

Tektronix®
COMMITTED TO EXCELLENCE

TVC 501 Time-to-Voltage Converter

OPERATOR'S MANUAL

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Product Group 60

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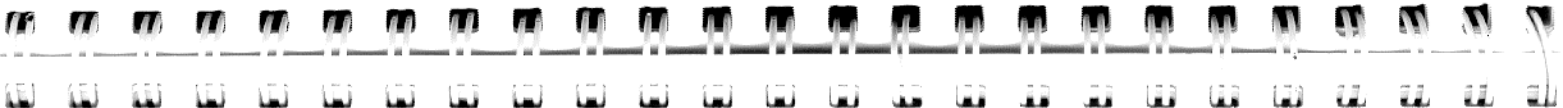
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About This Manual

Two manuals accompany the TVC 501 Time-to-Voltage Converter:

- *TVC 501 Operator's Manual*
- *TVC 501 Service Manual*

The service manual contains all the technical information needed to troubleshoot and repair the TVC 501. The operator's manual provides the information you need to set up and operate the TVC 501. The operator's manual is organized into the following chapters:

Chapter 1: Product Description introduces the TVC 501 and describes its features and standard accessories. This chapter also provides safety information.

Chapter 2: Getting Started describes how to plug in and set up the TVC 501, make connections to your oscilloscope and system under test, and prepare your oscilloscope for use with this instrument.

Chapter 3: Control Summary describes the controls (buttons and knobs) on the front panel, inputs and outputs, and explains common display messages that you may encounter when using the TVC 501.

Chapter 4: Operating Concepts discusses the types of measurements the TVC 501 makes and provides exercises to help familiarize you with instrument operation.

Chapter 5: Applications describes several representative applications.

Appendix A: Performance Specifications provides a detailed listing of the technical specifications for the TVC 501.

Appendix B: Diagnostic Summary lists and defines the error codes that can be displayed by the TVC 501.

Appendix C: Message Summary lists and defines the messages that can be displayed during normal operation by the TVC 501.

Manual Conventions

This manual uses the following conventions:

Power Module or Power Mainframe refers to any of the TM 500 or TM 5000 Series Power Modules.

Items enclosed in boxes, such as

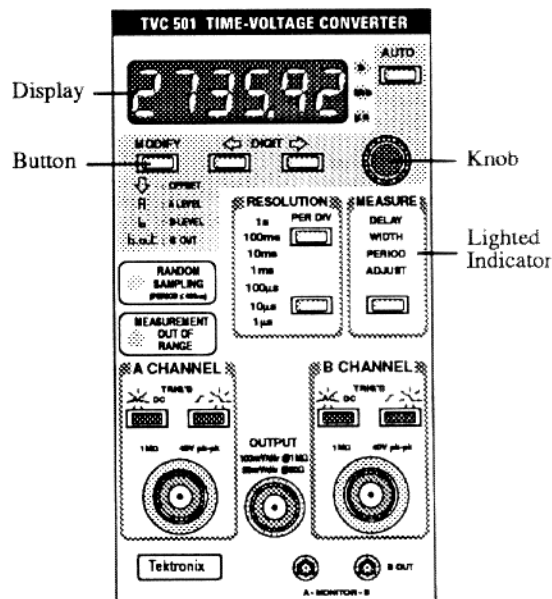
AdJUST

represent what you see on the display of the TVC 501.

Items in bold capitals, such as

MODIFY

represent a button, knob, indicator, or connector on the front panel.



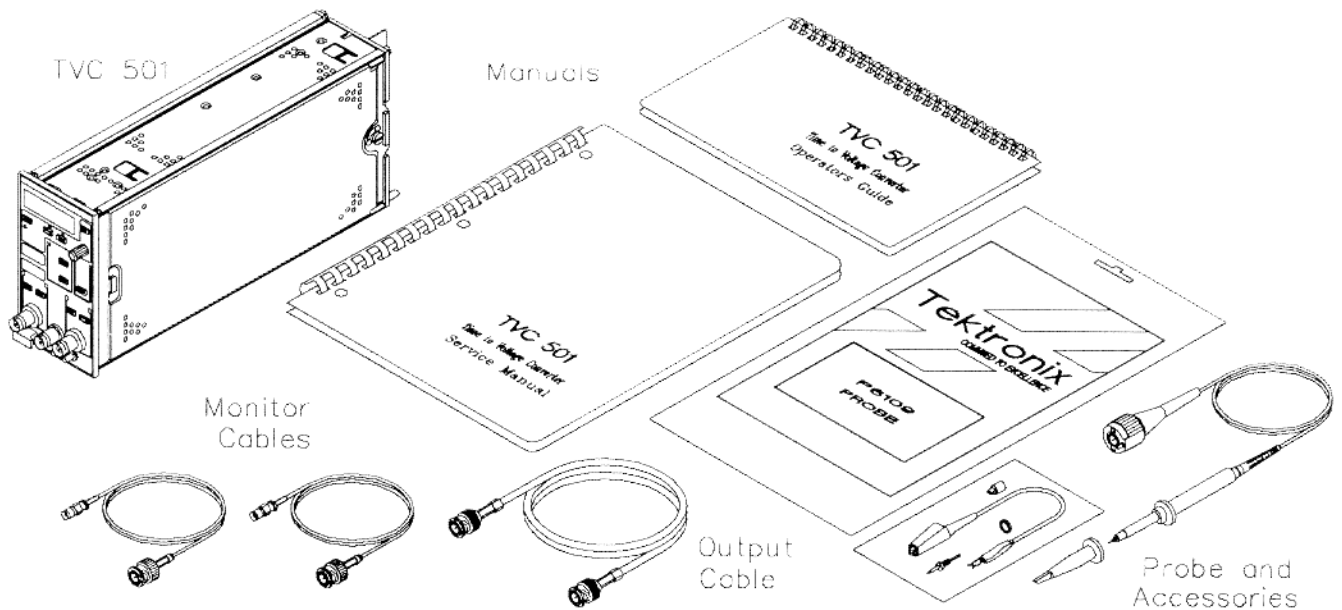


Figure 1-1. TVC 501 Time-to-Voltage Converter and accessories.

Chapter 1: Product Description

This chapter introduces the TVC 501. A product description and feature set are included, as well as a list of standard accessories. This chapter also provides safety information.

PRODUCT DESCRIPTION

The TVC 501 Time-to-Voltage Converter is a new and unique concept in test and measurement instrumentation. The TVC 501 provides continuous real-time conversion of timing interval measurements into voltages that can be displayed as a waveform on your oscilloscope. The voltage (vertical axis) on the oscilloscope display represents the time interval measurement; the time (horizontal axis) on the oscilloscope display represents the elapsed time. This oscilloscope waveform display gives a graphic representation of time-interval variations vs. time. For in-depth information about time-to-voltage conversion, see Chapter 4: Operating Concepts.

The TVC 501 works with both analog and digital oscilloscopes. Additionally, you can also connect the TVC 501 output to a counter/timer or to waveform processing equipment. Adding a TVC 501 to your voltage analysis system will increase your system's analytical capability.

The TVC 501 operates in a single slot of either a Tektronix TM 500 or TM 5000 Series Power Module.

Other TVC 501 features let you

- measure pulse width or period
- measure delay between two independent signals
- automatically set trigger parameters by pressing one button
- automatically set offset and resolution by pressing one button
- easily calibrate your oscilloscope to the TVC 501 by using the built-in adjust pattern

In addition to the preceding features, the TVC 501 automatically performs self-diagnostics at power up, assuring you of optimum instrument performance.

Permanent Test Installation

You can make the TVC 501 part of a permanent test station using a TM 500 or TM 5000 Series Power Module. All front panel inputs and outputs of the TVC 501 can be patched to the rear panel of the Power Module. Some of these connections require patching within the TVC 501 and should only be made by qualified service personnel.

For information about using the rear interface bus, refer to your Power Module user's manual and the *TM 500 and TM 5000 Series Rear Panel Interface Data Book* (Tektronix part number 070-2088-03). A list of TVC 501 rear-panel signals and internal patching instructions are found in the *TVC 501 Service Manual*.



STANDARD ACCESSORIES

Figure 1-1 shows the standard accessories shipped with the TVC 501. The following list describes these accessories.

Output Cable connects the **OUTPUT BNC** of the TVC 501 to the BNC input of an oscilloscope or other piece of test equipment. This is a BNC-to-BNC cable.

Monitor Cables (2) connect the channel A and channel B monitor outputs to test equipment with BNC connectors. Each is an SMB-to-BNC cable.

P6109 Passive Probe connects to the **A CHANNEL** or **B CHANNEL** input of the TVC 501. The P6109 is a miniature, 10X passive probe with a bandwidth of DC to 150 MHz and a 20 pF nominal input capacitance. For more information on the P6109, refer to the technical information sheet included with your probe.

TVC 501 Operator's Guide describes how to use the TVC 501.

TVC 501 Service Manual provides information about testing, repairing, and calibrating the TVC 501.

OPERATOR'S SAFETY SUMMARY

The general safety information in this summary is for both operating and servicing personnel. Specific warnings and cautions may be found throughout the manual where they apply, but may not appear in this summary.

Terms In This Manual

>>**Caution** These statements call attention to practices that could cause damage to the instrument.

WARNING

These statements call attention to practices that could lead to personal injury or death.

Terms Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the markings. **CAUTION** also refers to a hazard to property, including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Power Source

This product is intended to operate in a Power Module connected to a power source that will not apply more than 250 volts rms between the supply conductors or between either supply conductor and ground. A protective ground connection, by way of the grounding conductor in the Power Module power cord, is essential for safe operation.

Grounding the Instrument

This instrument is grounded through the grounding conductor of the Power Module power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to the instrument input or output terminals. A protective grounding conductor in the Power Module power cord is essential for safe operation.

Danger From Loss of Ground

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulated) can cause an electrical shock.

Use the Proper Fuse

To avoid fire hazard, use only a fuse of the correct type, voltage rating, and current rating as specified in the replaceable parts list of the *TVC 501 Service Manual*. Refer fuse replacement to qualified service personnel.

Do Not Operate In Explosive Atmospheres

To avoid explosion, do not operate this instrument in an explosive atmosphere unless it has been specifically certified for such operation.

Do Not Operate Without Covers

To avoid personal injury, do not operate this product without covers or panels installed.

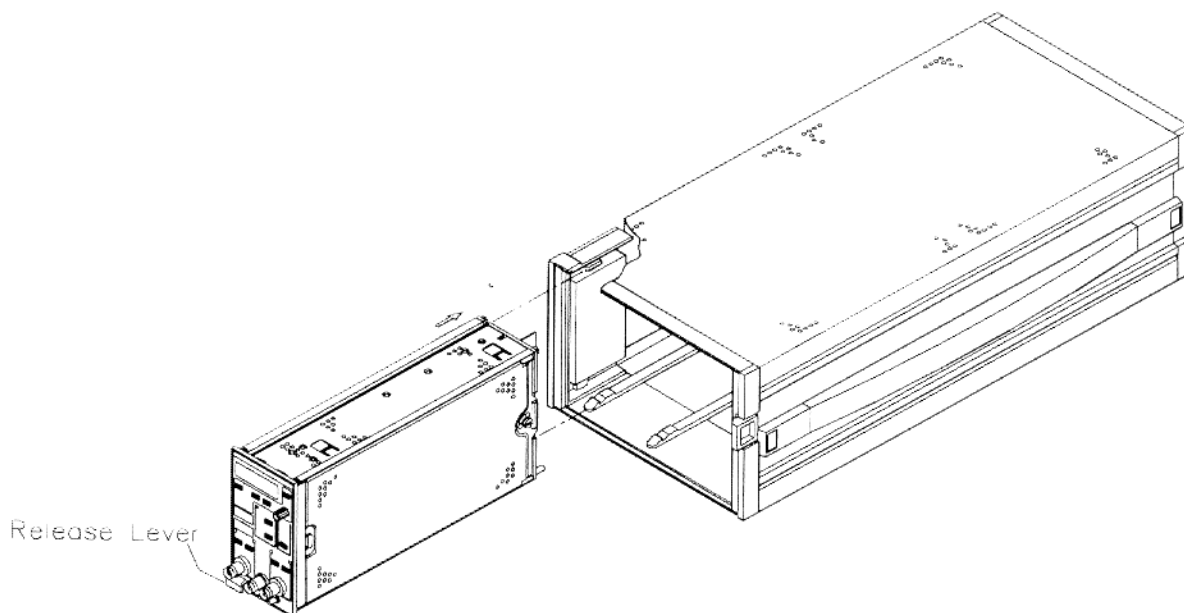


Figure 2-1. Installing the TVC 501 into the Power Module.

Chapter 2: Getting Started

This chapter will help you

- install the TVC 501 in a Power Module
- choose appropriate probes
- choose an oscilloscope for your application
- connect cables and probes to the TVC 501
- power up the TVC 501 and verify that it is working properly
- use the adjust pattern to calibrate your oscilloscope to the TVC 501 output

UNPACKING THE TVC 501

Carefully unpack the contents of the shipping carton and verify that you have all the items listed in Chapter 1 under the heading, "Standard Accessories." If any items are missing, contact your Tektronix sales representative.

INSTALLING THE TVC 501

The TVC 501 operates in a Tektronix TM 500 or TM 5000 Series Power Module.

>>Caution To prevent instrument damage, turn the Power Module off before inserting or removing the TVC 501.

Figure 2-1 shows how to install the TVC 501 into the Power Module. Align the top and bottom grooves of the TVC 501 with the rails of an empty plug-in compartment of the Power Module. Slide the TVC 501 in until the edge connector snaps into place so that the TVC 501 front panel is flush with the Power Module cabinet.

To remove the TVC 501 plug-in, grasp the release lever and pull the instrument out.

CHOOSING PROBES

A P6109 10X passive probe is included with your TVC 501. The specifications for this probe are listed in Table 2-1.

Table 2-1
P6109 Probe Specifications

| Characteristic | Specification |
|----------------|------------------------|
| Length | 2 m |
| Attenuation | 10X |
| Bandwidth | 150 MHz |
| Loading | 10 M Ω /13.2 pF |
| DC Max | 500 V |

You can use other probes with the TVC 501 as long as the probe is compatible with the 1 M Ω input impedance of the TVC 501.

The TVC 501 is capable of reading probe code pins. When it reads the probe code, it automatically scales the trigger level display by the attenuation factor of the probe. For example, if the TVC 501 displays a trigger level of **A 0.25** and you plug a 10X attenuator probe (such as the P6109) into the **A CHANNEL** input connector, the display will change to **A 2.5**. The TVC 501 scaled the trigger level from 0.25 volts to 2.5 volts.

NOTE

If the probe you are using does not have a readout pin or if you are using an attenuating feed-through termination, the TVC 501 can not scale the trigger level display by the attenuation factor. You must remember to interpret the trigger level voltage by mentally scaling it.



CHOOSING AN OSCILLOSCOPE

The TVC 501 works with both analog and digital oscilloscopes. In general, an analog oscilloscope is a good choice for viewing rapidly occurring repetitive events. Alternatively, a digital storage oscilloscope is capable of capturing transient events—those that occur very infrequently or repetitive events that occur slowly.

The TVC 501 is not limited to use with an oscilloscope. You can connect its output to a counter/timer or to waveform processing equipment. Adding a TVC 501 to your voltage analysis system will increase your system's analytical capability.

CONNECTING PROBES AND CABLES

The TVC 501 comes with one output cable. This cable is a 42-inch coaxial cable with a BNC connector at each end. Connect one end of the output cable to the BNC connector of the TVC 501 labeled **OUTPUT**, located at the lower middle of the front panel. Connect the other end of the output cable to one of the channel inputs of your oscilloscope.

The TVC 501 comes with two monitor cables. Each is a 42-inch coaxial cable with a SMB connector at one end and a BNC connector at the other. Connect the SMB end of the cable to the SMB connector of the TVC 501 labeled **A-MONITOR**, located at the lower right of the front panel. Connect the BNC connector of the monitor cable to another channel of your oscilloscope.

Connect the BNC connector of your probe to the BNC connector of the TVC 501 labeled **A CHANNEL**, located at the lower left of the front panel. Connect the other end of your probe to the signal to be measured.

After making these connections, your setup will look similar to Figure 2-2.

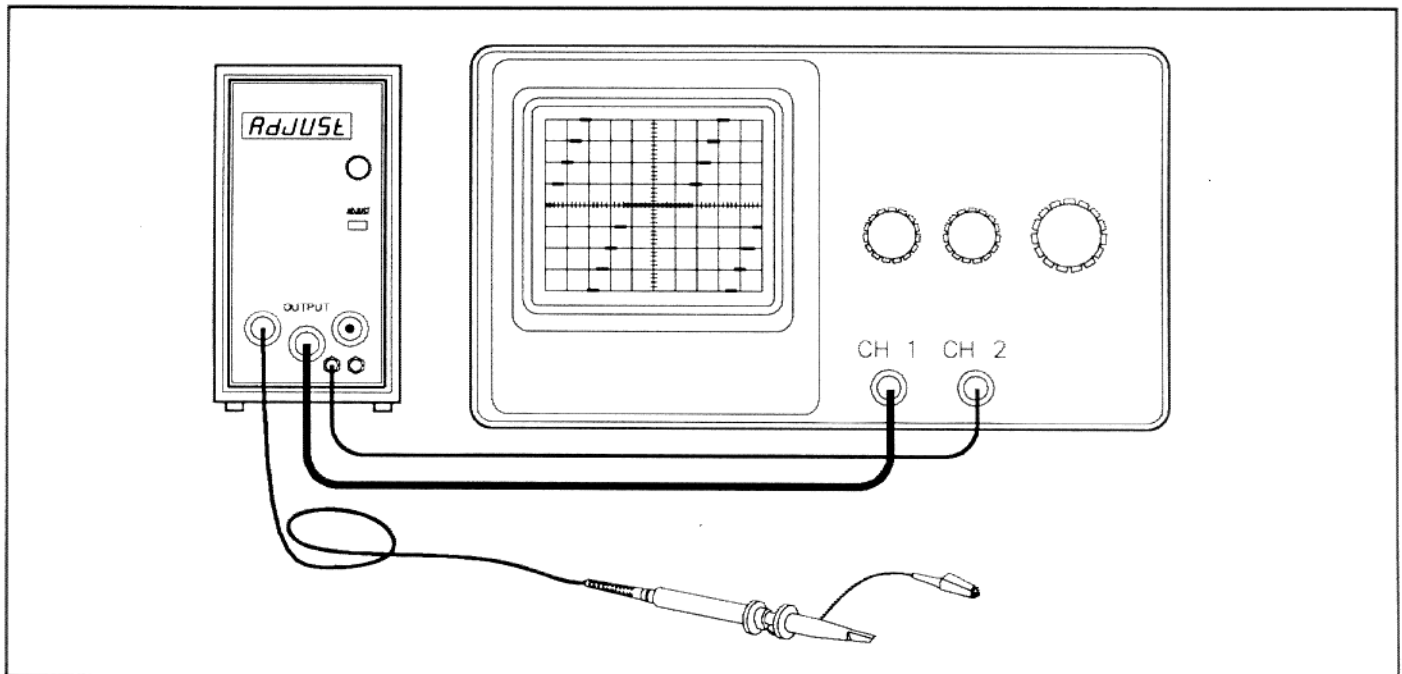


Figure 2-2. The TVC 501 Connected to an Oscilloscope.

POWERING UP

Turn on the power to the Power Module. At power-up, the TVC 501 tests each lamp on the front panel. Next, **rEL 1.0** appears momentarily on the display showing the firmware release number. The firmware release number is followed by **P45678**. Finally, **AdJUST** appears on the display and the **ADJUST** lamp in the **MEASURE** section lights. You are now ready to adjust your oscilloscope to the TVC 501.

NOTE

Depending on the latest available firmware, the release number may not be 1.0. Contact a Tektronix representative to obtain the latest release number.

When you turn on the TVC 501, if there is any deviation from the sequence in the previous paragraph, refer to Appendix B: Diagnostic Summary for more information.

USING THE ADJUST PATTERN TO CALIBRATE THE OSCILLOSCOPE TO THE TVC 501 OUTPUT

When the TVC 501 display shows **AdJUST** and the **ADJUST** indicator lights, the TVC 501 sends a calibration signal to the **OUTPUT** connector. (By default, when the TVC 501 powers up, it sends this signal out the **OUTPUT** connector.)

NOTE

You must calibrate the oscilloscope with the Adjust signal each time you power up the TVC 501, power up the oscilloscope, or when you change oscilloscopes.

When the display shows **AdJUST**, you are ready to calibrate the oscilloscope to the TVC 501. Do this by performing the following steps:

1. Verify that **AdJUST** is displayed on the TVC 501. If it is not, repeatedly press the **MEASURE** button until the **ADJUST** lamp is lighted.
2. Verify that the TVC 501 **OUTPUT** is connected to the oscilloscope input via the output cable. (See Figure 2-2 and the section titled "Connecting Probes and Cables" earlier in this chapter for information about connecting the TVC 501 to the oscilloscope.)
3. Obtain a display of the TVC 501 output on the oscilloscope with the following settings:

| | |
|-----------------------|--|
| Vertical gain: | 100 mV per division, DC coupled at 1 M Ω or 50 mV per division, DC coupled at 50 Ω |
| Time base: | 5 ms per division (or slower) |
| Trigger: | on input signal |
4. Adjust the oscilloscope vertical position so that the longest step is on the center graticule line. Now adjust the oscilloscope vertical gain (volts/div) so that each of the small steps line up on the other graticule lines. You may have to use the oscilloscope variable gain control to get a precise alignment to the graticule lines.

Figure 2-3 shows the oscilloscope's screen after correct adjustment. Once you have made this adjustment you will be able to accurately interpret the TVC 501 output.

NOTE

After adjusting the vertical position of the oscilloscope channel that shows the TVC 501 output signal, do not change the vertical position or gain controls while using the TVC 501. If you do, it will be impossible to accurately interpret the TVC 501 output.

If you are ready to experiment with the TVC 501, turn to Chapter 4 and try performing the instructional exercises.

If you want more descriptive information about the TVC 501 operating controls and indicators, turn to Chapter 3: Control Summary.

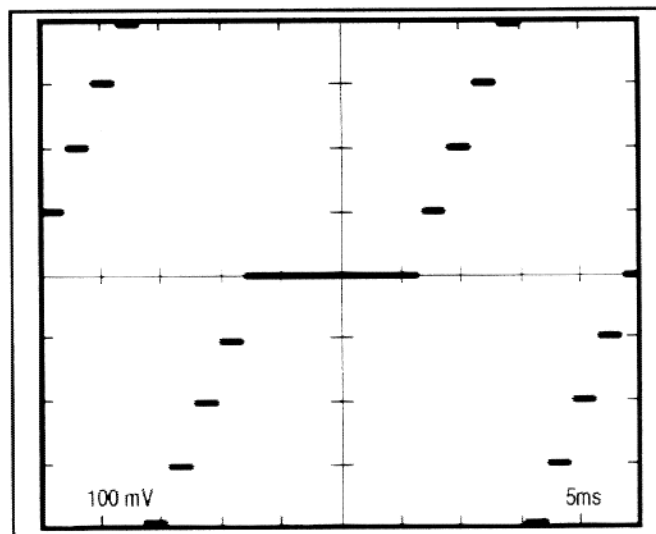
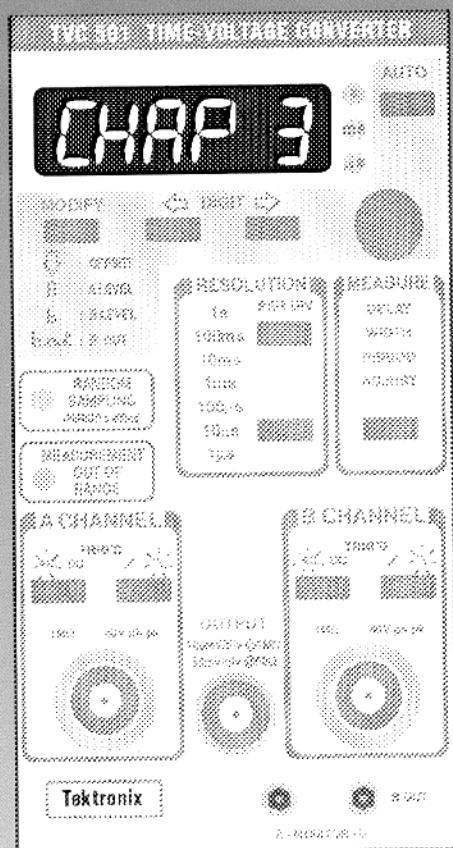


Figure 2-3. Correct Adjustment of the Adjust Signal on the Oscilloscope Screen.



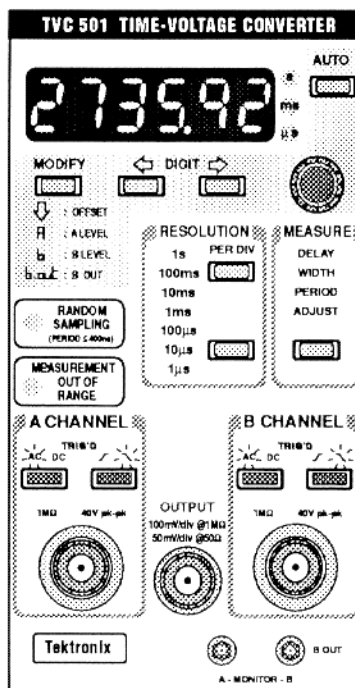


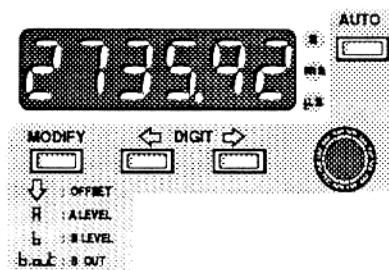
Figure 3-1. The front panel of the TVC 501.

Chapter 3: Control Summary

This chapter describes the TVC 501 display, controls, indicators, and connections. Figure 3-1 shows the front panel of the TVC 501.

THE DISPLAY

The display provides different types of information to the user. Upon powering up, it displays the results of the self-test routine; if the unit fails any test, the display will indicate the test that failed. In this event, refer to Appendix B: Diagnostic Summary.



When the TVC 501 has successfully passed all power-up diagnostics, **AdJUST** appears in the display. The **AdJUST** signal is used to calibrate the oscilloscope to the TVC 501 output.

When the TVC 501 shows an all-numeric display, the number displayed is the offset value. This value is the time interval value represented by the center graticule line on the oscilloscope. Three lamps to the right of the display indicate the unit of time that this number represents: s (seconds), ms (milliseconds), or μ s (microseconds). One of these indicators will be on when an offset value is displayed. When the display shows an offset value, the rotary knob, the **AUTO** key, and the **DIGIT** keys affect the offset value.

If the display shows a number preceded by **A**, this is the trigger level for channel A. The rotary knob, the **AUTO** key, and the **DIGIT** keys affect the channel A trigger level.

If the display shows a number preceded by **b**, this is the trigger level for channel B. The rotary knob, the **AUTO** key, and the **DIGIT** keys affect the channel B trigger level.

If the display shows **b.out** followed by a number from one to eight, this indicates an internal signal being sent out the **B OUT** monitor jack. The number following **b.out** indicates which signal is selected. Only the rotary knob can change this number. For more details about each signal, see Chapter 4: Operating Concepts.

MODIFY

To cycle through the display options, press the **MODIFY** button. The four display options are **OFFSET**, **A CHANNEL** trigger level, **B CHANNEL** trigger level, and internal signals that appear at the **B OUT** output.

DIGIT

To change the offset value or trigger level, press either of the two **DIGIT** buttons. The selected digit is indicated by an underscore. The left digit button moves the underscore to the left and the right button moves the underscore to the right.

To change the numerical value of the selected digit, rotate the knob located to the right of the digit buttons. A clockwise rotation increments the value and a counter-clockwise rotation decrements the value.

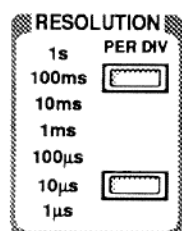
AUTO

The results of pressing the **AUTO** button depend on what the TVC 501 is displaying at the time. **AUTO** initiates a process to establish a suitable setting instead of manually turning the knob. The **AUTO** button affects whatever the knob affects, except for the **b.out** signals.

When the TVC 501 displays an offset value, press **AUTO** to make the TVC 501 select an appropriate offset value and resolution to display the input signal on the oscilloscope screen.

When the TVC 501 displays a trigger level, press **AUTO** to make the TVC 501 select an appropriate trigger level for the channel, usually midamplitude of the input signal.

RESOLUTION

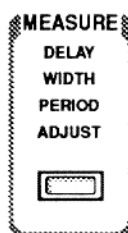


The resolution identifies what time unit is represented by each major graticule line on the oscilloscope display. The unit of resolution per division is indicated by which one of seven lamps is lighted:

| | |
|-------|------------------|
| 1s | 1 second |
| 100ms | 100 milliseconds |
| 10ms | 10 milliseconds |
| 1ms | 1 millisecond |
| 100µs | 100 microseconds |
| 10µs | 10 microseconds |
| 1µs | 1 microsecond |

Press the upper button in the resolution area to choose a resolution above the currently lighted indicator; press the lower button in the resolution area to choose a resolution below the currently lighted indicator.

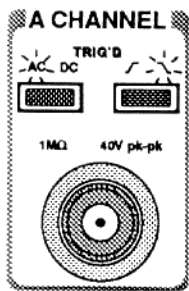
MEASURE



The TVC 501 makes three types of measurements: delay, width, and period. Press **MEASURE** to choose one of these measurements or to make the TVC 501 generate the adjust signal. The type of measurement selected is shown by the lighted indicator in the **MEASURE** area.

| | |
|---------------|---|
| DELAY | The time between channel A trigger and channel B trigger. |
| WIDTH | The time between alternate edges of the channel A input. |
| PERIOD | The time between channel A triggers. |
| ADJUST | A specific signal used to calibrate the oscilloscope to the TVC 501. This is not a measurement; it allows you to verify the measurement scaling on your oscilloscope. |

INPUT CHANNELS



There are two input channels labeled **A CHANNEL** and **B CHANNEL**. Each channel has a BNC input jack, a coupling control and a trigger slope control. When the channel has been triggered, an indicator labeled **TRIG'D** lights. The **TRIG'D** indicator is located above the input jack. The trigger voltage range without attenuation is ± 1.25 V.

AC-DC

This button toggles between AC coupling and DC coupling. The radial pattern around the AC symbol indicates that AC coupling is selected when the button lights.

Slope (↗↘)

The slope button toggles between rising-edge triggering and falling-edge triggering. The radial pattern around the falling edge symbol indicates that falling edge slope is selected when the button lights.

OUTPUT



This is the time-to-voltage converted output. The BNC jack labeled **OUTPUT** should be connected to an input channel of your oscilloscope, counter, or waveform processing device.

MONITOR OUTPUTS



There are two SMB connectors labeled **A-MONITOR-B** located at the bottom right of the TVC 501 front panel. Each acts as the trigger output monitor of the corresponding input channel. The monitor output shows the state of the trigger based on the level and slope selected for the input channel. Additionally, the channel B monitor acts as the output for the prescaled signals (b.out 2 and b.out 3) and instructional signals b.out 4 through b.out 8.

MEASUREMENT OUT OF RANGE



When the **MEASUREMENT OUT OF RANGE** indicator is on, it means that the measurements are occurring outside the range defined by the specified offset and

resolution per division. To get the measurements within range, change the offset or resolution per division manually or automatically. The indicator will remain on as long as the out-of-range condition persists.

RANDOM SAMPLING

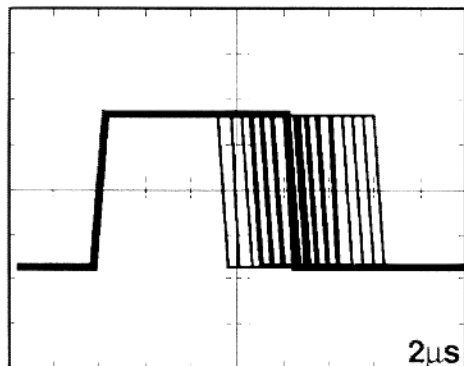


The TVC 501 can make up to 2.5 million uninterrupted measurements per second. If the input signal changes more quickly than this, the TVC 501 will skip some

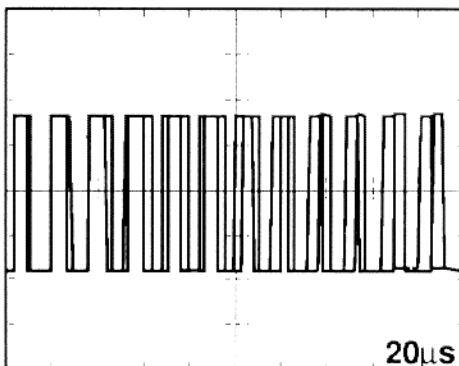
events. When this occurs, the **RANDOM SAMPLING** indicator will be lighted. The measurements will be made as quickly as the TVC 501 can make them, however, the measurement sequence will be interrupted. The indicator will remain on as long as the random sampling condition persists.



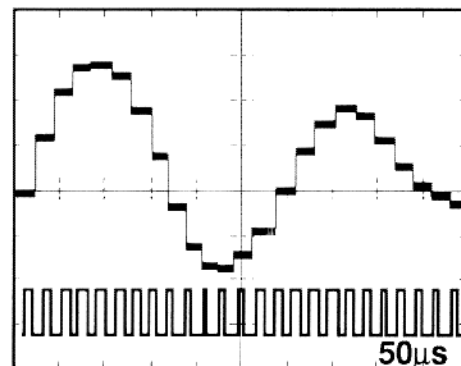
Pulse Width Modulated Input Signal



Conventional Scope Display

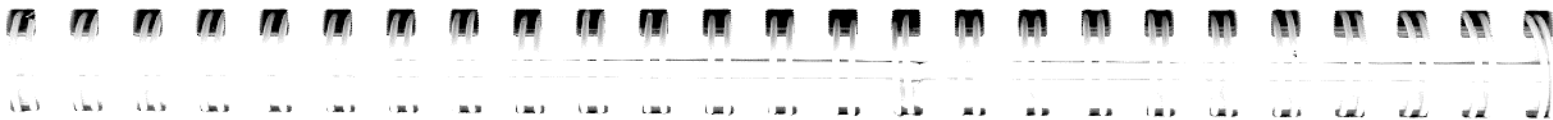


Conventional Scope Display



TVC 501 output of Width vs Time and the input signal below.

Figure 4-1. Three ways to view the input signal. Only one shows what's really happening.



Chapter 4: Operating Concepts

This chapter describes significant operating concepts of the TVC 501 and provides instructional exercises that help you learn how to make and interpret basic measurements. The concepts discussed include:

- width, period, and delay measurements
- the **AUTO** button
- the monitor outputs
- the prescaling feature

The instructional exercises teach you how to

- establish a trigger level
- establish a time offset and resolution
- interpret pulse-modulated signals
- detect and analyze glitches

For a complete reference of all of the TVC 501 operating controls and indicators, see Chapter 3: Basic Operations.

WIDTH MEASUREMENTS

Figure 4-1 shows three different ways to view a pulse-width modulated signal. The left view shows a conventional oscilloscope display with overlapping pulses that obscure important information. The center view shows the results of slowing down the oscilloscope sweep speed. The pulses still overlap and obscure information. The view on the right shows the TVC 501 width-converted output with the signal being measured shown below. The TVC 501 output reveals the true nature of the signal.

NOTE

*Only the **A CHANNEL** input of the TVC 501 can be used for width measurements.*

The TVC 501 continuously measures each pulse width in real time and converts it to a corresponding voltage level. Conversions are performed pulse-to-pulse without averaging. When the TVC 501 output is displayed on an oscilloscope screen, you can see the width of each consecutive pulse represented by the voltage displayed on the vertical axis. If the oscilloscope shows different levels, then the pulse width is varying. If the TVC 501 output remains at a constant level, then all of the pulse widths are identical.

Figure 4-2 shows a representation of the TVC 501 output on an oscilloscope display with the input waveform above it. The TVC 501 input trigger settings determine the measurement point of the input signal. In this example, rising edge is selected with the voltage level near the signal midpoint; therefore, the pulse width measurement begins on the rising edge and ends on the falling edge.

The offset value displayed on the TVC 501 readout is the time represented by the center graticule line of the oscilloscope. The TVC 501 offset value in this example is $40\ \mu\text{s}$, so the value at the center oscilloscope graticule represents $40\ \mu\text{s}$.

The resolution per div displayed on the TVC 501 front panel represents the vertical scaling of the oscilloscope screen. The TVC 501 resolution in this example is $10\ \mu\text{s}$ per division, so each vertical division of the oscilloscope represents $10\ \mu\text{s}$.

From this information, the minimum and maximum width values of Figure 4-2 can be calculated. The minimum width value is approximately $15\ \mu\text{s}$ and the maximum width value is approximately $69\ \mu\text{s}$.

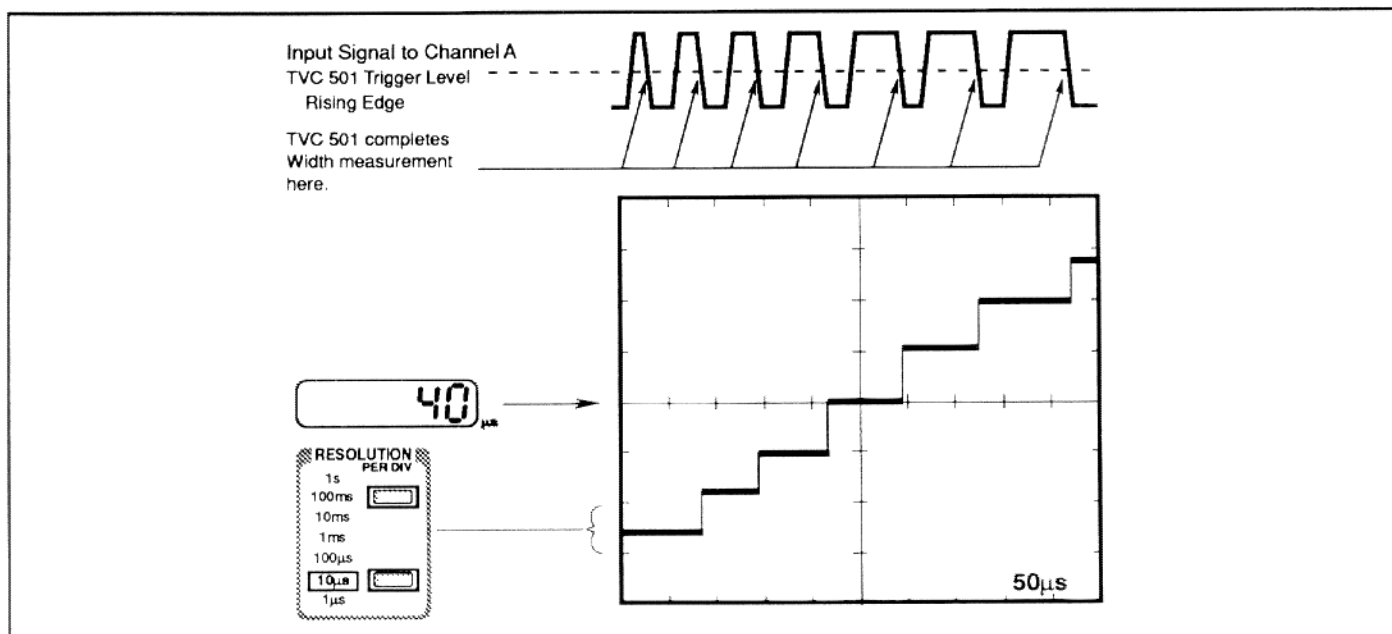


Figure 4-2. TVC 501 Width Measurement. The TVC 501 offset is $40\ \mu\text{s}$ and the resolution per division (vertical scale) is $10\ \mu\text{s}$. The oscilloscope time base is $50\ \mu\text{s}$.

PERIOD MEASUREMENTS

You can think of a period conversion in much the same way that you think of a width conversion. In this case, the measurement is of a complete cycle of the waveform, rather than of a pulse. The description of the width conversion applies to the period conversion: if the oscilloscope shows different levels, then the period is varying. If the oscilloscope shows a constant level, then the period is constant.

NOTE

*Only the **A CHANNEL** input of the TVC 501 can be used for period measurements.*

Figure 4-3 shows an example of a period conversion. The TVC 501 output is shown below with the input waveform above. The offset displayed on the TVC 501 is 44 μs . This is the time value represented by the center graticule line of the oscilloscope. The resolution per div displayed on the TVC 501 is 10 μs , so each vertical division of the oscilloscope represents 10 μs .

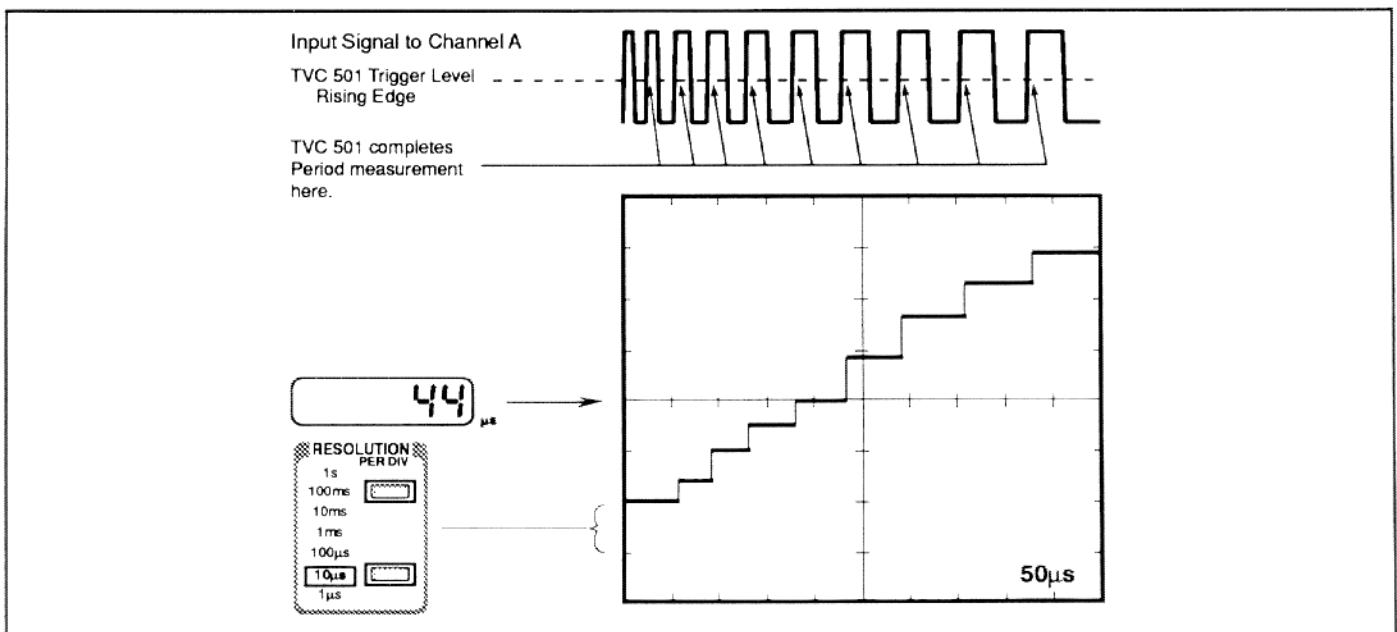


Figure 4-3. TVC 501 Period Measurement. The waveform at the top is the input signal. Below, is the oscilloscope display of period vs. time. The oscilloscope time base is 50 μs per division.

DELAY MEASUREMENTS

The TVC 501 delay measurement measures the time between triggering of the **A CHANNEL** input and triggering of the **B CHANNEL** input. If additional **B CHANNEL** triggers occur before another **A CHANNEL** trigger, the TVC 501 ignores the additional **B CHANNEL** triggers.

Figure 4-4 illustrates a delay measurement. The TVC 501 offset displays a value of $53\ \mu\text{s}$, so the center graticule line represents $53\ \mu\text{s}$. The TVC 501 resolution per division is $10\ \mu\text{s}$, so each vertical division of the oscilloscope represents $10\ \mu\text{s}$. If the oscilloscope shows different levels, it means that the delay between the **A CHANNEL** trigger and **B CHANNEL** trigger is varying. If the oscilloscope shows a constant level, then the delay is constant.

From this information, the minimum and maximum delay can be calculated. The minimum delay is about $25\ \mu\text{s}$ and the maximum delay is about $83\ \mu\text{s}$.

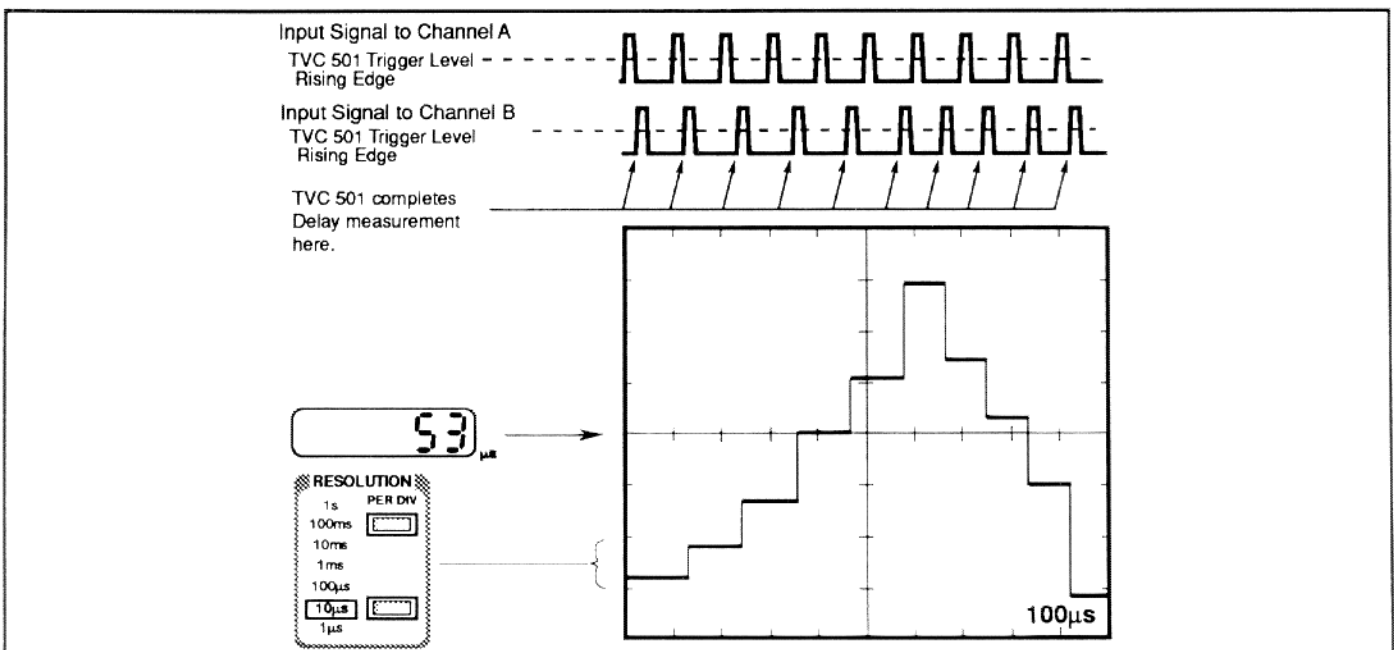


Figure 4-4. TVC 501 Delay Measurement. The two signals shown at the top are applied to channels A and B of the TVC 501. Below, the delay measurement from channel A to channel B is displayed on the oscilloscope.

THE AUTO BUTTON

The **AUTO** button can automatically set the channel A trigger level, channel B trigger level, or time offset. The behavior of the **AUTO** button depends on the TVC 501 digital display.

If the display shows **A** when the **AUTO** button is pressed, the TVC 501 automatically sets the trigger level for channel A. If the display shows **b** when the **AUTO** button is pressed, the TVC 501 automatically sets the trigger level for channel B.

If the display shows a number and a lighted scaling indicator (located to the right of the display) when the **AUTO** button is pressed, the TVC 501 automatically chooses an offset value and a resolution per division.

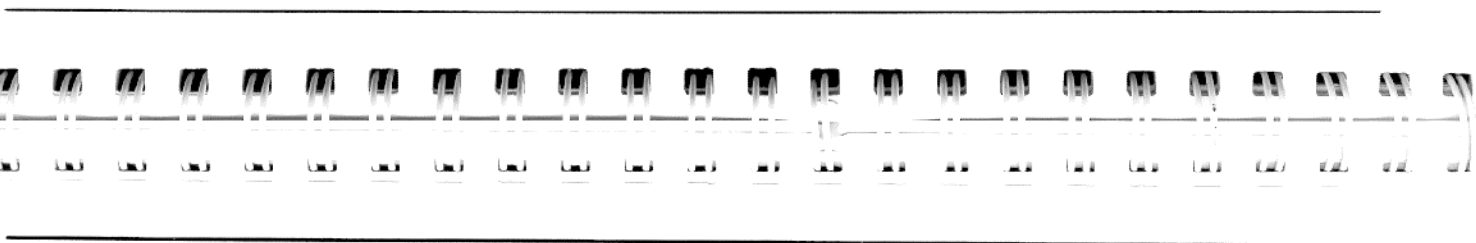
The **AUTO** button does not affect the b.out instructional signals. Repeatedly press the **MODIFY** button to cycle through the display choices.

Trigger Level

The TVC 501 determines the trigger level by searching for the maximum and minimum levels of the input signal and establishing the midpoint as the trigger level. This method ensures that the signal will cross the trigger threshold. If the TVC 501 cannot establish this level, it automatically displays the message **try AC**.

Since the TVC 501 is looking for transitions, a steady signal with no transitions will cause the **try AC** message to be displayed. In this case, changing the trigger to AC will not trigger the TVC 501 because there are no transitions in the input signal.

Pressing the **AUTO** button will consistently establish a reliable trigger level as long as the frequency is greater than 20 Hz and the pulse width is greater than 50 ns.



Offset and Resolution

Once triggering has been established, the TVC 501 can automatically select an offset value and resolution value. The TVC 501 selects the most-precise resolution and an offset value to produce an oscilloscope display without going out of range (maximum range is ± 4 vertical divisions on the oscilloscope).

When an event occurs infrequently (slower than 20 Hz), it may not be included in the measurements that the TVC 501 uses to establish the offset value. When this happens, the infrequent event may be out of range, and the **MEASUREMENT OUT OF RANGE** indicator lights. You may have to manually adjust offset and resolution per division to see the desired information.

MAKING MEASUREMENTS

Before making any measurements, adjust the TVC 501 settings in the following order:

1. Set the trigger level (either manually or automatically) so that the **TRIG'D** indicator lights.
2. Set the offset and resolution per division (either manually or automatically) as desired.

If you would like to practice setting trigger and offset levels, see the exercises described later in this chapter.

MONITOR OUTPUTS

Input channels A and B have associated monitor outputs. The monitor output signal represents how the TVC 501 interprets the input signal based on the trigger level and slope controls.

The block diagram in Figure 4-5 shows how the monitor signal is derived. The input signal is fed to a comparator where it is compared to the trigger threshold level. The comparator output drives an amplifier with inverted and non-inverted outputs. This amplifier offers the slope selection of rising or falling edge. The amplifier output, which is the monitor output, starts and stops a digital counter. The counter value is then converted to an analog voltage by the digital-to-analog converter (DAC).

Figure 4-6 graphically shows at what point the TVC 501 makes its measurements of a triangle wave with the trigger level set above the signal midpoint. The middle waveform shows the monitor output when the rising-edge slope is selected. The TVC 501 measures the signal when the signal exceeds the trigger threshold level. The bottom waveform shows the monitor output when the falling-edge slope is selected.

slope is selected. The TVC 501 measures the signal when it falls below the trigger threshold level.

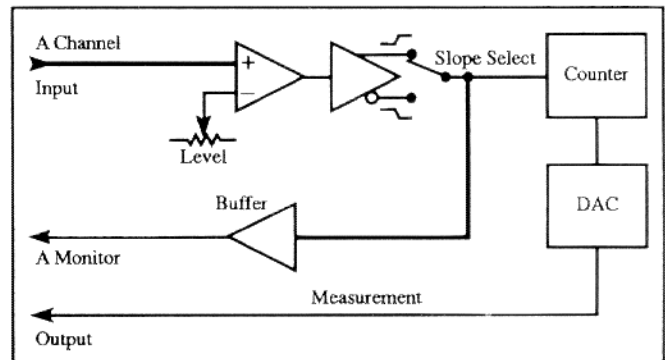


Figure 4-5. A Simplified Block Diagram of the Monitor Output Circuit.

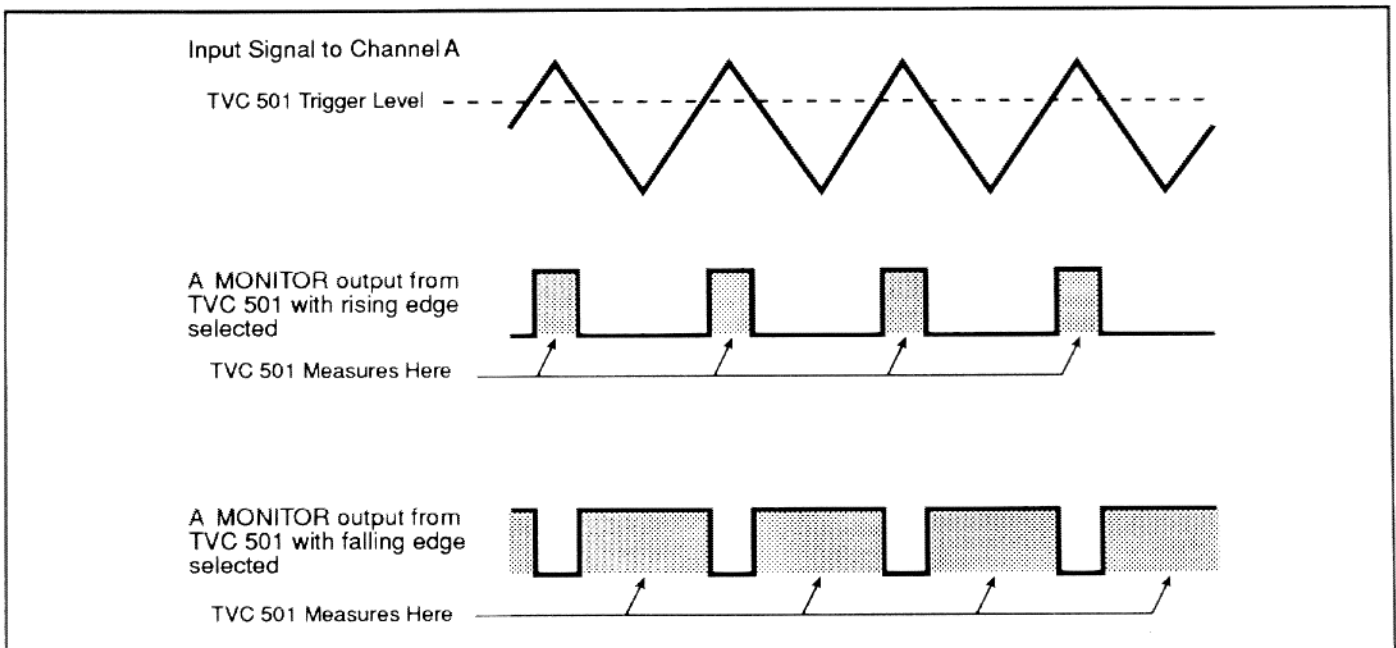


Figure 4-6. The Monitor Output Signal. The monitor output shows what part of the input signal is measured when WIDTH is selected.

Figure 4-7 shows a more dramatic benefit of the monitor output signal. Waveform noise or aberrations can cause the TVC 501 to measure the signal at undesirable intervals. By observing the monitor output, it is immediately evident that there are extra triggers that are not caused by the major input signal transitions. In this example, lowering the trigger level produces the expected number of trigger transitions.

Use the monitor output when adjusting the trigger level for noisy or marginal signals. If noise continues to be a problem, use a probe with a different attenuation factor or provide external filtering.

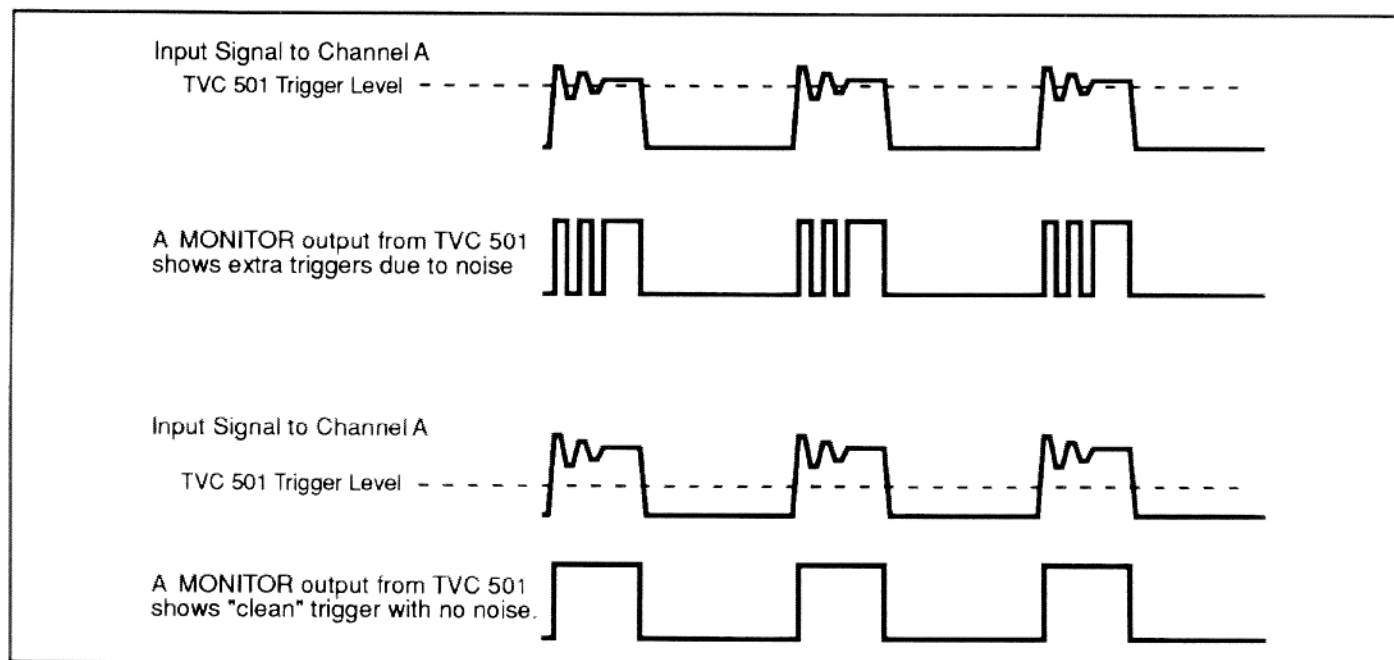


Figure 4-7. Using the Monitor Output Waveform. The monitor output waveform shows if you are triggering at a desirable voltage.

The b.out Signals

The TVC 501 outputs one of eight possible signals at the **B OUT** connector. These signals include the channel B monitor output, two prescaled (frequency-divided) outputs, and five instructional signals. These signals are labeled **b.out 1** through **b.out 8**.

To select a b.out signal, press the **MODIFY** button until **b.out** appears on the display and then turn the knob to select the desired signal. Table 4-1 describes each b.out signal. Figure 4-8 illustrates the waveforms produced by signals b.out 4 through b.out 8.

NOTE

To use the channel B monitor output, be sure that the b.out 1 signal is selected.

Table 4-1
B OUT signals

| Signal | Description |
|---------|---|
| b.out 1 | Channel B trigger monitor |
| b.out 2 | Channel B input prescaled (frequency-divided) by 100 |
| b.out 3 | Channel B input prescaled (frequency-divided) by 1000 |
| b.out 4 | 60 Hz square wave |
| b.out 5 | Alternating periods of 100 μ s and 66.7 μ s |
| b.out 6 | Approximately 600 ns negative-going pulse at 60 Hz rate superimposed on b.out 5 |
| b.out 7 | 18 kHz modulated signal |
| b.out 8 | Pseudo-random period variations with two misplaced pulses |

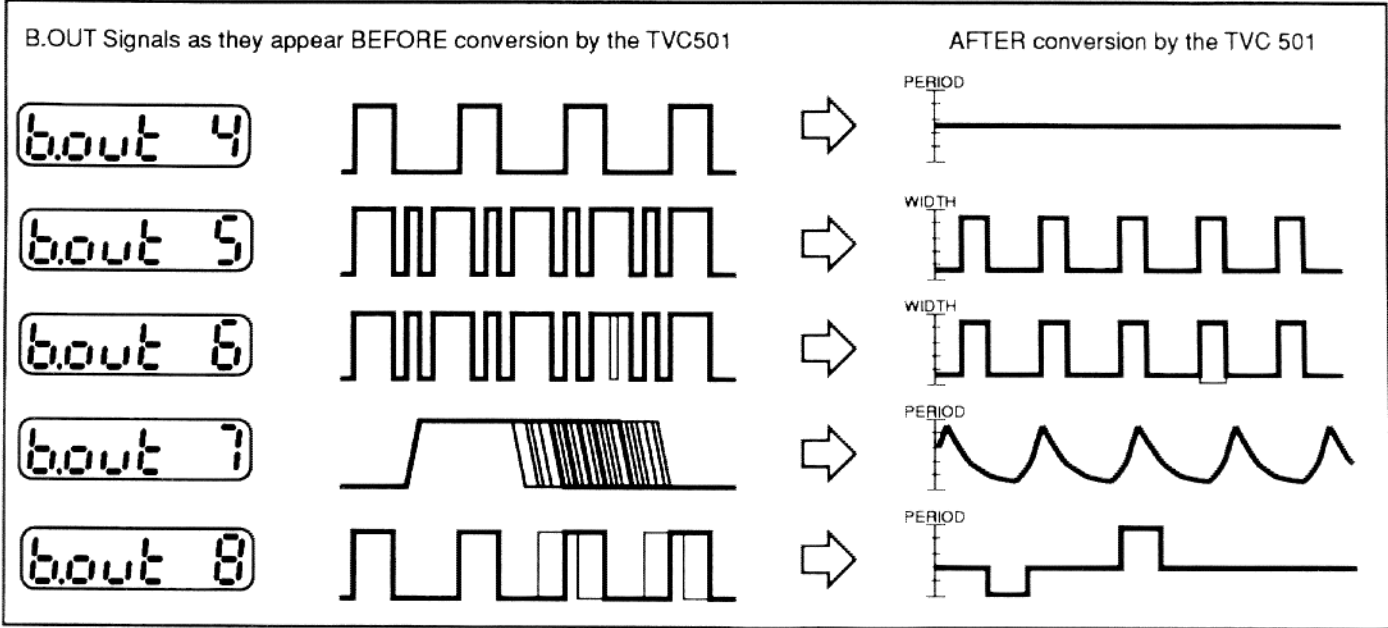


Figure 4-8. The b.out Test Signals. The waveforms on the left show the signals as output from the B OUT jack. The waveforms on the right show the signals after time-to-voltage conversion.

PRESCALING SIGNALS THAT ARE TOO FAST

The TVC 501 can accommodate signals that are too fast for direct measurement by using the built-in digital prescaler available at the B monitor output. Signals input to the **B CHANNEL** can be prescaled (frequency-divided) by 100 or 1000 and output at the **B OUT** connector. The **B OUT** connector can be connected to the **A CHANNEL** input for period measurements. Figure 4-9 illustrates the signal prescaling. The signal at the top is a 10-MHz signal connected to the **B CHANNEL** input. The b.out 2 output is the **B CHANNEL** input prescaled by 100 and the b.out 3 output is the **B CHANNEL** input prescaled by 1000.

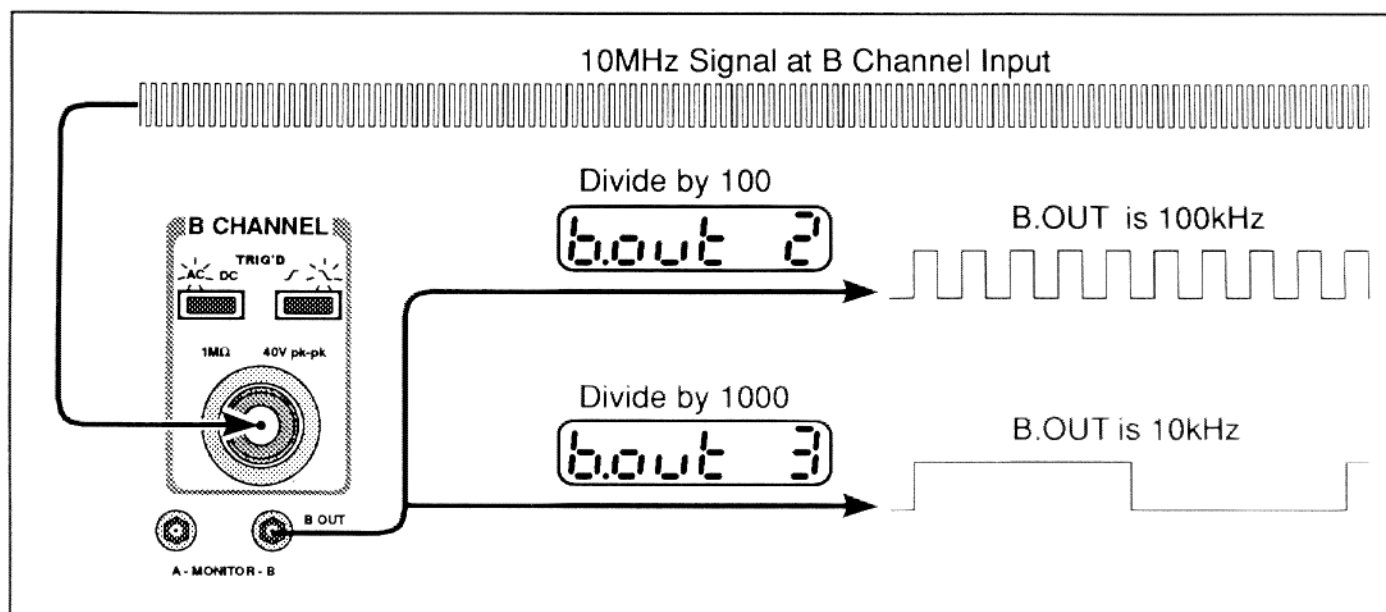


Figure 4-9. Prescaled B CHANNEL signals. The TVC 501 can digitally prescale (divide the frequency of) the B CHANNEL input signal by a factor of 100 or 1000.

INSTRUCTIONAL EXERCISES

The exercises in this section provide step-by-step instructions to familiarize you with TVC 501 operation. Four exercises are provided:

- establishing a trigger level
- establishing time offset and resolution
- interpreting pulse modulation
- detecting a timing anomaly (glitch)

The first two exercises describe how to perform basic operations necessary for measuring any signal. The second two exercises show how to make and analyze measurements. If you are already familiar with basic TVC 501 operation and want to practice measuring and analyzing signals, you may want to go to Exercises 3 and 4.

Required Equipment and Connections

The following equipment is required for these exercises:

- TVC 501 and associated cables
- TM 500 or TM 5000 Series Power Module
- oscilloscope

To prepare the equipment for operation, perform these steps:

1. Install the TVC 501 into the Power Module.
2. Turn on the power to the Power Module and Oscilloscope. The TVC 501 should display AdJUST.
3. Connect the TVC 501 **OUTPUT** to the channel 1 input of the oscilloscope.

4. Calibrate the oscilloscope to the TVC 501 output using the adjust pattern (for more information about the adjust pattern, see Chapter 2: Getting Started). Use the vertical settings specified in Table 4-2 for your oscilloscope.

Table 4-2
Oscilloscope Calibration Settings

| Input Impedance | Vertical Sensitivity |
|-----------------|----------------------|
| 1 MΩ | 100 mV/div |
| 50 Ω | 50 mV/div |

Exercise 1: Establishing a Trigger Level.

The following exercise illustrates how to manually and automatically set the trigger level using an instructional signal provided by the TVC 501 called b.out 5. Using the TVC 501 and an oscilloscope, perform the following steps to establish a trigger level.

1. Repeatedly press **MEASURE** until the **WIDTH** indicator lights.
 2. Connect the monitor cable from **B OUT** to the **A CHANNEL** input of the TVC 501.
 3. Connect another monitor cable from the **A MONITOR** output to the channel 2 input of the oscilloscope.
 4. Repeatedly press **MODIFY** until **b.out 5** shows on the display.
 5. Turn the knob until the display reads **b.out 5**.
 6. Display only channel 2 on the oscilloscope. You can now observe the **A MONITOR** output.
 7. To establish a trigger level, repeatedly press **MODIFY** until **A** appears at the left side of the display and
- then press **AUTO**. The trigger level should be approximately 0.25 V and the **TRIG'D** indicator should be on.
8. Set channel 2 of the oscilloscope to 200 mV/div vertical sensitivity and set the horizontal sweep to 50 μ s/div. Your oscilloscope should display a signal that looks like the one on the center right side of Figure 4-10.
 9. Using the TVC 501 knob, slowly increase the trigger value until the TVC 501 displays a value of about 0.5 or more. A straight line should appear on the oscilloscope as shown in the upper right corner of Figure 4-10. Note that the **TRIG'D** indicator is off.
 10. Using the TVC 501 knob, slowly decrease the trigger value until the TVC 501 displays a value of about -0.02 or less. A straight line should appear on the oscilloscope as shown in the lower right corner of Figure 4-10. Note that the **TRIG'D** indicator is off.
 11. Press **AUTO** to restore triggering. The **TRIG'D** indicator should be on and you should see a signal that looks like the one on the right in Figure 4-10 on your oscilloscope.

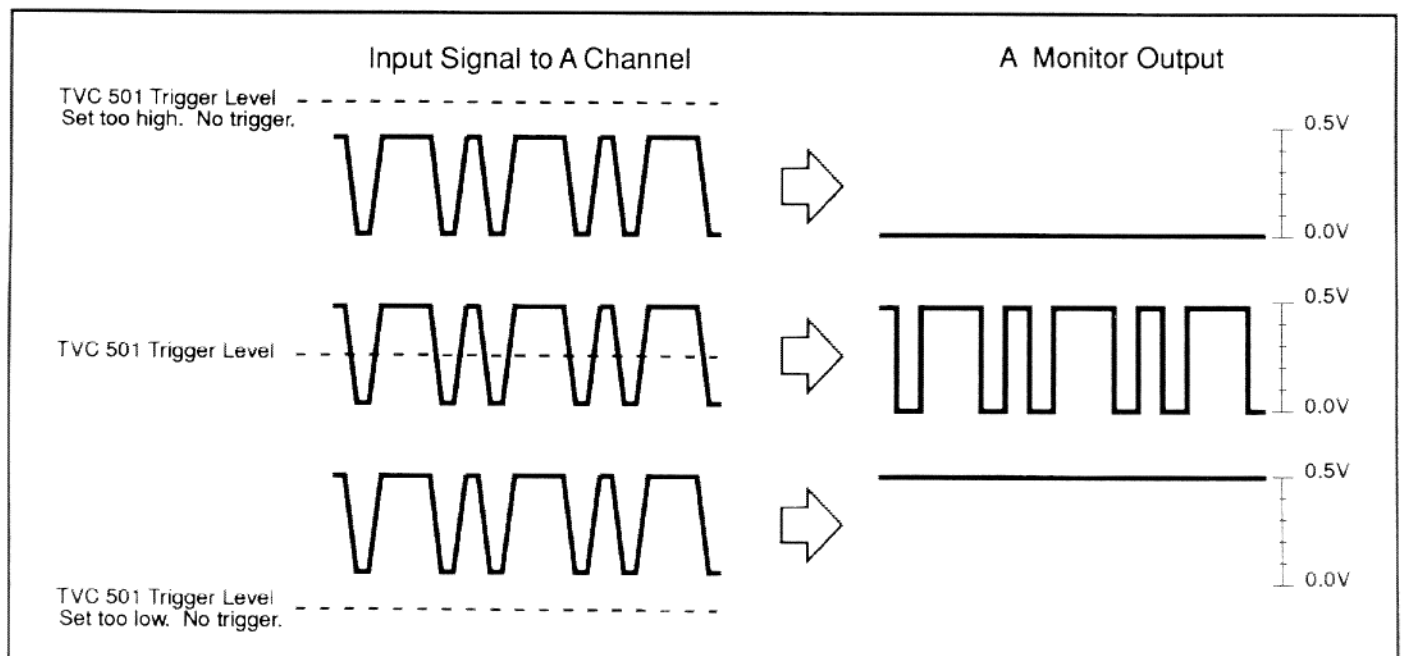
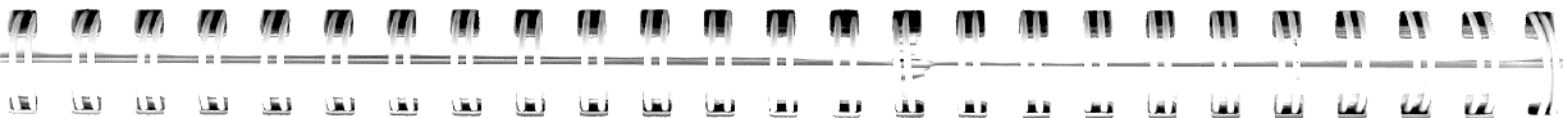


Figure 4-10. The A Monitor Output Signal. This signal can be used to see how the TVC 501 interprets the input signal based on the trigger level and slope controls.

Exercise 2: Establishing Time Offset and Resolution.

The following exercise illustrates how to manually and automatically set the offset and resolution per division using an instructional signal called b.out 5. Using the TVC 501 and an oscilloscope, perform the following steps to set an offset and resolution value.

1. Repeatedly press **MEASURE** until the **WIDTH** indicator lights.
2. Connect the monitor cable from **B OUT** to the **A CHANNEL** input of the TVC 501.
3. Repeatedly press **MODIFY** until **b.out** shows on the display.
4. Turn the knob until the display reads **b.out 5**.
5. To establish a trigger level, repeatedly press **MODIFY** until **A** appears at the left side of the display and then press **AUTO**. The trigger level should be approximately 0.25 V and the **TRIG'D** indicator should be on.
6. Press **MODIFY** to display the offset value. A scaling indicator at the right of the six-digit display will light, showing the time units (**s**, **ms**, or **μs**).
7. To automatically establish an offset and resolution value, press **AUTO**.
8. Set the horizontal sweep of the oscilloscope to 100 μs/div. You should see a signal that looks like the oscilloscope display in Figure 4-11.
9. Using the TVC 501 knob and **DIGIT** button, vary the offset value and note how it shifts the waveform up or down.
10. Using the **RESOLUTION PER DIV** buttons, vary the resolution and note how it expands or contracts the waveform around the offset value (center graticule line).

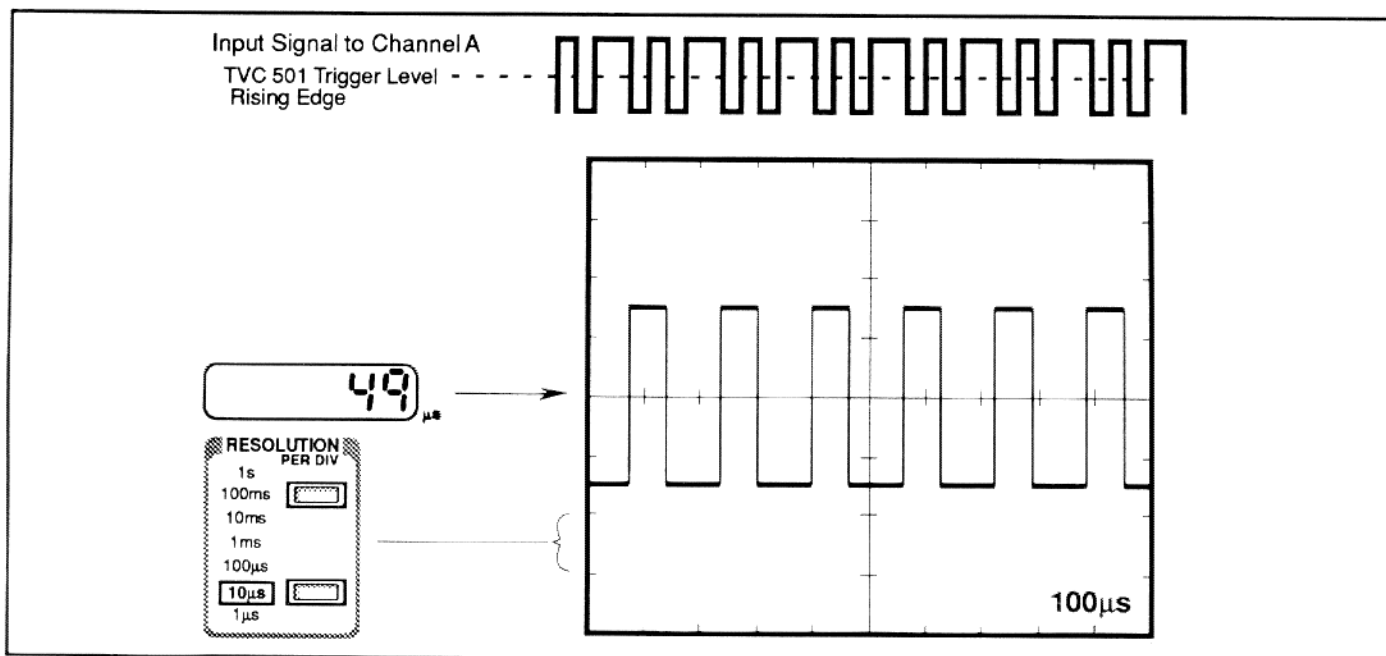


Figure 4-11. Width vs. Time Display. The oscilloscope shows the width vs. time display for the instructional signal called b.out 5.

Exercise 3: Interpreting Pulse Modulation.

The TVC 501 can help you make sense of a signal that is difficult to interpret. In this exercise, use the TVC 501 instructional signal called b.out 7. Using the TVC 501 and an oscilloscope, perform the following steps to analyze the signal.

1. Repeatedly press **MEASURE** until the **PERIOD** indicator is on.
2. Repeatedly press **MODIFY** until **b.out** appears on the display.
3. Turn the knob until **b.out 7** appears on the display.
4. To observe the b.out 7 signal, connect the **B MONITOR** output to the channel 2 input of the oscilloscope and display the waveform. Set the oscilloscope time base to 10 μ s per division. The resulting waveform should look like the one in Figure 4-12. Notice how the falling edge of the pulse is blurred. It is difficult to analyze the pulse sequence. The next steps will help show what the

signal is doing by performing time-to-voltage conversions.

5. Move the **B MONITOR** cable from the oscilloscope input to the **A CHANNEL** input of the TVC 501.
6. To establish a trigger level, repeatedly press **MODIFY** until **A** appears at the left side of the display and then press **AUTO**. The trigger level should be approximately 0.24 V and the **TRIG'D** indicator should be on.
7. Repeatedly press **MODIFY** to display the offset value. A scaling indicator at the right of the six-digit display will light, showing the time units (**s**, **ms**, or **μ s**).

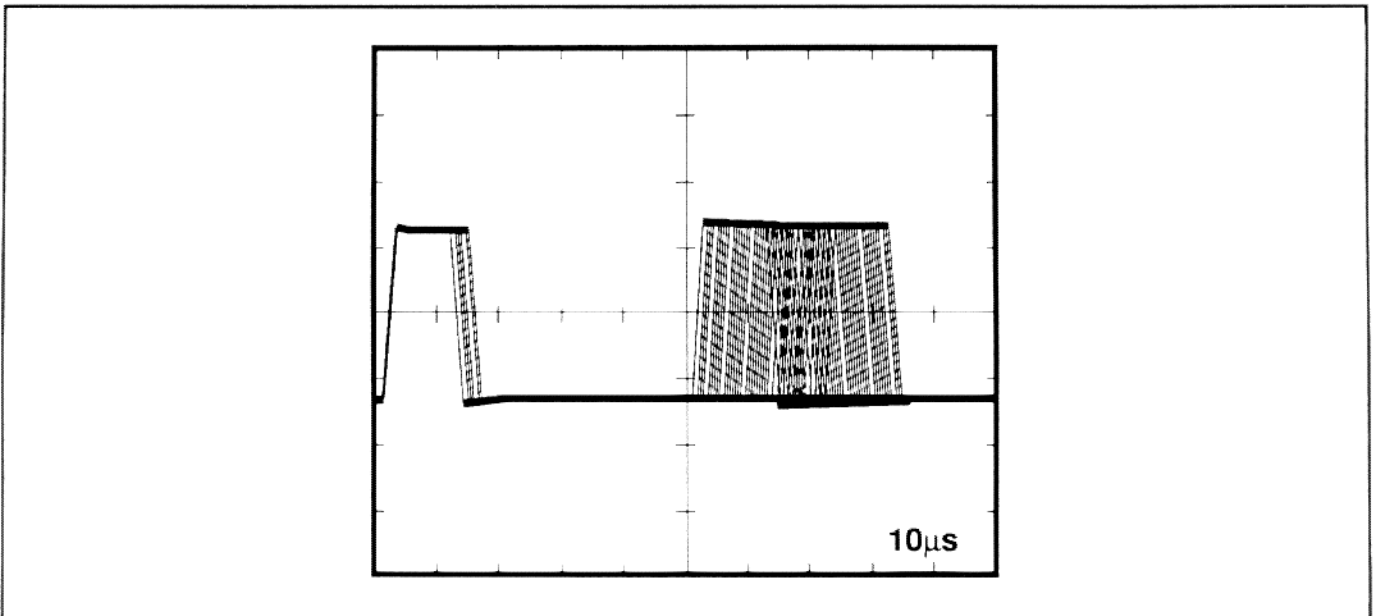


Figure 4-12. A Time-Modulated Signal. The conventional oscilloscope display lends no clue as to what the signal is doing.

8. To automatically establish an offset and resolution value, press **AUTO**. The offset should be about $60\ \mu\text{s}$ and the resolution per div should be about $10\ \mu\text{s}$ (see the TVC 501 readout in Figure 4-13).
9. Set the horizontal time base of the oscilloscope to $5\ \text{ms}/\text{div}$. The resulting waveform should look like the oscilloscope display in Figure 4-13.

The TVC 501 produces a regular pattern showing the true nature of the signal. The period variation is about 2.5 divisions or $25\ \mu\text{s}$ (2.5 divisions multiplied by $10\ \mu\text{s}/\text{division}$).

For a closer examination, you can "zoom in" on any portion of the TVC 501 output.

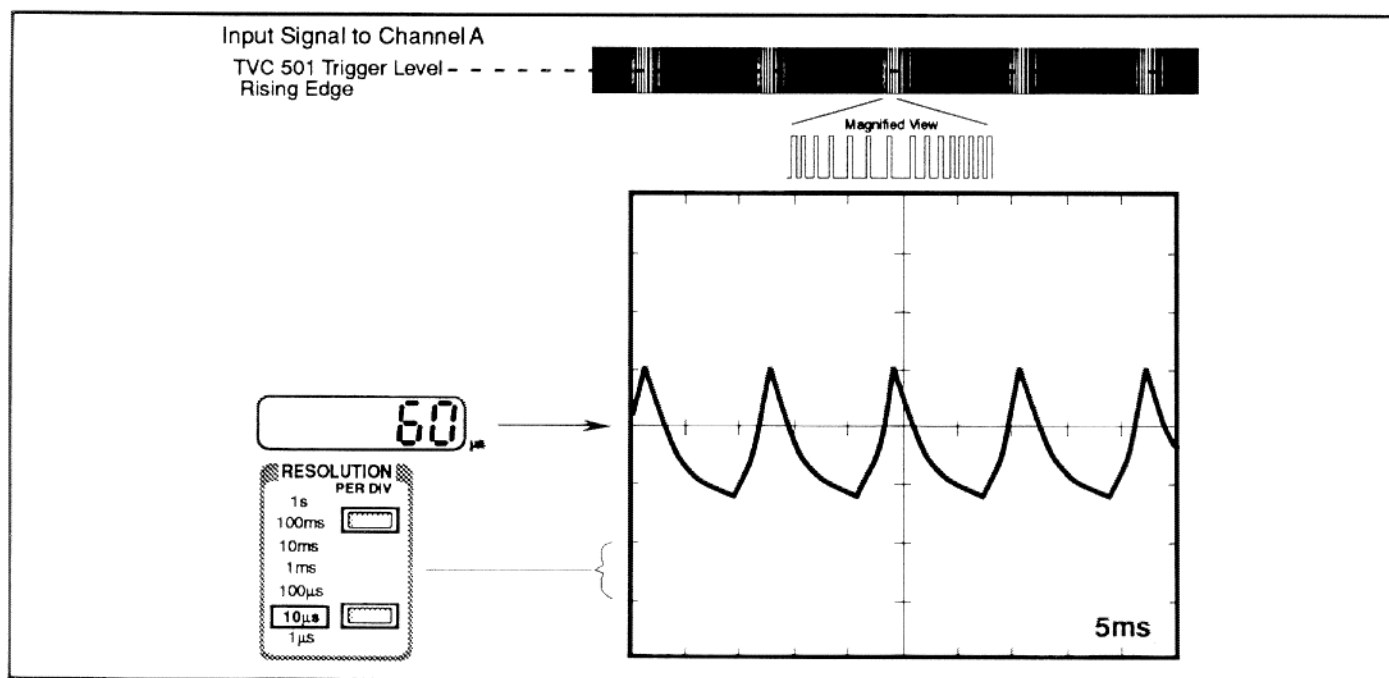


Figure 4-13. Period-to-Voltage Converted Pulses. The true nature of the modulated signal is revealed.

10. Change the TVC 501 offset so that the minimum level of the period-vs-time waveform is at center screen (see Figure 4-14). The offset value should be about 51 μ s.
11. Change the TVC 501 resolution per division to 1 μ s. You should see a waveform similar to the one in Figure 4-15. Notice that the TVC 501 output signal has expanded vertically and that much of the information is off the screen.

You do not need to show the entire signal on the oscilloscope screen. By changing the offset value and increasing the resolution, you can zoom in on either the high or the low portion of the signal. Because an increase in the resolution shows a smaller view of the waveform, the entire signal may not be visible on the oscilloscope screen. When this happens, the **MEASUREMENT OUT OF RANGE** indicator will light. Don't panic! This is merely a reminder that there is additional information beyond what you are presently viewing.

By changing the TVC 501 offset to align a portion of the TVC 501 output waveform with the center oscilloscope graticule line, you can read the time value directly from the TVC 501 digital readout.

12. Using another monitor cable, connect the TVC 501 **A MONITOR** output to the channel 2 input of the oscilloscope and change the oscilloscope sweep speed to 200 μ s/div. Display channel 2 but keep the oscilloscope triggered on channel 1.

Notice how the measured signal correlates to the TVC 501 output waveform on channel 1 of the oscilloscope. As the measured periods get longer, the TVC 501 output grows more positive.

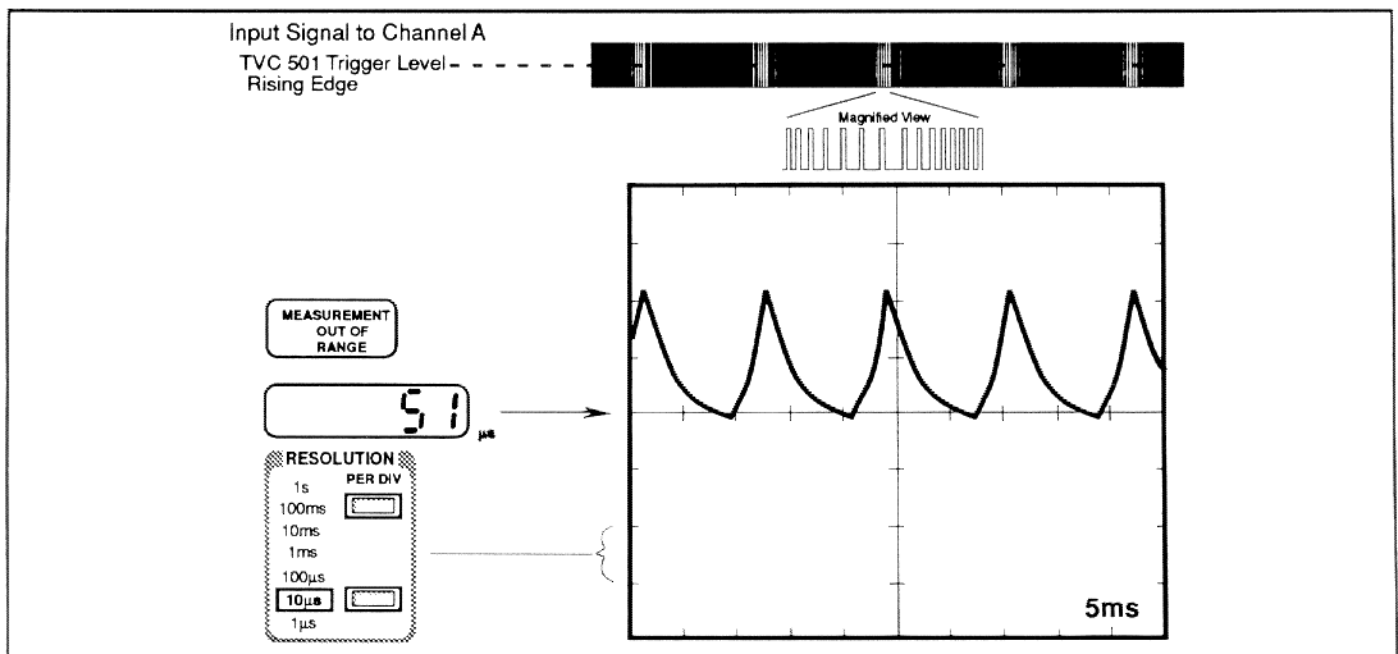


Figure 4-14. Preparing to Zoom in on a Signal. Position the TVC 501 Output by using the OFFSET control to put the area of interest at center screen.

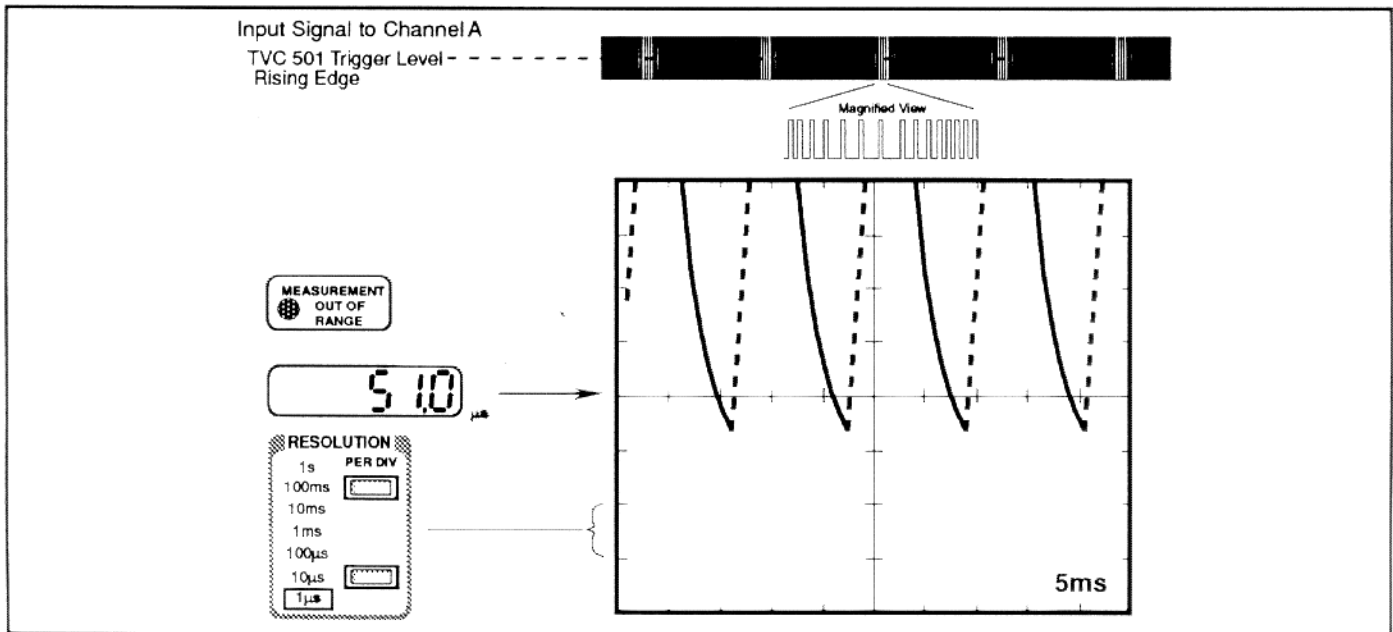


Figure 4-15. Zooming in on a Signal for Detail. Notice the TVC 501 OFFSET shows an extra digit. The lighted **MEASUREMENT OUT OF RANGE** indicator means that there is information beyond the oscilloscope screen.

Exercise 4: Detecting a Timing Anomaly (Glitch).

When viewing a signal with an oscilloscope, you may experience what appears to be a triggering problem. Sometimes an occasional anomaly, such as an additional pulse, can be the culprit.

An experienced oscilloscope user will be able to adjust trigger level, slope, and holdoff and conclude that indeed there is an additional pulse (glitch); however, the oscilloscope leaves many questions unanswered.

- How often does the glitch occur?
- Is the glitch periodic or random?
- Does the glitch correlate to other signals?

The TVC 501 allows you to answer these questions.

This exercise uses the TVC 501 instructional signal called b.out 6 to illustrate how to analyze glitches. This signal has an occasional, negative-going pulse. This exercise will show how to detect it and determine if it is periodic or random.

1. Repeatedly press TVC 501 **MEASURE** until the **WIDTH** indicator is on.
2. Repeatedly press **MODIFY** until **b.out** appears in the digital display.
3. Turn the TVC 501 knob until **b.out 6** appears in the display.
4. Connect the **B MONITOR** output to the **A CHANNEL** input.
5. To establish a trigger level, repeatedly press **MODIFY** until **A** appears at the left side of the display and then press **AUTO**. The trigger level should be approximately 0.25 V and the **TRIG'D** indicator should be on.
6. Connect the **A MONITOR** output to channel 2 of the oscilloscope and display the waveform.
7. On the TVC 501 **A CHANNEL** input, select falling edge and notice that the channel A monitor waveform inverts. This inverted signal is what will be measured. Turn off channel 2 of the oscilloscope.

8. Repeatedly press the **MODIFY** button until the offset value appears in the digital readout. A scaling indicator (**s**, **ms**, **μs**) to the right of the readout will light.
9. Press **AUTO** to establish a time offset and resolution value. The offset value should be approximately 33 μs and the resolution should be 10 μs.
10. Set the time per division of the oscilloscope to 50 μs and set the oscilloscope to trigger on the falling edge (negative slope).
11. Change the TVC 501 offset to 16 μs. You should see a waveform similar to that in Figure 4-16. The vertical step displayed represents the pulse-width difference between the narrow pulse and the "normal" pulses.
12. Change the time base of the oscilloscope to 5 ms/division and increase the oscilloscope screen intensity to see that the signal is repetitive. The time between glitches should be approximately 16.6 ms.

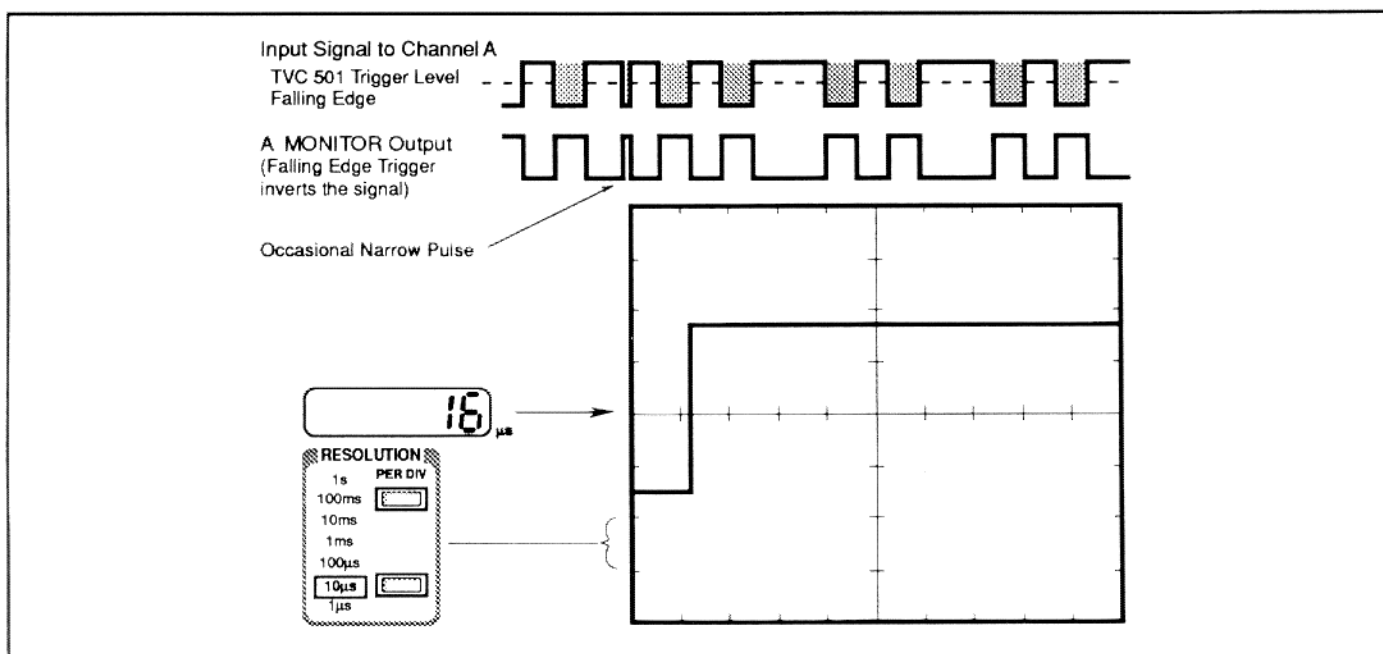


Figure 4-16. Detecting a Timing Anomaly. An occasional narrow pulse is measured and detected by triggering the oscilloscope on the shorter time.

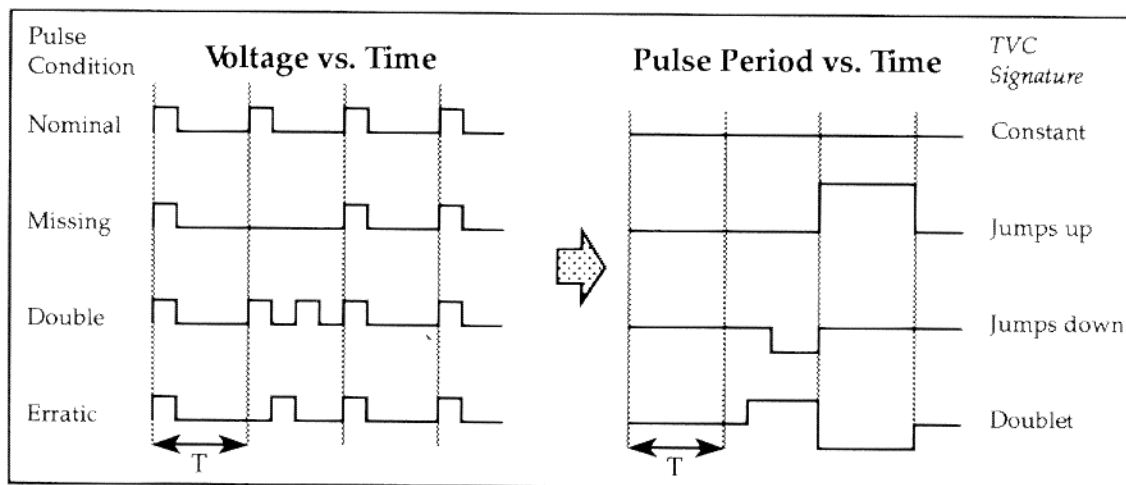


Figure 5-1. TVC 501 signatures produced by pulse modulation errors.

Chapter 5: Applications

This chapter describes several ways to use your TVC 501 for time-interval measurements. The following examples discussed include:

- measuring pulse modulation and timing violations
- detecting comparator switching errors
- measuring oscillator start-up stability
- comparing a signal to a reference

MEASURING PULSE MODULATION AND TIMING VIOLATIONS

Modulators used in switched-mode power converters have a characteristic mode of operation. The control pulse width may be fixed or modulated. The period of the control pulse may be fixed or modulated. The pulses may need to start or stop at specific switching interval locations. Time-to-voltage conversion detect faulty modulator operation.

Figure 5-1 shows a control pulse that occurs at fixed intervals. The TVC 501 converts this constant period into a constant output voltage, which appears as a straight line on an oscilloscope.

If the modulator misses or adds a pulse, the TVC 501 output jumps accordingly. If the pulse occurs at the wrong time, the TVC 501 generates a doublet waveform, indicating late and early pulse arrivals.

Since the TVC 501 generates real-time voltages proportional to measured time intervals, waveform capture and display can be aligned relative to pulse timing violations. The missing pulse in Figure 5-1 generates a *positive-going* voltage at the TVC 501 output which can trip a *positive-edge* oscilloscope trigger. The double pulse generates a *negative-going* voltage which can trip a *negative-edge* oscilloscope trigger.

The TVC 501 output can be used to count error events also. Connect a digital counter-timer to the TVC 501 output to total the number of pulse faults or measure the frequency of double pulse violations.

DETECTING COMPARATOR SWITCHING ERRORS

High-speed comparators can be subject to output oscillations. The TVC 501 easily reveals this problem.

Figure 5-2 shows a typical comparator circuit. A 1-kHz source drives the comparator. The pulse output of the comparator is connected to the **A CHANNEL** input of the TVC 501. You can use either width vs. time or period vs. time measurements for these tests.

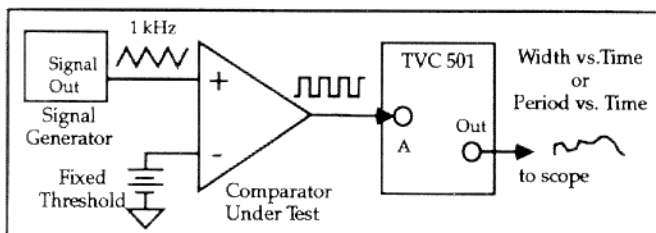


Figure 5-2. Typical Comparator Circuit.

The oscillations appear on the pulse edges. To see them you would need to magnify the signal as shown in Figure 5-3.

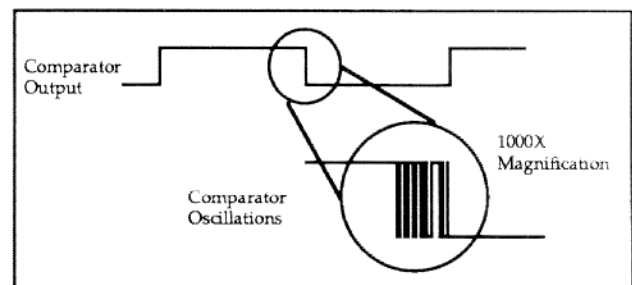


Figure 5-3. Magnification of Pulse Oscillations.

To view oscillations, a typical oscilloscope user might flip back and forth between horizontal time base settings. For example, to view the overall 1-kHz comparator output signal, you might use 1 ms/division to view 10 cycles across the screen. To see the oscillations, you might set the timebase to 1 μ s/div; however, the results do not tell you when or how often the oscillations occur.

Figure 5-4 shows the TVC 501 width vs. time measurements of the example comparator circuit. The normal pulse width of 500 μ s nearly drops to zero when oscillations occur. Oscillations occur on the second falling edge and the seventh rising edge of the displayed pulse train. With the TVC 501, you can correlate the data in real time to see which pulses have problems.

Another feature of the TVC 501 is the ability to trigger your measurement system on test violations. In this example, the oscilloscope was set to trigger when the TVC 501 output fell below 500 μ s. The oscilloscope triggered whenever the comparator oscillated on a transition. You could also connect TVC 501 output to a counter to record the number of violations in a given time period.

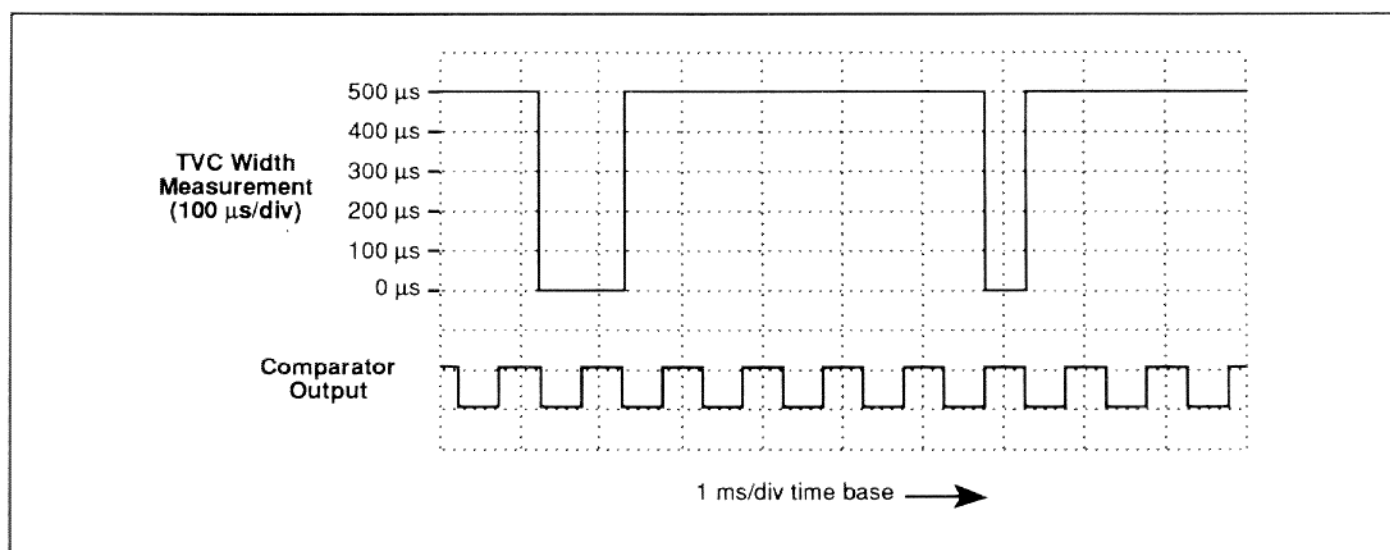


Figure 5-4. Comparator Oscillations Detected by the TVC 501.

MEASURING OSCILLATOR START-UP STABILITY

This example uses the TVC 501 built-in digital prescaler to measure period variations on signals with repetition rates beyond the uninterrupted measurement rate of the TVC 501. The oscillator used in this example is a 74HCT14 Schmitt-trigger inverter gate with the output fed back to the input, resulting in a steady state oscillation with a period of approximately 17 ns (about 60 MHz). The power-up condition was examined.

The signal is prescaled (frequency-divided) by the TVC 501 +100 prescaler (b.out 2) so that one pulse comes out of the **B MONITOR** output connector for every 100 pulses input to the **B CHANNEL** input connector (see Figure 5-5). The prescaled signal is then measured using the TVC 501 period measurement.

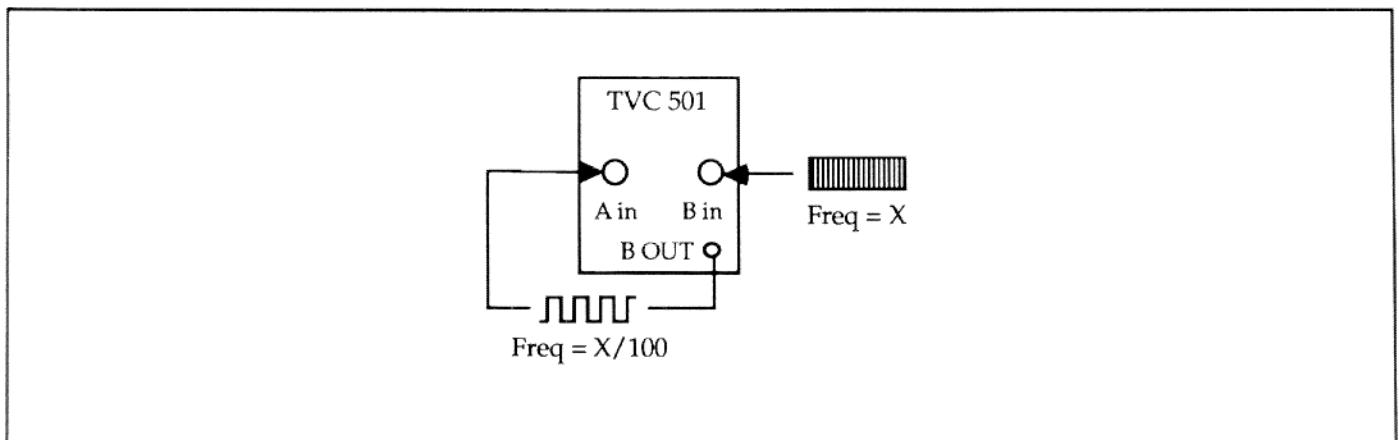


Figure 5-5. TVC 501 Prescaler Divides the Channel B Input Pulse Rate by 100.

Figure 5-6 shows the test results of the period measurement at power-up. The top trace is the TVC 501 output showing the oscillator settling into a period of approximately 17 ns. The beginning of the trace is off the top of the screen because the period is infinite prior to power-up. The middle trace is the +5V power supply voltage while the bottom trace is the prescaled output signal.

The traces show that the oscillator started at about three volts and tracked the +5V line for approximately 300 μ s right into the final period. The period is clearly dependent on the supply voltage.

Since the TVC 501 measured a prescaled value, the scale factors were adjusted. The prescaler generates a signal with a period of about 1.7 μ sec (100 times 17 nsec), so the TVC 501 will center the result at 1.7 μ sec. Likewise, the TVC 501 resolution was set to 1 μ sec/division but this should be interpreted as 10 nsec/division since it represents deviations from 100 cycles instead of one. Prescaling removes the ability to measure cycle-to-cycle time-interval variations. However, prescaling is still appropriate for viewing timing dynamics that occur over hundreds or thousands of cycles of the direct signal.

For example, the 74HCT14 oscillator started up in about 300 μ s as shown in Figure 5-6. The period vs. time curve shows the relevant settling characteristics by measuring approximately 180 prescaled cycles instead of each of the approximate 18,000 actual cycles.

The TVC 501 internal prescaler will operate to ≥ 100 MHz. A Tektronix DP 501 digital prescaler module can be used with the TVC 501 to externally extend the prescaling range to 1.3 GHz.

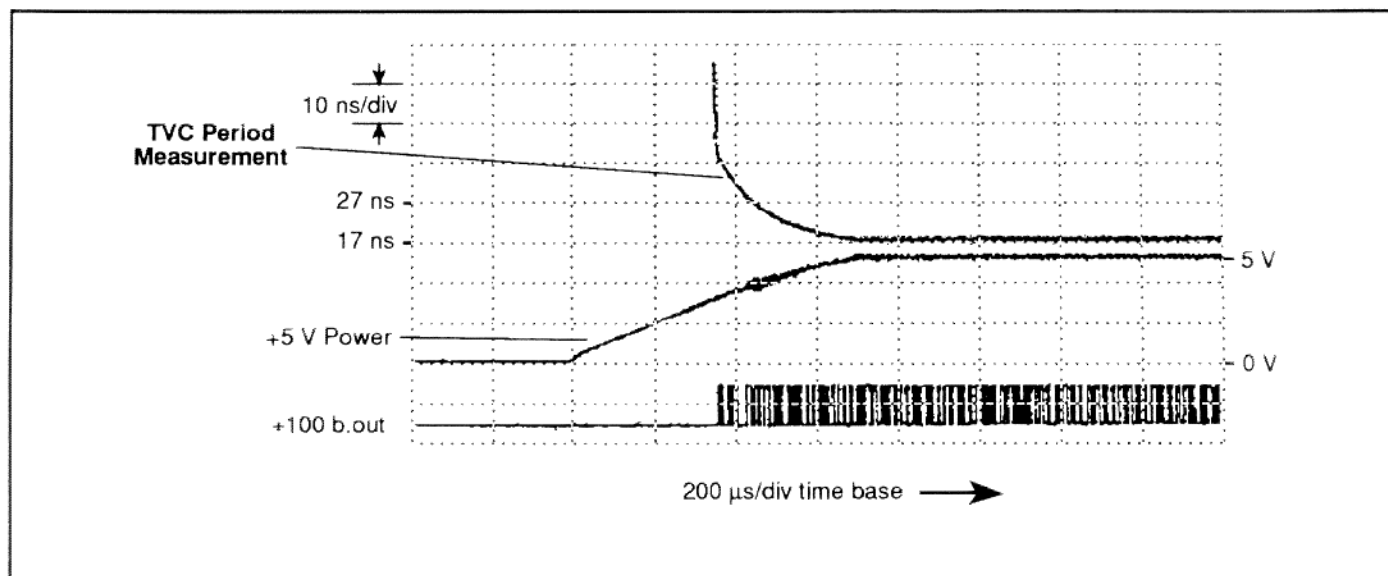


Figure 5-6. Start-up Characteristics of a 60 MHz Inverting Gate Oscillator. The TVC 501 prescaler was used to make this measurement.

COMPARING A SIGNAL TO A REFERENCE

You can use the TVC 501 delay vs. time measurement with the **A CHANNEL** and **B CHANNEL** inputs to make continuous timing measurements between two frequency sources. Figure 5-7 illustrates how the TVC 501 was connected to measure the AC line frequency against a stable 60 Hz reference clock.

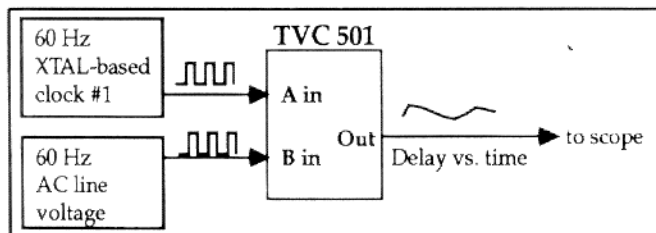


Figure 5-7. TVC 501 Measurement Between Two "Stable" 60 Hz Clocks.

Figure 5-8 shows the resulting TVC 501 output over a 15 minute interval. The trace began with a negative slope,

indicating that the line frequency (B input) started out slightly faster than the reference clock (A input). (The delay from A to B was decreasing.) The delay stabilized somewhat, then the line frequency drifted to a slightly slower rate, as evidenced by the positive slope of the display (the delay from A to B was increasing).

Notice that the delay never exceeds 16 ms. That's because 16 ms is the period of 60 Hz. You can use the rollover period of the TVC 501 output waveform to calculate the frequency difference between the two signals. At the end of the waveform in this example, the line frequency lagged the reference clock by approximately 0.007 Hz (the rollover period was about 140 seconds).

The delay function of the TVC 501 can be used for many comparison applications, including phased-locked loop delay. All measurements can be correlated in real time with other relevant signals.

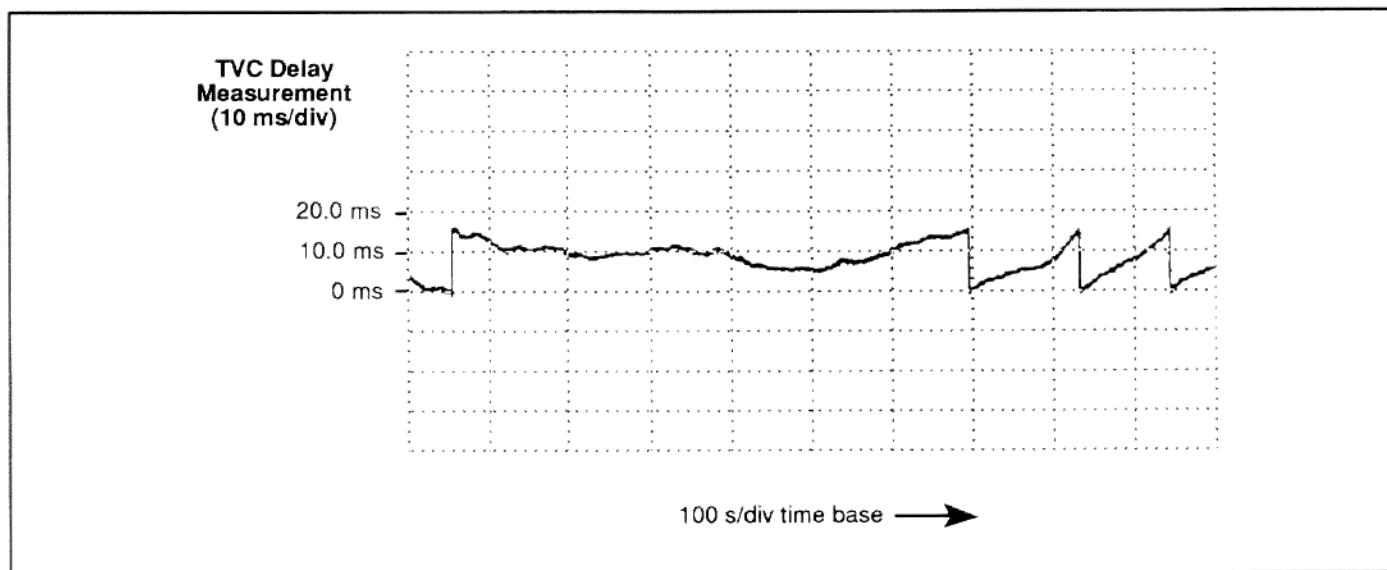
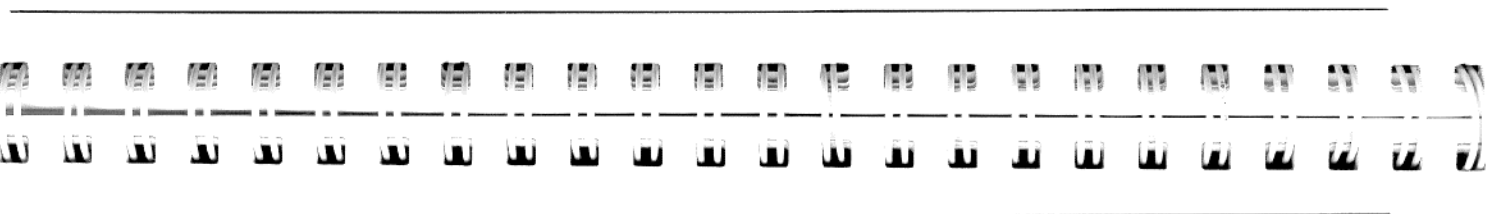


Figure 5-8. Comparing Delay Between a Reference Clock and Line Frequency.

Appendix A: Specifications

Appendix A contains tables that list TVC 501 performance specifications. These specifications are only valid for an instrument calibrated at an ambient temperature between +20° C and +25° C and operated within the environmental specifications listed in Table A-2. The instrument should have a minimum warm-up period of 20 minutes.

Table A-1
Electrical Specifications

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|--|---|
| Total Measurement Accuracy (500ns after the event into DMM. Time Measured ≥ Res. per Div. + 5) | Refer to Figure A-1 and accompanying text for specification requirement. |
| Output Rise Time (full scale) 50-Ω load 1-MΩ load | 75 ns to 200 ns 150 ns to 350 ns |
| A and B Inputs: Impedance | 1 MΩ shunted by ≤50 pF |
| Level Range | ±1.25 X probe attenuation factor |
| Dynamic Range | ±2 V at the BNC connector |

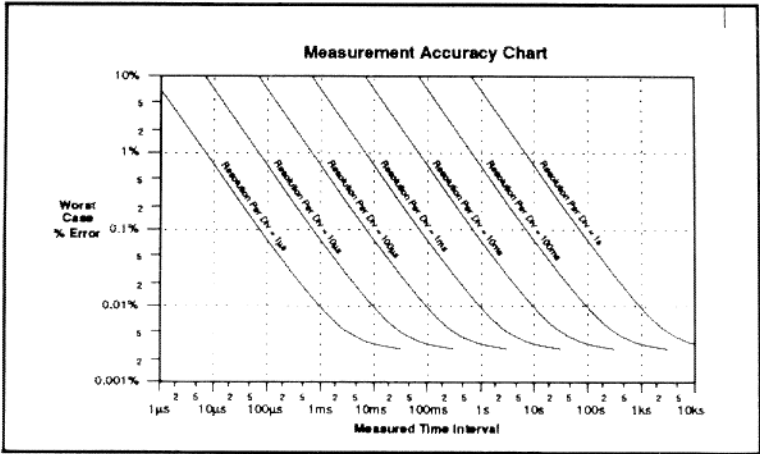


Figure A-1. Worst Case Error (Total Measurement Error) as it relates to the measured time interval and the Resolution Per Division.

Figure A-1 assumes that there is no trigger jitter. It is a graphic representation for:

Total Measurement Error (in %) = ± { [7 X Resolution per Div] / Time Measured } + 0.0025 }

For example, if the measured period is 1 ms (freq = 1 kHz) and the Resolution Per Division is 1 μs, then the error is ±0.0095%.

Table A-1
Electrical Specifications (continued)

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|--------------------------------|--|
| A and B Inputs (cont.): | |
| Level Error | $\pm[5\% \text{ of displayed value} + (20 \text{ mV} \times \text{probe attenuation factor})]$ |
| Probe Scaling | Recognizes 1X, 2X, 5X, 10X, 20X, 50X, 100X, 200X, 500X, and 1000X resistor-encoded probes |
| Trigger Sensitivity | 100 mV p-p at BNC connector |
| AC Coupling | Blocks DC components and significantly attenuates below 2 Hz |
| Measurable Pulse | $\geq 10 \text{ ns}$ (250 mVp-p) |
| Indicator (TRIG'D LED) | $\geq 10 \text{ ns}$ (250 mVp-p) |
| Auto Trigger: | |
| Minimum Reliable Frequency | 20 Hz |
| Minimum Reliable Pulse Width | 50 ns |

Table A-1
Electrical Specifications (continued)

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|---------------------------------|--------------------------------|
| Auto Offset/Resolution: | |
| Minimum Reliable Frequency | 20 Hz |
| A and B Monitor Outputs: | |
| High Level | |
| 50 Ω load | 250 mV ± 75 mV |
| 1 M Ω load | 450 mV ± 100 mV |
| Low Level | |
| 50 Ω load | 0V to 75 mV |
| 1 M Ω load | 0V to 100 mV |
| Maximum Frequency | 10 MHz |
| Minimum Pulse Width | Responds to 50 ns input signal |

Table A-1
Electrical Specifications (continued)

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|--------------------------|---|
| Range: | |
| Output | $\pm 4.2 \text{ X}$ resolution per division |
| Offset | 0 to 30,000 X resolution per division |
| Timing Stability | $\pm 25 \text{ ppm}$ (0.0025%) |
| Maximum Measurement Rate | 2.5 million measurements per second |
| Power Dissipation | Approximately 10 Watts |

Table A-2
Environmental Specifications

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|------------------------|---|
| Temperature | |
| Operating | 0° C to +50° C |
| Non-Operating | -55° C to +75° C |
| Humidity | Meets MIL-T28800D Type III, Class 5 |
| Altitude | Meets MIL-T28800D Type III, Class 5 |
| Vibration | Meets MIL-T28800D Type III, Class 5 |
| Shock | Meets MIL-T28800D Type III, Class 5 |
| Bench Handling | Meets MIL-T28800D Type III, Class 5 |
| Packaging | Passed National Safe Transit Association's pre-shipment test procedures |
| Electrostatic Immunity | 20 kV maximum |

Table A-2
Environmental Specifications (continued)

| CHARACTERISTICS | PERFORMANCE REQUIREMENT |
|-------------------|---|
| EMI Compatibility | Meets FCC regulations, Part 15, Subpart J, Class A. Meets VDE 0871/6.78, Class B |
| Safety | Conforms to UL 1244 |

Table A-3
Physical Specifications.

| CHARACTERISTICS | DESCRIPTION |
|-----------------|------------------|
| Weight | 0.8 kg (1.8 lbs) |

Appendix B: Diagnostic Summary

Table B-1 lists the diagnostic error codes possible with the TVC 501, defines the codes, and provides a recommended action for each. If the action states a specific function needs to be repaired, then only that function is defective; the rest of the instrument is still functional. If the action states that instrument repair is necessary, then repairs must be made before measurement accuracy can be restored. Refer to the *TVC 501 Service Manual* (Tektronix Part Number 070-7992-00) for service information.

>>>**Caution** Refer all instrument repairs to qualified service personnel only.

For a list of messages that can be displayed during normal operation, refer to Appendix C: Message Summary.

Table B-1
Diagnostic Code Summary

| Displayed Code | Definition | Action |
|----------------|--|--|
| EPro- | Checksum failure in EPROM | Repair the instrument. |
| HC11 | Microprocessor hardware failure. | Repair the instrument. |
| P45678 | All b.out signals passed | Continue to use instrument |
| P----- | All b.out signals failed. | Repair the instrument. |
| P-5678 | Instructional signal b.out 4 failed. The unit will function, except for b.out 4. | If you need the b.out 4 signal, repair the instrument. |
| P4-678 | Instructional signal b.out 5 failed. The unit will function, except for b.out 5. | If you need the b.out 5 signal, repair the instrument. |
| P45-78 | Instructional signal b.out 6 failed. The unit will function, except for b.out 6. | If you need the b.out 6 signal, repair the instrument. |
| P456-8 | Instructional signal b.out 7 failed. The unit will function, except for b.out 7. | If you need the b.out 7 signal, repair the instrument. |
| P4567- | Instructional signal b.out 8 failed. The unit will function, except for b.out 8. | If you need the b.out 8 signal, repair the instrument. |

Table B-1
Diagnostic Code Summary (continued)

| Displayed Code | Definition | Action |
|----------------|---|------------------------|
| AdC | Microprocessor A/D converter failed. Probe encoding may not be read properly. | Repair the instrument. |
| HALT | Displayed if a shift register or counter failure occurs | Repair the instrument. |
| SHF xx | Shift register failure. | Repair the instrument. |
| Cntr x | Counter failure. | Repair the instrument. |

Table B-1
Diagnostic Code Summary (continued)

| Displayed Code | Definition | Action |
|----------------|----------------|--|
| Erxxxx | Software error | To restore operation, turn the instrument off and then on again. Verify that the latest firmware version is installed. ¹ If problem persists, then repair the instrument. |
| Efxxx | Software error | To restore operation, turn the instrument off and then on again. Verify that the latest firmware version is installed. ¹ If problem persists, then repair the instrument. |

¹To check the firmware version number, power-up the TVC 501 and watch the display. The number should briefly appear. To determine if your version is the latest available, contact your Tektronix sales representative.

Appendix C: Message Summary

Table C-1 lists and defines the messages that can be displayed by the TVC 501 during normal use. For messages displayed during the power-up diagnostics, refer to the tables in Appendix B: Diagnostic Summary.

Table C-1
Message Summary

| Displayed Message | Definition |
|-------------------|--|
| Abort | An operation that was busy has been interrupted |
| AdJUSt | The adjust signal is active |
| A x | Channel A trigger level (threshold currently set at x volts) |
| b x | Channel B trigger level (threshold currently set at x volts) |
| b.out x | Instructional signal b.out number x is currently selected |
| buSY | The instrument is busy executing a command |
| CAL | Calibration mode. Press MEASURE button to return to normal operation. |
| P45678 | Power-up test of the b.out signals |

Table C-1 (continued)
Message Summary

| Displayed Message | Definition |
|-------------------|--------------------------------------|
| ProbEA | Channel A probe ID button is pressed |
| ProbEb | Channel B probe ID button is pressed |
| rEL1.0 | Firmware release number |
| trY AC | Unable to auto trigger on signal |

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