development System at the same time.
- P6408 word recognizer probe.
- Prism 3000 Logic Analyzer with Opt. 1A (30DA01). This is the Performance Analysis Software package.

There's a good chance that they work with real-time microcontrollers or are concerned about system level performance.

Action:

Ask if they are interested in system timing variations. If so, suggest they look at App. Note AN2 (Timing Constraints in Real-time Controllers) and AN3 (Rate and Value Dependencies in Embedded Systems) in the Applications Brochure #60W-7869.

Product Clue:

- AM 503 Current Probe Amplifier.

There's a good chance that they work with switch-mode power suppliers or pulse width modulated converters.

Action:

Ask if they are design or evaluate switch-mode power converters or PWM amplifiers. If so, suggest they look at App. Note AN1 (Real-time pulse modulation measurements) in **TVC 501** Applications Booklet #60W-7869.

Selling- Qualification

This section addresses the technical side of **TVC 501** qualification. How does the **TVC 501** come up in conversation?

- You bring it up because you think the customer is a **TVC 501** suspect. This happens because you know something about the customer's application, the customer's job, or the customer's instrumentation usage.
- You bring it up because you see that the customer is struggling with a timing measurement or because the scope is not quite showing the customer what she wants to see.
- Customer brings it up because he read or heard about it.

We suggest the following three areas to probe in:

Q1. **Are there timing variations in your circuit? Do you measure timing variations? What is the range of the variations?**

Typical responses:

"Normally 1000 µs periods but it varies between 900 µs and 1100 µs."
"The pulses should be 1 µs wide but every so often there's a glitch."
"It's actually a 10 kHz oscillator, but the frequency varies by 2%."
"It's a burst of pulses that varies in width between 5 µs and 8 µs."
"It's the interrupt response time; it varies between 10 and 100 µsec."
"100 psec of jitter on the falling edge."

If the numbers are expressed in milliseconds, microseconds, or 100's of nanoseconds, then move forward. Note that in the third example, a 2% variation on a 10 kHz period is 2 µs of timing variation (2% x 100 µsec). The **TVC 501** is not a suitable tool for measuring psec or nsec variations. In these cases, refer customers to 11403 statistics, or CSA 803 timing histograms.

Q2. **How much time is there between each pulse? What is the repetition rate of the events?**

Typical responses:

"It's a burst of about 50 pulses that occurs every 10 msec."
"It's a 144 kBit/sec ISDN basic rate interface line"
"Every 15 msec. But sometimes it's faster."
"455 kHz intermediate frequency (IF)"
"Usually 1 MHz but sometimes we test at 100 MHz."

If the numbers are Hz, kHz, or up to 2 MHz, then move forward. For example, in switching power supplies this number is the switching or chopping frequency (typically 20 KHz - 1 MHz, >1 MHz in advanced designs). In a communications applications, this would be the baud rate or the bits/second rate (ranges from 50 baud for telex lines to >1 Gbit/sec for fiber optic links). The **TVC 501's** uninterrupted measurement rate is about 2 MHz. At event rates faster than this it skips events (the Random Sampling LED turns on). For event rates faster than 2 MHz, suggest the statistical sampling capabilities of the 11403 or the CSA 803.

Q3. How do you <u>know</u> that the timing variations are within tolerance? What are the consequences if variations occasionally fall out of the specified range? Is there a pattern to the timing variations?

Typical responses:

"I use an MCP scope and the signal seems stable."
"I don't care, the circuit seems to work."
"It's controlled by a crystal. So it shouldn't change...or maybe it does?"
"It's done in software. The software guy tell me that blah, blah, blah."
"I'm not sure. Do you have something that can measure this?"

The reality is that debugging and evaluation involves a lot of assuming, guessing, and believing. Many people assume that if the scope does not show it, then it is not there. The **TVC 501** presents timing measurements in an easy to understand format that leads to discovery. It unveils hidden correlations. It finds the 1 in a million anomaly. It replaces guessing and assuming with knowing. It answers the question "How do you know?" This is a powerful statement. If you detect any uncertainty in their response, you have a prospect.

Remember:

The **TVC 501** is **NOT** a:	Time Interval Analyzer
The **TVC 501** is **NOT** a:	Jitter Analyzer
The **TVC 501** is **NOT** a:	Modulation Domain Analyzer
The **TVC 501** is **NOT** a:	Frequency-to-Voltage Converter

Customer says- "Can I see it work?"

Alternative 1. You have more pressing business to attend to, so your plan is to drop off the unit with the customer.

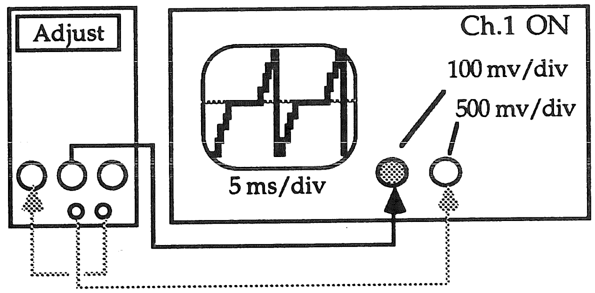
1. Qualify the customer. See previous section on qualification.
2. Are all three cables and the Operator's Manual (070-7991-00) in the box?
3. Be sure you have a mainframe such as a TM 501A.
4. Write a note suggesting that the customer try the exercises in the Operator's Manual. Note: the **TVC 501** has a built-in demo signal source.

Alternative 2. You're curious enough to make the demo.

1. Qualify the customer. See previous section on qualification.
2. Do you have all three cables and the Operator's Manual (070-7991-00)?
3. Be sure you have a mainframe such as a TM 501A.
4. Get your favorite demo scope...analog or digital.
5. Read the Introduction Article in the Applications Brochure #60W-7869. Be sure you understand the concept.
6. Practice a demo using Exercise 3 in Chapter 4 in the Operator's Manual (070-7991-00). It takes about 20 minutes to figure it out the first time. Less than 5 minutes if you've done it before. Note: the **TVC 501** has a built-in signal source.
7. Take some spare Applications Brochures #60W-7869. Others who see the demo may get real interested, real quickly. The Brochure is a good tool to lean on for applications questions. Refer to the Operator's Manual for questions on the instrument itself.
8. Briefly explain the **TVC 501** concept... the live demo will speak for itself. The 'before' then 'after' technique is extremely effective. In other words, first show the 'b.out 7' signal. Play with the trigger, holdoff, timebase, whatever. Then show the **TVC 501** view; be sure to show the **TVC 501**'s AUTO function. Explain how the scope can now trigger on time instead of voltage. See next page for details.
9. If customers insist on hooking up to their own signal, query them on what they expect to see! You'll typically need a 10X probe to look at customer signals; the trigger voltage range without a 10X probe is ±2V; it's ±20V with a 10X probe such as the P6109 (standard accessory).
10. Don't hesitate to call Beaverton for support. Write a Field Feedback Memo on any ideas that can help other SE's.

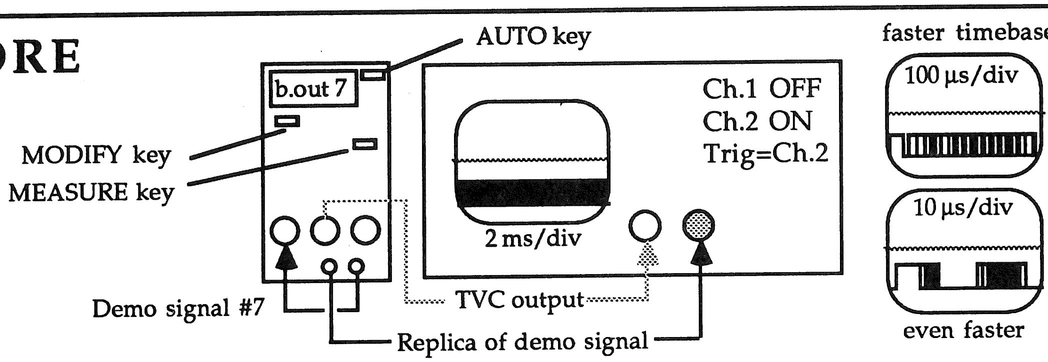
SUMMARY OF TVC 501 DEMO TECHNIQUE

SET-UP



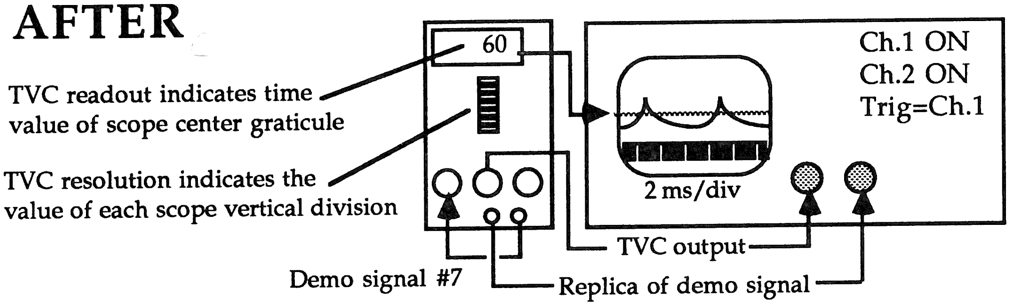
Connect three cables as shown. Turn on scope. Set Ch.1 to 100 mV/div (1 MΩ/DC). Set Ch.2 to 500 mV/div (1 MΩ/DC). Set timebase to 5 msec/div. Turn on TVC; when 'Adjust' appears on TVC display, use scope position control to align staircase pattern so that longest step is centered on screen. Shorter steps should be aligned to each vertical division. After this, DO NOT use the scope's Ch.1 vertical position control!

BEFORE



Use TVC 501 MODIFY key to select b.out menu in numerical display. Use knob to select b.out 7. Verify that TVC A channel is triggered (green TRIG'D light); the b.out 7 demo signal from the B monitor output connector is triggering the A channel. The A monitor output connector then generates a trigger view signal that replicates the b.out 7 signal. Use the scope to try to make sense of the b.out 7 demo signal. Change the scope timebase, use holdoff, or any other techniques to try to stabilize the signal on Ch.2.

AFTER



Refer to: Exercise 3 in Chapter 4 of the Operator's Manual

Use TVC 501 MEASURE key to select PERIOD measurement. Press MODIFY key until only a numerical value is shown on the display and a time-unit indicator is lit to the right of the display. Then press AUTO. This selects a timing resolution and offset. Use the TVC 501 knob to change the timing offset. Note how the TVC 501 output moves up or down on the scope screen (do not touch the scope's Channel 1 position knob!). Note how the Ch.1 scope signal can be interpreted as pulse period vs. time and that the vertical scale is calibrated in units of time! The TVC 501 is measuring each and every period in the pulse stream (about 16000 per second at a period of ~60 µs). The scope's horizontal timebase works 'normally.' Change it and see! Note that by triggering on scope Ch.1, you are trigger on time; when the measured time-interval gets larger, the TVC 501 generates a larger voltage. Change the TVC 501 resolution! Change to WIDTH measurement mode!

For further information refer to TVC 501 Operator's Manual (070-7991-00)

Message to the sales engineer- Why bother?

The **TVC 501** goes for $2500; add a mainframe and maybe you're up to $3000, a small fraction of even the most generous sales quota. So why bother?

1. **The TVC 501 will get you phone calls.** It's a truly new type of instrument. These are not our words...these came from customers. This means you get your foot into new doors.

2. **The TVC 501 will uncover scope opportunities.** The **TVC 501** is used with a scope. You have to demo the **TVC 501** with something. Take in your favorite new DSO. There are thousands of 400 series scopes still in use. There are thousands of people out there who have never touched a DSO.

3. **The TVC 501 gives you more scope credibility.** It enhances Tek's position as the scope leader. Even if they don't buy, they'll remember about that unique scope accessory that you told them about. The **TVC 501** is real-time tool and Tek has the hold on fast update rates. Scope=Tek.

4. **The TVC 501 gives you something to sell that HP, LeCroy, and Philips do not have.** Period.

5. **The TVC 501 gives you something new to say** to the age old question, "What's new?" Some customers are tired of hearing about more bandwidth, more channels, and more record length.

6. **The TVC 501 can make your day.** What does it feel like to be a hero? Intermittent timing problems are everywhere and nowhere at the same time...ask any customer. The **TVC 501** finds them and puts them right on a scope screen. Who do you think customers will call the next time they need a scope?

Most Asked Questions

During development and customer previewing, we heard the following questions most often.

Does the TVC 501 work more effectively with a DSO than an analog scope?

The **TVC 501** should not confuse scope selection. You would choose a DSO because of a DSO's advantages (pre-trigger, storage, etc.). The **TVC 501** requires only one input channel at 100 mV/div. Note that many 2400 scopes have Ch.3 and Ch.4 fixed attenuators at 100 mV/div.

Are you going to build it into a scope?

I don't know, yet. There is interest in this question and much depends on the success of the **TVC 501**. It's obvious that building it in would make it easier to use and would probably lower cost and price for similar capabilities. However, all attempts were made to make the **TVC 501** easy to use. Be sure to point out the Autoset capability to automatically find a suitable resolution and offset, or to find a suitable trigger voltage level on the A or B input channels.

Why is it in TM 500?

In this form factor it goes with any scope. Not just Tek scopes but any scope out there. There are over 1 million scopes in the world...and none of them have a **TVC 501**! We considered a monolithic unit. However, one of our primary applications is power supply design; all power supply designers already use AM 503 (TM 500 plug-in) current probe amplifiers. There were technical and time-to-market issues that also led us into TM 500.

How do I choose a TM 500 mainframe?

It would be nice if a customer latched on to the modular instruments concept and purchased a 6-wide mainframe full of instruments. However, many people will just want the **TVC 501**. The TM 501A one-wide mainframe makes the most compact and visually appealing (my opinion) package; but it is not the least expensive mainframe. The TM 502A (2-wide) and the TM 503B (3-wide) are actually lower in price than a TM 501A. Be sure to suggest blank front panels (Part #016-0195-03) if they end up with spare slots.

Is it programmable?

No. Our target market is the design engineer or the evaluation engineer. Our observations were that these individuals do not hook their scope to a computer when debugging or troubleshooting. The extent of instrument interconnection was a plotter on their DSO. The **TVC 501** is a discovery tool appropriate for benchtop debugging. It's a real-time visualization tool, not an analyzer for after-the-fact study. Without programmability it will be difficult to sell into manufacturing test. If there is a need for these measurements in a test applications, refer the customer to Tek's VXI counter card (CDS 73A-541) that has measurement time-stamping.

Why isn't it faster and with better timing resolution?

The **TVC 501** was designed for the class of applications broadly known as digital control. I readily admit that there are applications for a faster version of the **TVC 501**. These include disk drive read channel analysis (>1 Mbit/sec), high speed (>10 Mbits/sec) digital communications, and RF synthesizers or oscillators (>10 MHz). The 11403's measurement statistics, the CSA 803's timing histograms, and the i-Pattern software package are potential solutions to these timing applications.

Can the TVC 501 measure frequency vs. time?

No. The **TVC 501** is a timing instrument. In many cases, a <u>period</u> vs. time waveform can unveil all the information that is needed. But period vs. time is <u>not</u> the same as frequency vs. time. See Engineering Brief EB2 (Frequency vs. Time Measurements) in the Applications Brochure.

Can't you buy a real low cost frequency-to-voltage converter?

Yes. In fact, an automotive tachometer is a good example of a frequency to voltage converter. Semiconductor vendors (Analog Devices, Burr-Brown, National Semi) also sell F-V chips for a few dollars. LM Instruments sells a 20 MHz frequency-to-voltage converter (packaged like a scope probe) for only $70; for example it can generate 1 mV/100 kHz. But these converters are averaging devices (poor transient response); they do not perform cycle-to-cycle or pulse-to-pulse measurements. They are based on analog integrating techniques that limit accuracy over a wide dynamic input frequency range. Don't be taken aback by a customer who says that he/she can build a frequency-to-voltage converter for $10.

Chili Dog- It would not have happened without you

The **TVC 501** is the official nomenclature for the ***Chili Dog*** project. Many of you in the field deserve credit for making this project happen. Customer feedback was critical to us during concept testing. Taking something sight unseen and completely different to your paying customers required faith and courage on your part.

One of our tasks when visiting potential customers was to ask what they would call this device. Most of you did not realize that we would actually show up with instruments that had ***Chili Dog*** printed on the front panel. By the way, the majority of those that we showed it to suggested that we should call it a ***Chili Dog***!

We would like to share a few of the highlights of the field visits. We remember:

...visiting a power supply manufacturer in Minneapolis where the receptionist announced our visit over their Public Address system, "The ***Chili Dog*** demonstration will commence in 5 minutes."

...the engineer at a semiconductor manufacturer in Sunnyvale who, after we demonstrated the ***Chili Dog***, exclaimed, "Wow... Wow... Wow... Wow..." Four times in a row... each spaced about 5 seconds apart. We can't remember what he said after that.

...the technician at an Air Force Base near Sacramento who promptly fell asleep during our presentation. He was nudged when we went around the table asking for suggested names for the ***Chili Dog***. In a flash of inspiration, he exclaimed, "Time-Axis-Translator" which was probably the most intriguing name we heard.

...the power supply designer who hooked up the ***Chili Dog*** to his switching power supply and discovered that his constant pulse rate was not so constant after all. We watched with amusement as he lowered his voice and huddled over the scope screen so his manager couldn't see what the ***Chili Dog*** uncovered. We watched with greater amusement when the manager climbed on top of a desk to see over the engineer's shoulder.

...the engineer at a disk drive manufacturer in San Jose who, after seeing the ***Chili Dog***, said, "Nice toy." After he referred to the ***Chili Dog*** as a toy about five more times, I finally had the courage to ask, "What do you mean by a toy?" He replied, "Oh, anything less than $10,000."

The ***Chili Dog*** project team thanks the field sales force for their support!

Remember:

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Sales Support Tools and Sample Mail Pieces

TVC 501 Data Sheet (Order #60W-7875). 2-page back-to-back.

TVC 501 Applications Brochure (Order #60W-7869). The Applications Brochure (120 page booklet includes data sheet) is your primary technical support tool. The table of contents is reproduced below.

Field Office Local Mailings. The next two pages were extracted from direct mail pieces that we are sending out at PSR (in the U.S.). My idea is that you can copy these as-is and insert them with local mailings or distribute them at product seminars. One is targeted at hardware engineers. The other is targeted at firmware engineers. The picture quality is good even after copying.

For assistance contact: **Oscilloscope Group Support Center (M/S 39-519)**
Tel: (503) 627-2400 **Fax: (503) 627-5695**

MAP Contacts for Marketing Philosophy or to talk to the TVC 501 designers:

Stan Sasaki C1-708 (206) 253-5655 Voice Mail: 253-5655 FAX: (206) 256-5980
Clark Foley C1-708 (206) 253-6066

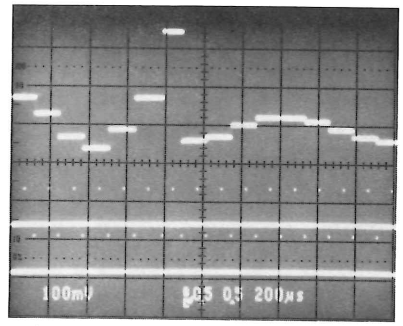
NEW! <u>Firmware Engineers</u> NEW!

See what you've been looking at...

Tektronix introduces the TVC **501**, a real-time time-interval to voltage converter. The TVC measures time delays between system events and instantaneously converts each measurement to a voltage proportional to the measured time-interval. The TVC output becomes a time-interval vs. time waveform on your scope and can be viewed simultaneously with other target hardware signals.

Finally, software and firmware designers, evaluators and integrators can:

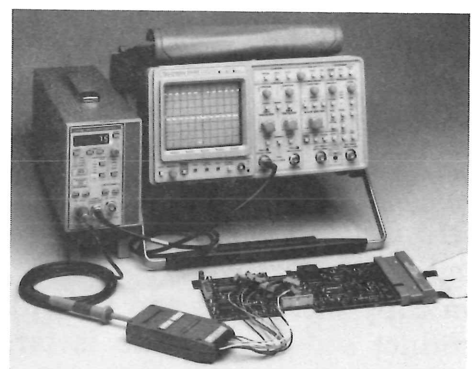
- View interrupt or throughput latency on the fly
- Trigger a scope or logic analyzer on excessive latency or throughput delays
- Monitor subroutine or procedure execution times on target hardware
- Verify that tasks are scheduled or dispatched within specified rate windows
- Correlate firmware faults to other system events such as coincident interrupts



Top trace (TVC output) shows the event-by-event response time performance of each consecutive pair of request-response signals on the lower two traces.

Time-Interval to Voltage Conversion... When Real-time means Right Now!

- Measure time-intervals between events such as interrupt requests and i/o operations
- Measure consecutive events without interruption up to 2 million events/sec
- View timing variations with selectable resolution from microseconds to seconds
- Output goes to any analog or digital scope. Or to any logic analyzer with an analog input channel
- Compatible with Tek's P6408 Word recognizer probe for pattern triggering such as on address or data bus word matches
- $2500 + TM 500 mainframe. Mainframes start at $395



TVC 501 in TM 501A mainframe. Shown with Tek 2440 oscilloscope and P6408 probe.

Call Tektronix today for further information!

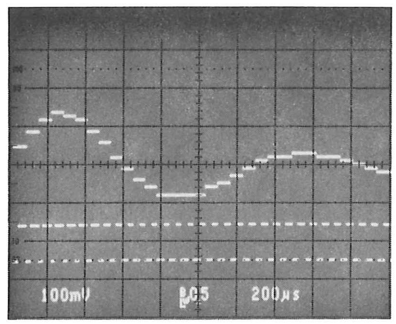
NEW! Hardware Engineers NEW!

See what you've been looking at...

Tektronix introduces the **TVC 501**, a real-time time-interval to voltage converter. The TVC measures pulse timing parameters of each sequential pulse in a pulse stream and instantaneously converts each measurement to a voltage proportional to the measured time-interval. The TVC output becomes a time-interval vs. time waveform on your scope and can be viewed simultaneously with other system waveforms. The TVC adds pulse width vs. time, pulse period vs. time, and pulse delay vs. time capability to your scope's voltage vs. time function.

Finally, hardware designers, evaluators and integrators can:

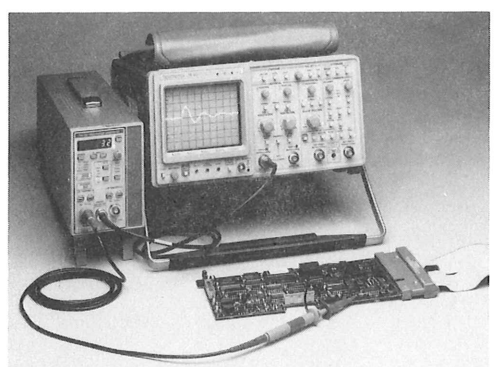
- See pulse modulation dynamics in digital control systems
- Uncover switch mode converter pulse modulation faults during start-up or shut-down sequences
- Trigger a scope on timing violations such as a glitches, double-pulses or missing pulses
- Decode complex pulse code modulation sequences
- Quantify and visualize system response time performance
- Directly measure group delay timing variations in equalization filters



The top trace (TVC output) shows the pulse-to-pulse width variations of the lower stream of pulses (TVC input).

Time-Interval to Voltage Conversion... When Real-time means Right Now!

- See up to 2 million uninterrupted sequential pulse timing measurements per second
- View small timing deviations around large average values with up to 30,000 divisions of timing offset
- Use with any analog or digital scope. TVC 501 vertical scale factors selectable from 1 μsec/division to 1 sec/division
- Correlate timing variations with voltage variations. TVC 501 output uses only one scope channel
- Timing measurements are made using digital counters with crystal timebase accuracy
- $2500 + TM 500 mainframe. Mainframes start at $395


TVC 501 in TM 501A mainframe. Shown with Tek 2440 oscilloscope.

Call Tektronix today for further information!