# INCREASED MEASUREMENT ACCURACY USING A 7D15 UNIVERSAL COUNTER/TIMER IN ANY 7000 SERIES OSCILLOSCOPE

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COMMITTED TO EXCELLENCE
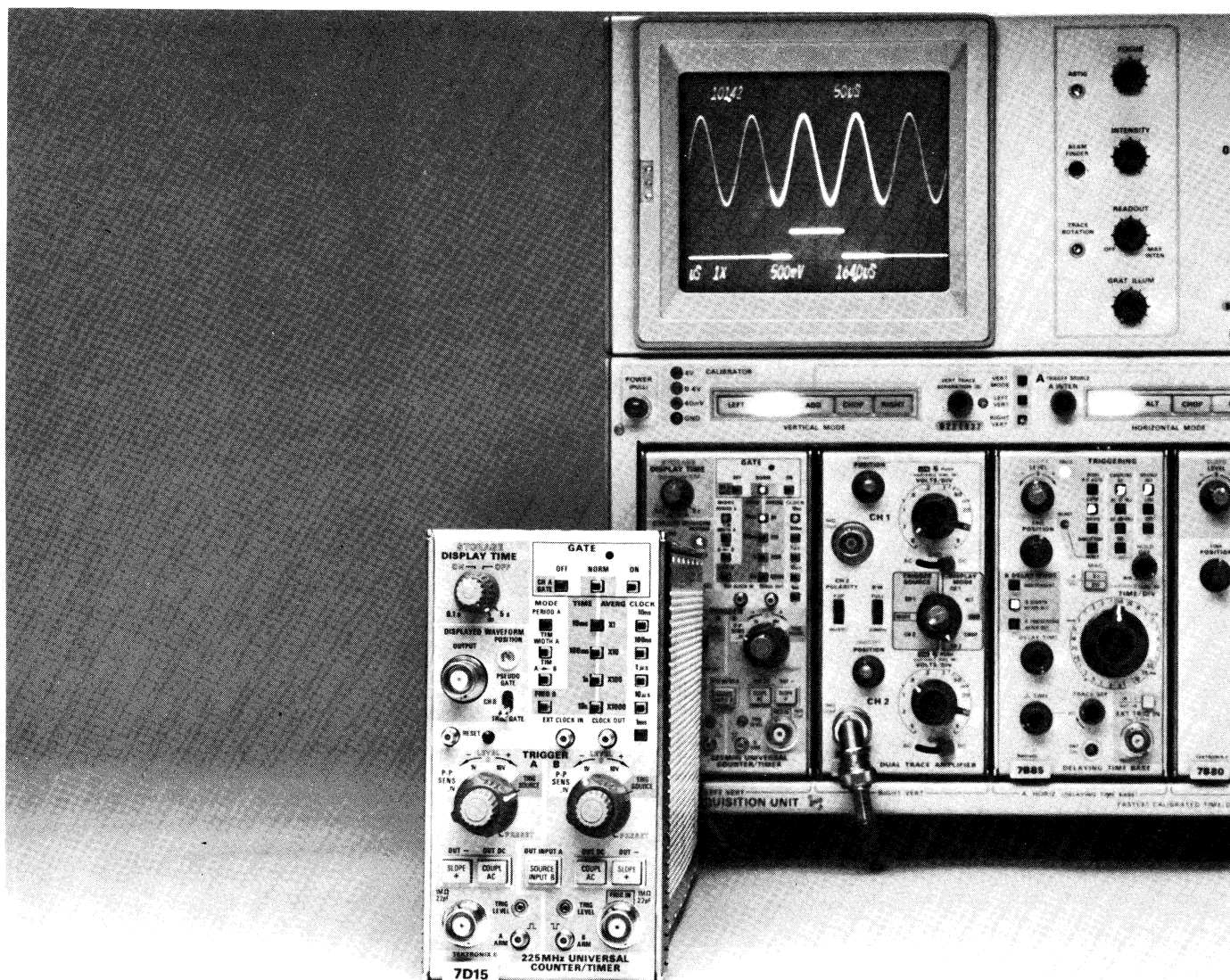
# The 7000 Series

The 7D15 is a universal counter/timer designed for use in all 7000 Series Oscilloscope Mainframes which have CRT readout capability.

It offers all counter/timer measurement capabilities, including time interval, period, frequency, frequency ratio, totalize, and manual stop watch.

The TEK 7000 Series of modular laboratory instruments embodies more state-of-the-art performance features than any other oscilloscope-based measurement system.

This unique line of interdependent CRT mainframes and instrumentation plug-in modules has the versatility, flexibility, and expandability to provide you with a scope package configured to meet your measurement requirements and performance needs, now and for the future.

Over 20 mainframes offer a wide choice of useful bandwidth ranges and a broad selection of additional features. Over 30 plug-in modules are available, including oscilloscope vertical amplifiers, time bases, and a large array of instruments for more specific applications.

Each mainframe and each plug-in reflects the latest technology at its inception, yet each fits into a well-planned niche in this interdependent product line. The result is an array of instrumentation components that can adapt to new developments while protecting your initial investment.
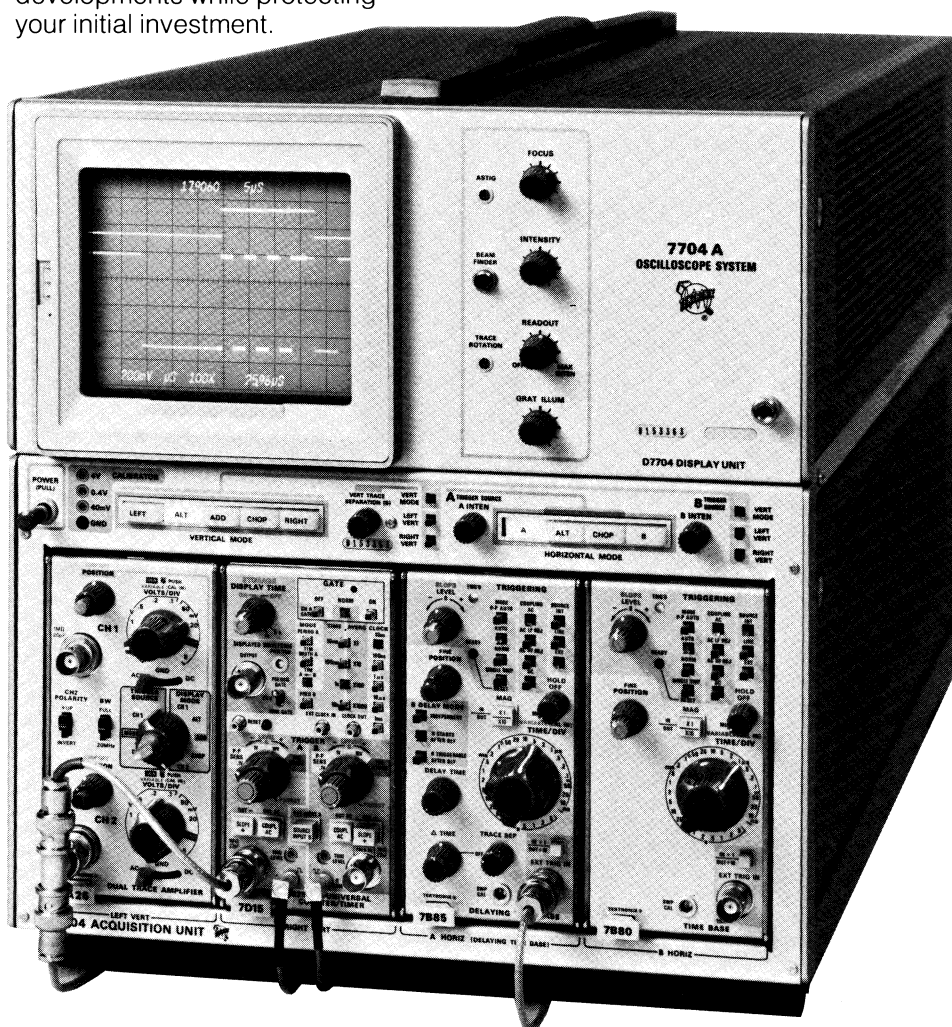
# The 7D15 Universal Counter/Timer
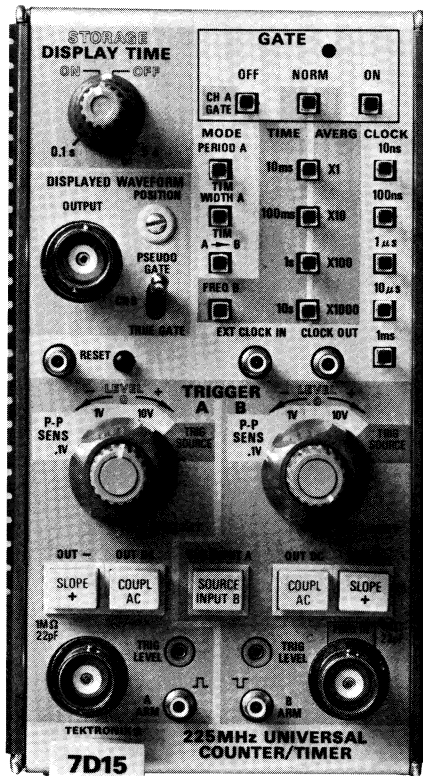


Although the 7D15 works well with any 7000 Series mainframe, the mainframe and plug-ins selected to complement the 7D15 in the applications and operations described in this handbook include the 7704A Oscilloscope System, the 7A26 Dual Trace Amplifier, the 7B80 Delayed Time Base, and the 7B85 Delaying Time Base. The visual display reduces errors, speeds up measurement time, and allows you to make a greater variety of measurements. This combination also makes possible the unique feature of oscilloscope controlled trigger arming, which allows you to visually select specific time intervals for measurement, providing greater resolution and accuracy than could possibly be achieved with either an oscilloscope or a counter alone.

Counter/oscilloscope measurement systems have proved invaluable to engineers and designers in digital electronics, computer electronics, industrial controls, communications, and many other fields.

## Purpose of this Handbook

The purpose of this handbook is to introduce you to the 7D15 Universal Counter/Timer and its many measurement capabilities, and to show you how to make a variety of counting and timing measurements with greater versatility, speed, accuracy, and resolution.

Each application is described in detail, with step-by-step instructions for set-up, interconnections, and control settings, so that you can prove to yourself that the 7D15 Universal Counter/Timer is indeed an exceptionally versatile, accurate, and easy to use measurement tool.

## CONTENTS

# Application and Operation of the 7D15 Universal Counter/Timer

The 7D15 Universal Counter/Timer is a plug-in unit designed to operate in any compartment of a TEK Series oscilloscope mainframe.* It has many unique measurement capabilities that stand-alone counters do not provide. This booklet describes and explains how the 7D15 is operated to perform these unusual counting/timing measurements. It also serves as a user's guide to first-time operation of the unit.

For these descriptions, the 7D15 was operated in the right vertical compartment of a 7704A Oscilloscope so that its unique display capabilities could be used to demonstrate how the guesswork can be taken out of counting and timing measurements.

When used in a horizontal compartment, the 7D15 Displayed Waveform Output is connected to the input of a vertical amplifier so that the Displayed Waveform appears on the CRT.

The basic mainframe set-up remains much the same for the entire sequence of applications, except for some of the time base operations. The user should have some familiarity with 7000 Series Oscilloscope mainframe operation, such as vertical mode switching, triggering, and delayed sweep time base operation.

The mainframe complement of plug-ins and set-up is as follows. This may vary slightly depending on mainframe selection and the complement of plug-ins used.

*A word of caution – the 7704A Oscilloscope and other 7000 Series mainframes can be ordered *without* CRT Readout. Digital plug-ins such as the 7D15 can only be used in mainframes with CRT Readout, since their measurement results are displayed via CRT Readout almost exclusively.

```
MAINFRAME   ..............7704A†
PLUG-INS   ...............7A26/7D15/7B85/7B80

                   SET-UP
                 MAINFRAME

VERTICAL MODE   ..........ALT
TRIGGER SOURCE   ........LEFT VERT
HORIZONTAL MODE   ........A

                 TIME BASE

TRIGGER   ................AC, AUTO, INT
HORIZONTAL MODE   ........MAIN SWP OR INTENSIFIED
                         AS REQUIRED

TIME/DIV (INITIAL)
    MAIN   .................10 ms
    DLY'D   .................0.5 ms
†The 7D15 can be used with *any* of the 7000 Series mainframes available.
```
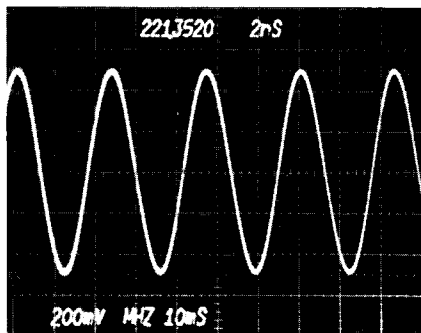
# Repetitive Signal Frequency Measurement



**Figure 1**
Repetitive frequency measurement. Input frequency found to be 221.352 MHz.

The 7D15 can measure the frequency of repetitive waveforms up to 225 MHz. Gate times may be selected in decade steps from 10 ms to 10 s. Resolution and accuracy increase with gate time. Orange color coding on the 7D15 front panel helps the user identify the input and controls for FREQUENCY mode.
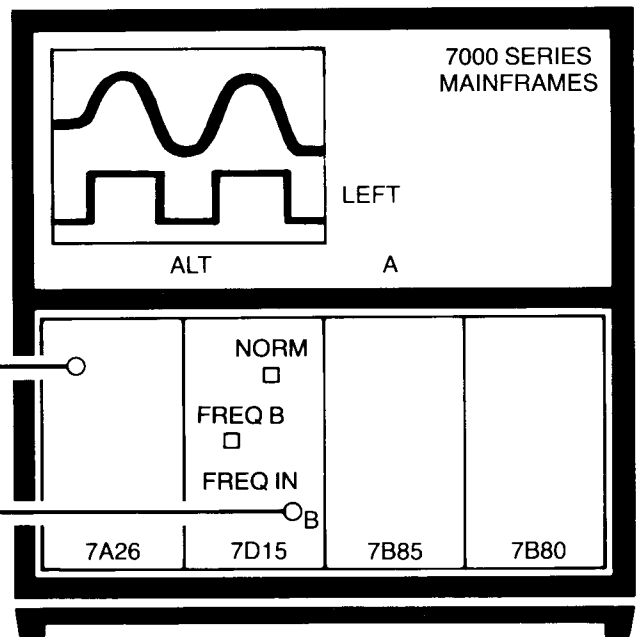


```
                              7D15 SET-UP
        GATE  . . . . . . . . . . . . . . . . . . . . . NORMAL
        MODE  . . . . . . . . . . . . . . . . . . . . FREQUENCY
        TIME  . . . . . . . . . . . . . . . . . . . . 10 ms
        DISPLAY WAVEFORM  . . . . . . . . . CH B
        DISPLAY TIME  . . . . . . . . . . . . . . 0.1 s
        B TRIGGER SOURCE  . . . . . . . . . INPUT B
        SENSITIVITY  . . . . . . . . . . . . . . AS REQUIRED
        LEVEL  . . . . . . . . . . . . . . . . . . . AS REQUIRED
```

Using a "Tee", connect the signal to the 7D15 B TRIGGER (FREQ IN) input and to the vertical amplifier input. Adjust the B TRIGGER SENSITIVITY and LEVEL controls for a triggered display. The display from the 7D15 is the output of the trigger shaper circuit. Using either position control, the exact trigger point on the waveform may be determined by superimposing the vertical amplifier display on the 7D15 display. Either positive or negative slope may be selected. The CH B DISPLAY also allows the user to determine if the counter is triggering on unwanted signals such as ringing on a square wave.

Change the DISPLAY WAVEFORM setting to PSEUDO GATE and set the sweep speed at 10 ms/div. You will notice that the measurement interval is non-synchronous with the displayed waveform. Observe the effects of the DISPLAY TIME control on the repetition rate of the measurement interval. Also note the effects of the TIME control on the width of the gate. By changing the mainframe TRIGGER SOURCE to RIGHT VERT the display can be triggered from the 7D15 PSEUDO GATE. Switch the DISPLAY WAVEFORM from PSEUDO GATE to TRUE GATE and note that these two waveforms are the same in the FREQUENCY mode. The DISPLAYED WAVEFORMS are described in more detail later (see pages 16 and 17).
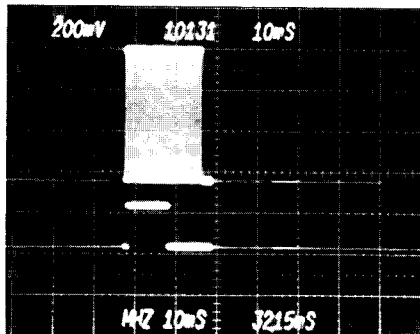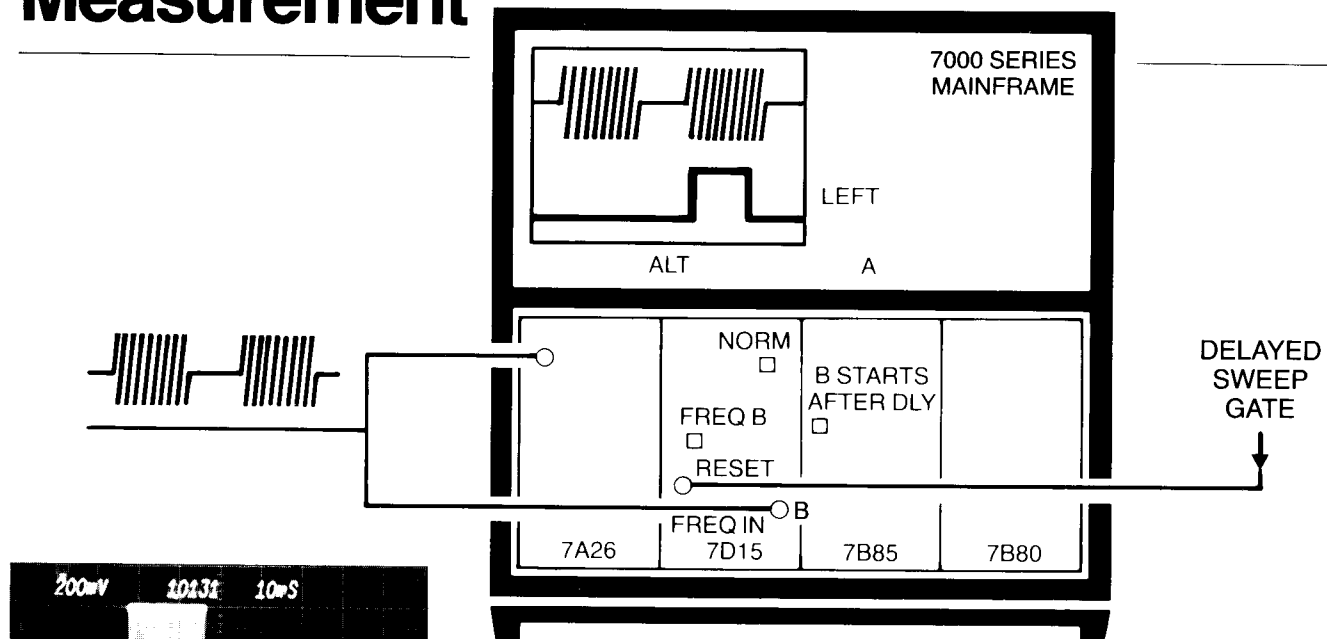
5

# Burst Frequency Measurement



Figure 2

**Figure 2**
**FREQUENCY Mode**
Using Delayed Gate to control
measurement interval for measuring
frequency of a burst. Burst frequency
measured to be 1.0131 MHz.

The 7D15 is capable of measuring
burst frequencies of 1 MHz and
above to four digits of resolution.
The primary concern in making this
measurement is assuring that the
counter's gate or counting interval
occurs at the proper time with
respect to the burst signal being
displayed. To accomplish this, the
oscilloscope's delayed gate is
used to trigger the 7D15's gate or
counting interval at the proper
time.

Since the 7D15's shortest gate or
counting interval in the frequency
mode is 10 ms, the burst of the
signal being measured must be
wider than the 10 ms gate, or at
least 11 ms wide.

Figure 2 shows the CRT display of
a burst signal frequency measure-
ment. The lower trace is the
counter's gate being triggered by
the oscilloscope's delayed gate.

The 7D15 set-up for measuring
burst frequency is as follows.

| 7D15 | |
|---|---|
| GATE | NORMAL |
| MODE | FREQUENCY |
| TIME | 10 ms |
| DISPLAY WAVEFORM | CH B |
| DISPLAY TIME | 0.1 s |
| B TRIGGER SOURCE | INPUT B |
| SENSITIVITY | AS REQUIRED |
| LEVEL | AS REQUIRED |

With a "Tee", connect the burst
signal to the 7D15 B TRIGGER
(FREQ IN) input and to the vertical
amplifier input. Connect the
Delayed Sweep Gate to the 7D15
RESET input with the BNC to
Sealectro cable provided. Trigger
the display. Using the DELAY TIME
MULTIPLIER control, align the
7D15 GATE display with the burst

signal as shown in Figure 2, then
adjust the trigger level of the 7D15
for a count display on the CRT read-
out.

Since the 7D15 counter is reset
each time the delayed sweep runs,
the readout may change slightly as
it is updated. This can be minimized
by running the main sweep as
slowly as possible.
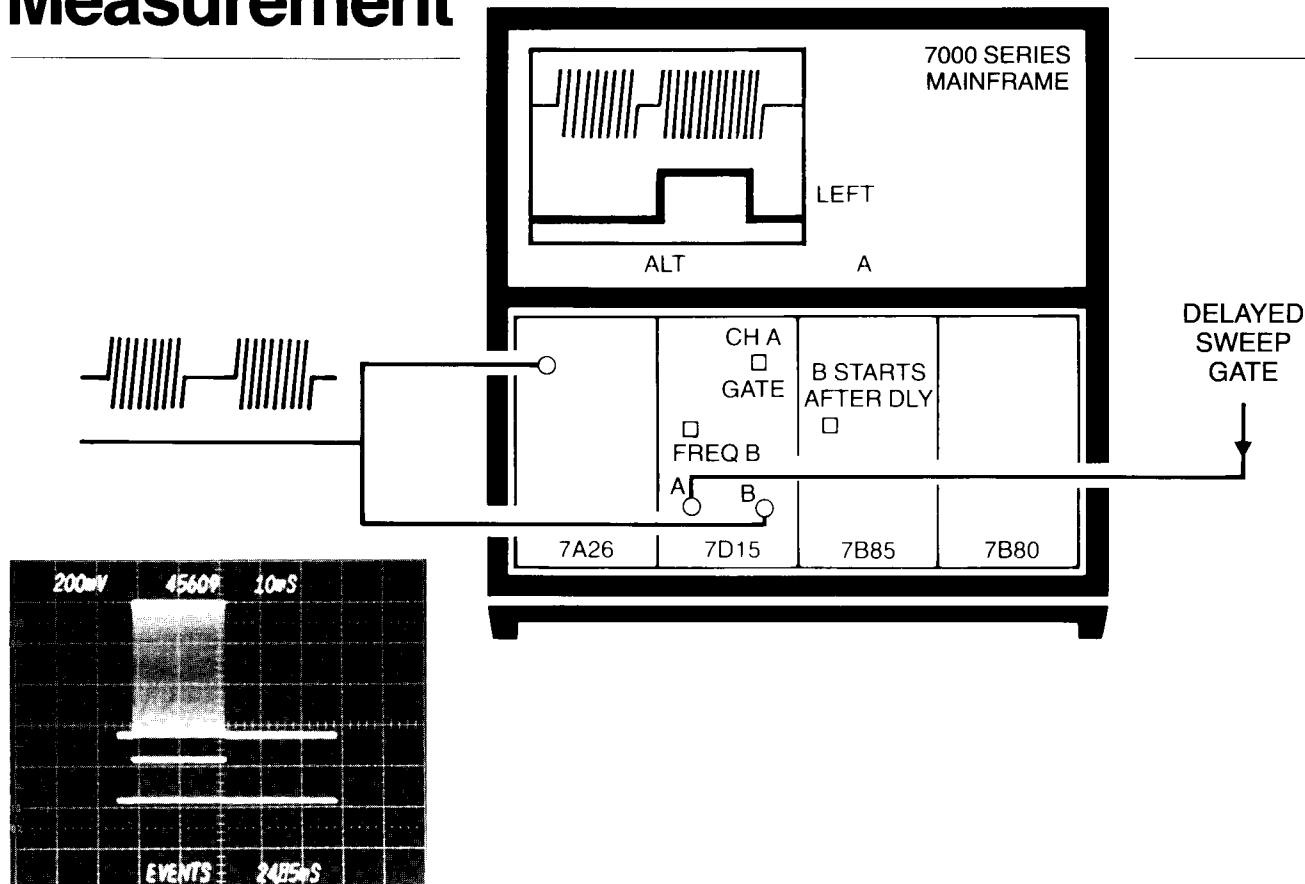
6

# Burst Events Measurement



7000 SERIES MAINFRAME

LEFT

ALT          A

CH A
□
GATE     B STARTS
AFTER DLY
□                □
FREQ B
A          B

7A26     7D15     7B85     7B80

DELAYED
SWEEP
GATE



**Figure 3**

**FREQUENCY Mode**

Using Delayed Gate into CH A input to totalize the number of events in a burst. There are 45609 events counted in the burst.

| 7D15 SET-UP | |
| --- | --- |
| DISPLAY TIME . . . . . . . . . . . . . 0.1 s | |
| GATE . . . . . . . . . . . . . . . . . . . OFF (CH A GATE) | |

The 7D15 also provides you with the capability of counting the number of cycles or events in a burst. Set-up is the same as for burst frequency measurements except as noted in the setup block.
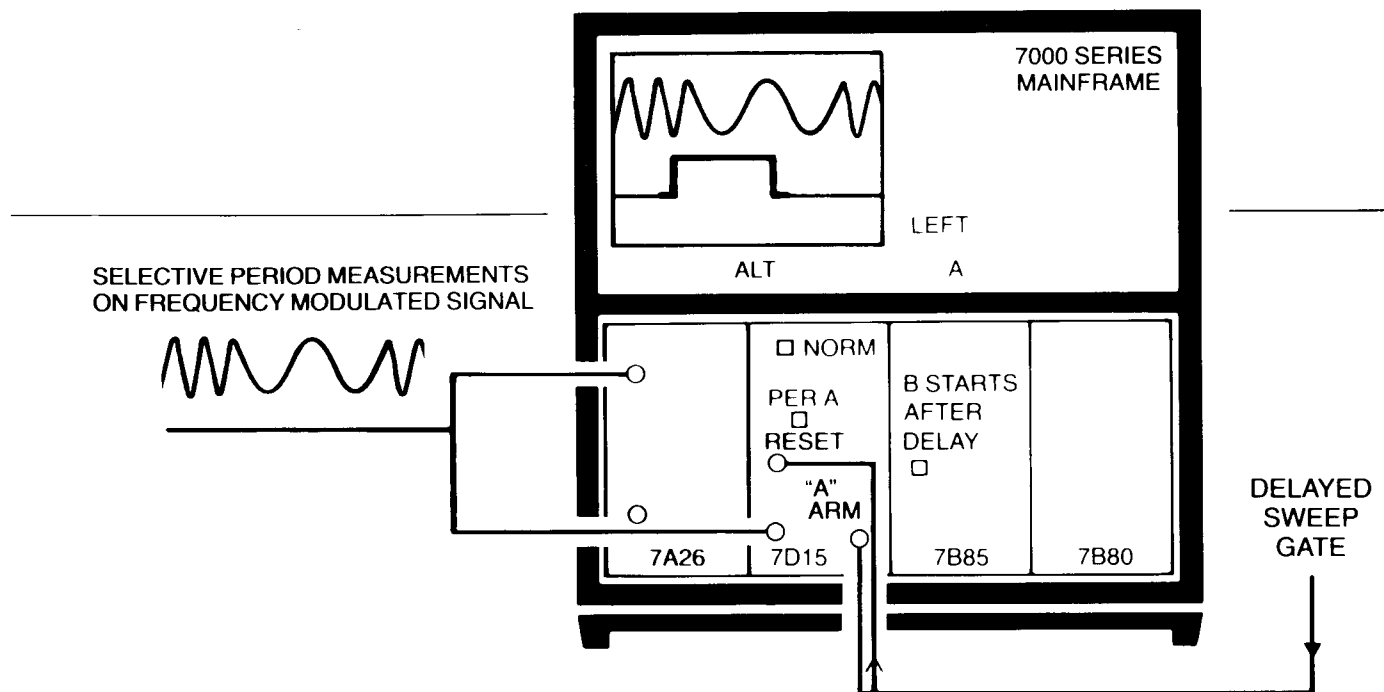
First connect the Delayed Sweep Gate to the A Trigger input of the 7D15 instead of to the RESET input. Next, adjust the Delayed Sweep TIME/CM and the DELAY TIME MULTIPLIER (DTM) control for a display as shown in Figure 3.

With the B Input Trigger LEVEL in PRESET, triggering should occur at the zero volt crossover point on the waveform. Changing the 7D15 DISPLAY WAVEFORM switch to CH B will show you exactly which events are being counted and the point on the waveform where the triggering occurs.

# Waveform Period Measurement



7000 SERIES MAINFRAME

MEASURING PERIOD OF A
REPETITIVE WAVEFORM



**Figure 4**
Period measurement on a repetitive
waveform. Period found to be 10.61 µs.

You can make period measure-
ments with the 7D15 on repetitive
waveforms such as sinewaves,
square waves, etc. and on non-re-
petitive waveforms such as digital
word trains. The initial set-up is for
period measurements on repetitive
waveforms, which are made from
one point on a waveform to a
corresponding point on the suc-
ceeding cycle of that waveform.

For period measurements only the
A trigger input and the A trigger
controls are used. Set up your
7D15 as noted.

| 7D15 SET-UP | |
|---|---|
| DISPLAY TIME | 0.1 s |
| STORAGE | ON |
| GATE | NORMAL |
| MODE | PERIOD |
| AVERG | X1 |
| CLOCK | 10 ns |
| DISPLAYED WAVEFORM | PSEUDO GATE |
| A TRIGGER | |
| SLOPE | PLUS |
| COUPLING | AC |
| SENS | AS REQUIRED |

With a "Tee", connect the signal to
the A Input of the 7D15 and to the
input of the vertical amplifier.
Adjust the A trigger controls of the
7D15 for a PSEUDO GATE display
as shown in Figure 4. The least
significant digit will change by plus
or minus one count when properly
triggered. Select either plus or
minus slope. The PSEUDO GATE
display shows where triggering
occurs on the slope. This can be
seen more readily on a sine wave
signal.

SELECTIVE PERIOD MEASUREMENTS
ON FREQUENCY MODULATED SIGNAL

The set-up for this selective period measurement is the same as shown previously for repetitive period measurements, except for the following:

Switch DISPLAY TIME TO ∞
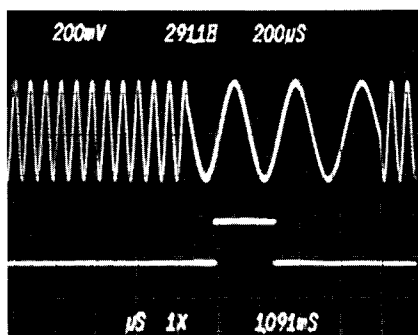Switch DISPLAYED WAVEFORM to TRUE GATE



**Figure 5**
Selective period measurements on a frequency modulated signal. Upper trace is the measured waveform, lower trace is the 7D15 pseudo gate display. Period of signal within measurement zone is 291.18 μs.

The "visually selective" period measurement technique adds a new and powerful dimension to your period measurement capabilities, since you are no longer limited to measuring only repetitive signals. Now you can "arm" the 7D15 to measure selected portions of non-repetitive waveforms. This capability can be extremely useful on waveforms such as digital word trains, frequency modulated sine waves, radar ranging pulses, etc.

Using a BNC "Tee" and the two Sealectro to BNC cables supplied with the instruments, connect the oscilloscope's delayed sweep gate to the RESET input and to the A ARM input. Adjust the delayed sweep TIME/DIV control so that the intensified zone is at least twice as long as the period being measured.

Position the DELAY TIME MULTI-PLIER dial so that the 7D15 TRUE GATE display is coincident with the period that is to be measured.

Figure 5 shows a selective period measurement on a frequency modulated sine wave. This measurement can be especially useful for analyzing the distortion in a burst caused by the burst gating signal.

When measuring repetitive burst signals, additional accuracy and resolution will result from averaging the measurements up to 1000 times. On repetitive burst signals like those shown in Figures 2 and 3, the 7D11 Digital Delay Unit can be used in conjunction with the
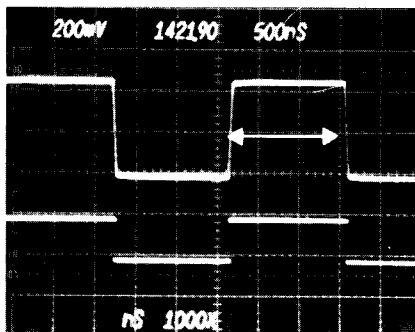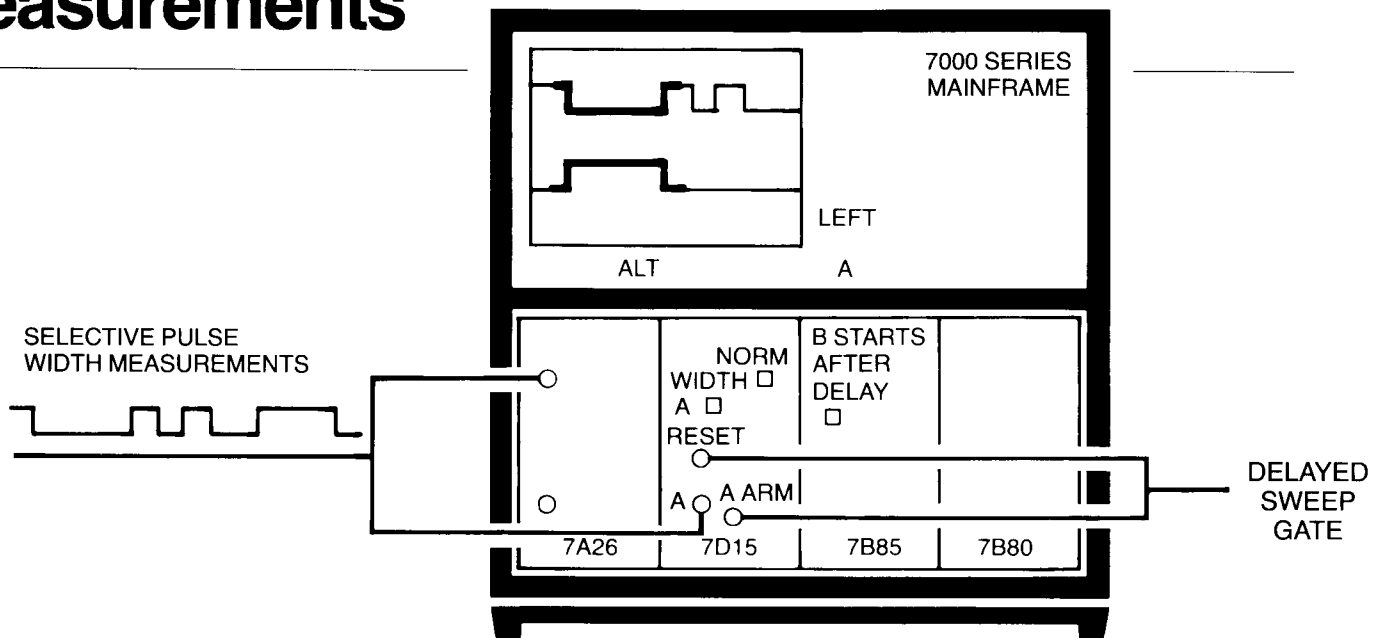
7D15 and 7B80 to provide an accurate, jitter-free delayed/delaying operation, thus allowing distortion analysis of a string of burst signals. For this application the 7D11 is used in the TIME mode to delay the sweep out to the second burst.

If the 7D11 is used in a vertical compartment, the 7B80 can be triggered internally through the mainframe trigger path, but if it is used in the left horizontal compartment the 7B80 **must** be triggered externally from the 7D11 Delay Trig Out.

Once the second burst is displayed on screen the 7D15 can be controlled with the 7B80 delayed gate to make a selective period measurement as shown in Figure 4A.

Once the second burst is displayed on screen the 7D15 can be controlled with the 7B80 delayed gate to make a selective period measurement as shown in Figure 5.
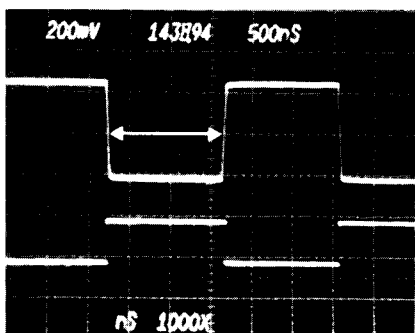
# Waveform Width Measurements



SELECTIVE PULSE WIDTH MEASUREMENTS

7000 SERIES MAINFRAME

ALT    LEFT    A

NORM
WIDTH □
A □
RESET

B STARTS
AFTER
DELAY
□

A ARM

7A26    7D15    7B85    7B80

DELAYED
SWEEP
GATE



+ SLOPE

TIME WIDTH A MODE

**Figure 6**
Upper trace is measured waveform, lower trace is the PSEUDO GATE display, which defines measurement zone, (1421.90 ns).



− SLOPE

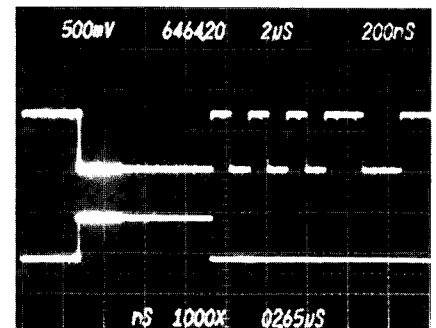The 7D15 Set-Up is the same as the block on page 8 except mode goes to width A.

**Figure 7**
Upper trace is the measured waveform, lower trace is the PSEUDO GATE display, defining measurement zone, (1438.94 ns).



**Figure 8**
Selective pulse width measurement of a digital word train. The 7D15 is being triggered on the negative slope, and measures width of single pulse in train, (6464.20 ns).

The 7D15 also features the capability of either repetitive or selective pulse width measurements. Except for MODE, the set-up for repetitive or selective pulse width measurements is exactly the same as for period measurements.

Figures 6 and 7 show examples of pulse width measurements on repetitive waveforms. Figure 8 shows an example of a selective pulse width measurement. In all instances, the measurements were averaged 1000 times to improve resolution.

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# Time Interval Measurements



TIME INTERVAL MEASUREMENTS
ON A REPETITIVE WAVEFORM
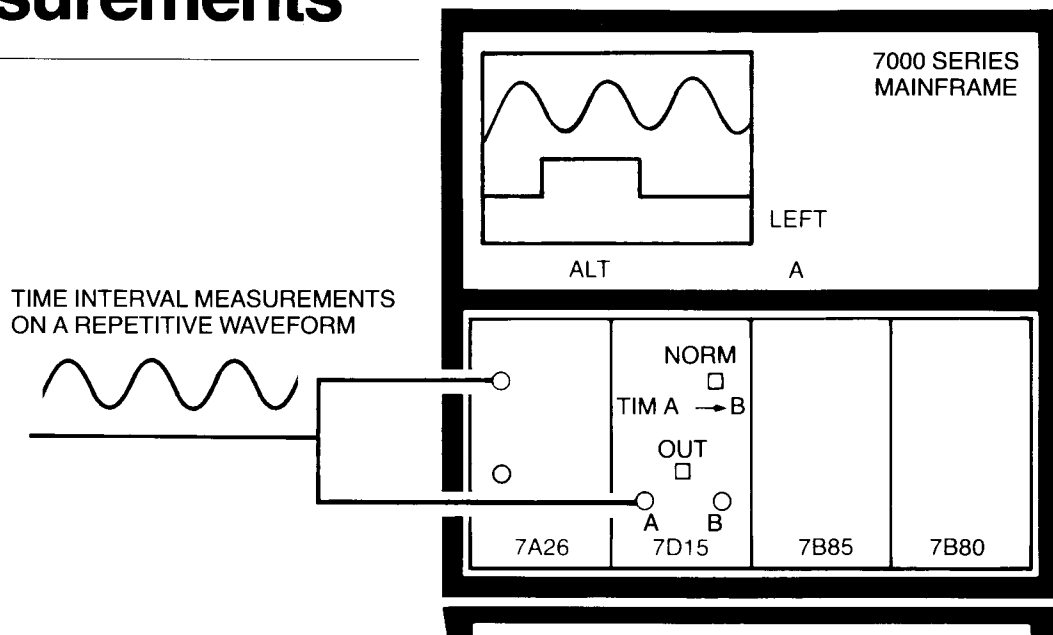
Using the 7D15 in the TIM A → B mode provides the capability of making time interval measurements on either repetitive or non-repetitive waveforms in the same manner as period or width measurements. The primary difference is that the TIM A → B mode uses both the A and B triggers of the 7D15. In this mode both inputs can be used, the A input for triggering the start of the measurement interval, the B input to trigger the stop of the measurement interval.

When measuring the time interval between two signals from different sources, or between two signals with different DC levels, both inputs would be used.

A single signal can be routed to both trigger circuits by means of the trigger SOURCE button located between the A and B trigger controls. When the button is "IN", the A input feeds the A trigger only. In the "OUT" position the B input is disconnected, and the A input feeds **both** trigger circuits.

Set-up for making a TIM A → B measurement on repetitive waveforms is the same as for period or width measurements except for the MODE switch. Change the MODE to TIM A → B. Connect the signal with a "Tee" to the A input of the 7D15 and to the vertical amplifier input. Select the desired A and B slope on which the measurement is to be made. Adjust the A and B trigger LEVEL controls of the 7D15 for a PSEUDO GATE display as shown in Figure 9.

Figure 9 shows the signal superimposed on the PSEUDO GATE waveform to show where triggering occurs on the slopes of the waveform. The rising portion of the gate display indicates where the start of the measurement is triggered and the falling portion of the gate display shows where the stop of the measurement is triggered.

Switch MODE to TIM A → B
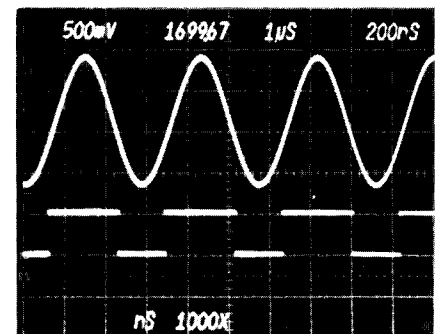Disconnect DLY'D SWP GATE



**Figure 9**
TIME A→B measurement on a repetitive sinewave. Pseudo gate visually indicates time zone of count (1699.67 ns).
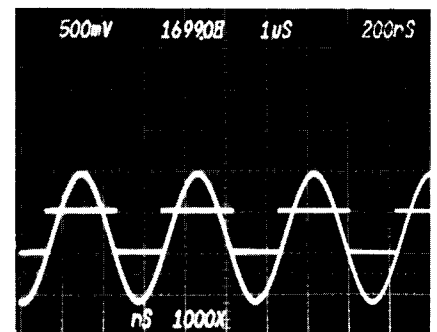


**Figure 10**
By superimposing the displays, the exact trigger points on the waveform can be determined

**Additional Time Interval Measurements described on following pages**

SELECTIVE TIME INTERVAL
MEASUREMENTS

7000 SERIES
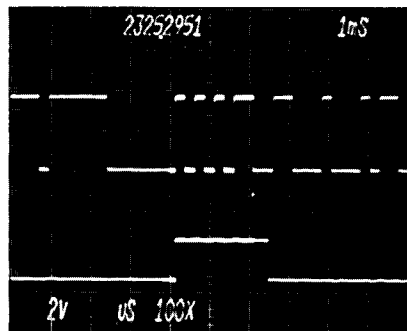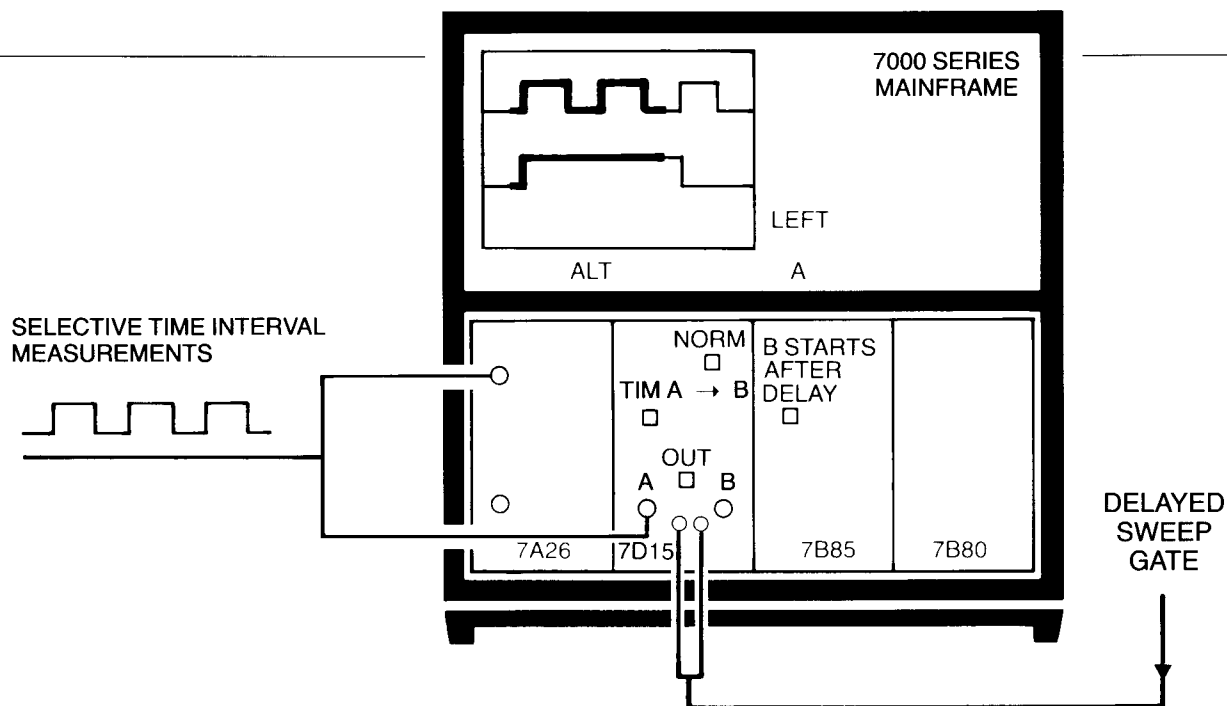MAINFRAME

DELAYED
SWEEP
GATE



**Figure 11**
Counter CH A is "armed" with leading edge of B gate while CH B counter is "armed" with falling edge of B gate. Lower trace is pseudo gate of 7D15. CRT readout displays the result of 2325.295 μs.

**TIME A→B**

┌─────────────────────────────┐
│ Connect DLY'D SWP GATE      │
│ to A and B ARM inputs       │
└─────────────────────────────┘

For selective time interval measurements in the TIM A → B mode connect the delayed sweep gate (intensified mode) to the A and B ARM inputs. Select the desired measurement interval, using the DELAY TIME MULTIPLIER control

and the delayed sweep TIME/DIV and/or the delayed sweep TIME/DIV VARIABLE controls. Figure 11 shows displays of typical measurements.

The A and B trigger circuit ARM inputs of the 7D15 use reverse logic, the A ARM input requiring a logical HI and the B ARM input requiring a logical LO to arm it. When the delayed sweep gate is applied to both inputs, A is armed during the time B is disarmed and vice versa.

Since the delayed sweep gate is used merely to arm the A and B trigger circuits, accuracy of the counter is not affected. The 7D15 still has full control over the exact trigger points on the waveform, and also controls the trigger slope -positive and negative.

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TIME INTERVAL MEASUREMENTS ON
TWO SEPARATE SIGNALS OR ON TWO
SIGNALS WITH DIFFERENT DC LEVELS

7000 SERIES
MAINFRAME

LEFT

ALT                    A

NORM

TIM A → B

IN        B

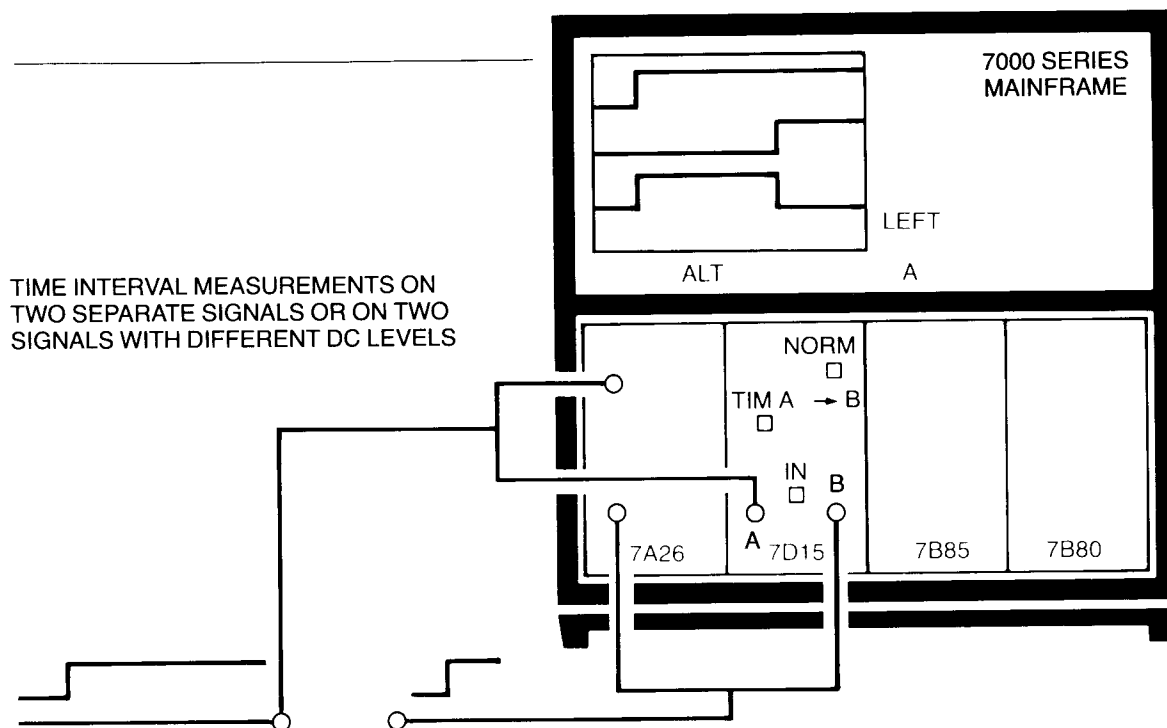7A26        A 7D15        7B85        7B80

Figure 12 shows the display of a
time interval measurement of the
input and output of a delay line.
Both inputs must be used for this
measurement. The input and
output displays (upper two traces)
were sampled at the 7D15 A and B
inputs with two probes.

For this measurement the input of
the delay line was connected with
a "Tee" to the A trigger input of the
7D15 and to channel 1 of the dual
trace vertical amplifier. The output
of the delay line was "Tee" con-
nected to the B trigger input of the
7D15 and to channel 2 of the dual
trace vertical amplifier. The dual
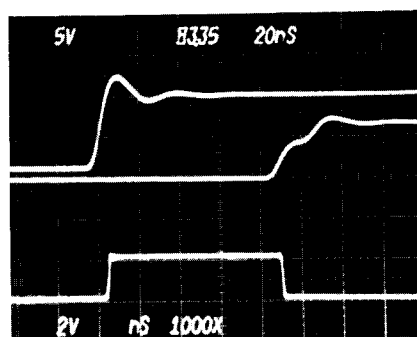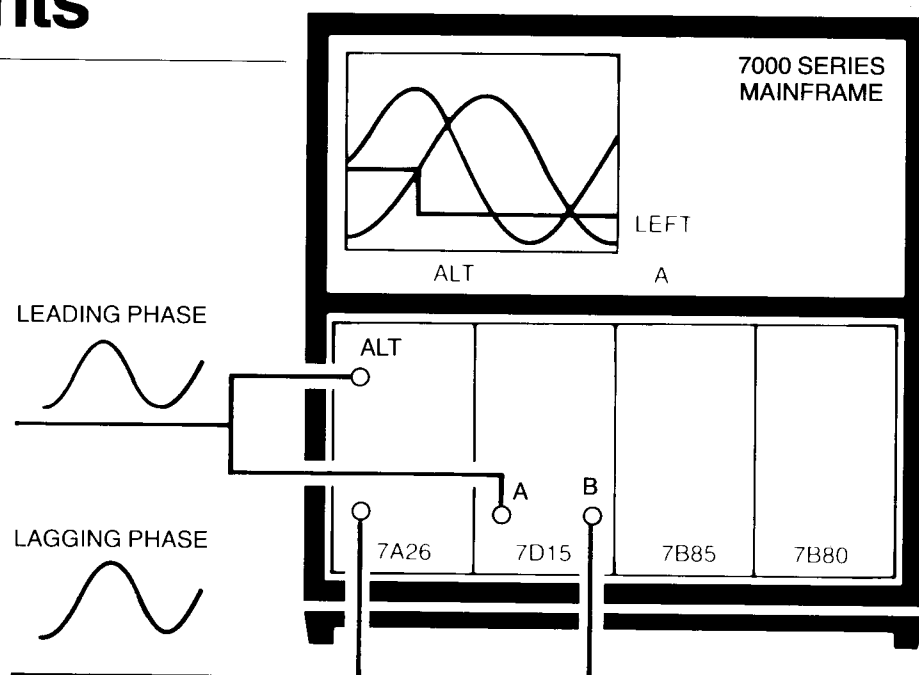trace vertical amplifier was oper-
ated in the ALT mode.

**Figure 12**

Measuring input and output of a delay
line and observing the count interval
of 83.35 ns.

**TIME A→B Mode**

Disconnect DLY'D SWP
GATE, connect first signal to
A input. Connect second
signal to B input.

# Phase Measurements



Phase measurements between two sinewaves can be made with the 7D15 Universal Counter/Timer by measuring the delay time interval between the leading and lagging signals. Since there are a number of conditions that can affect the accuracy of this measurement, care must be taken to assure the highest degree of accuracy while using this capability. Factors which can affect accuracy are:

1. Amplitude of the two signals – It is more difficult for the 7D15 trigger circuits to detect the zero crossover point on low amplitude signals.

2. Relative amplitude of the two signals – Ideally both signals should be the same amplitude.

3. Noise on the signals – Noise may fire the trigger circuits prematurely, causing jitter in the measurement, ultimately affecting the resolution of the readout.

4. Frequency of the signals – If the frequency is too low, the slope at the zero crossover is relatively flat. If the frequency is too high, the time interval is too short. The frequency range, for best results, is 60 Hz to 100 kHz.

The set-up for this measurement is as follows:

| 7D15 | |
| --- | --- |
| MODE | TIM A → B |
| AVERG | X1000 |
| CLOCK | 10 ns |
| GATE | NORM |
| DISPLAY | PSEUDO GATE |
| TRIGGER LEVEL | PRESET |
| TRIGGER SLOPE | PLUS |
| TRIGGER COUPLING | AC |
| B TRIGGER SOURCE | INPUT B |

Using a "Tee", connect the leading signal to the A input of the 7D15 and to CH 1 of the dual trace vertical amplifier. With another "Tee", connect the lagging signal to the B input of the 7D15 and to CH 2 of the dual trace vertical amplifier. Select ALT on the mainframe Vertical Mode and trigger the mainframe from the 7D15 Pseudo Gate display.

For better accuracy, check the 7D15 Trigger Level monitor jacks with a DVM to verify that both are triggering at the zero volt level. An internal "Preset Level" for the A and B triggers of the 7D15 can be readjusted if these levels are incorrect. Refer to the 7D15

Service Manual for this procedure.

Always use the most sensitive trigger positions of the 7D15 so that the slope of the signal through the zero crossover is as fast as possible.

Measure the time interval between the leading and lagging signal, then measure the frequency of the signal and use the following formula to determine the phase.

Phase Shift = $f\Delta t \times 360°$
(in degrees)

where $f$ = frequency of signal, and $\Delta t$ = time interval between leading and lagging signal

# Ratio Measurement of Two Signals



**Figure 13**
Ratio measurement of a digital clock
to a digital word train. Ratio is 3.9691:1.

Ratio measurement with the 7D15 is an extension of the FREQUENCY mode of operation. The only significant difference is that an external reference is used instead of the internal oscillator. The external reference may be some accurate in-house standard or it may be some other external reference signal.

The frequency range of the EXT CLOCK IN is 20 Hz to 5 MHz and requires an amplitude of 0.8 V for proper operation. The EXT CLOCK IN should always be used for the lowest frequency signal being measured for ratio. This insures that the CRT readout displays the numerator of the ratio. The denominator or reference signal is understood as 1.

Ratio measurements are not limited to sinewave signals. Ratios of two pulse trains, such as a computer's clock and word train, is shown in Figure 13. The 3.9691 shown in the photo is the ratio of the clock signal (lower trace) to the word train (upper trace). When the symbol in the lower readout slot reads MHz (10 ms TIME position) the number in the upper readout slot is a direct ratio of the two signals. However, when the symbol changes to kHz (as in the 100 ms, 1 s, and 10 s TIME positions) the number displayed in the upper readout slot must be divided by $10^3$ to get the direct ratio.

**The 7D15 must be removed from the mainframe for access to an internal slide switch located on the right side (as you face the instrument). This switch must be in the EXT position for ratio measurements.**
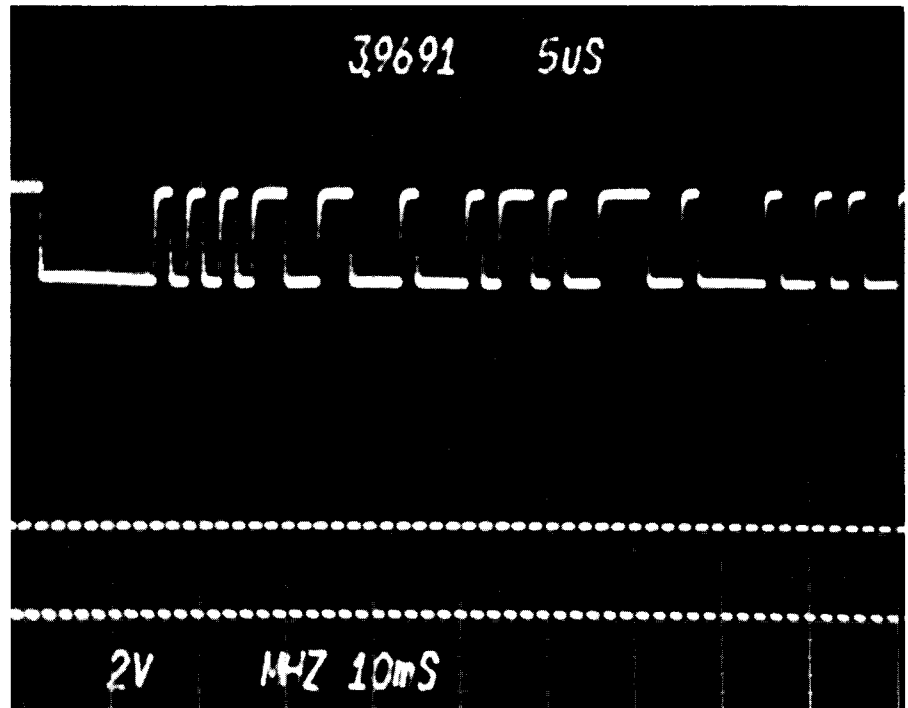
The set-up for making ratio measurements is as follows:

```
                    7D15 SET-UP
        GATE  . . . . . . . . . . . . . . . . . . . NORMAL
        MODE  . . . . . . . . . . . . . . . . . . FREQUENCY
        TIME  . . . . . . . . . . . . . . . . . . . 10 ms
        DISPLAY WAVEFORM  . . . . . . . PSEUDO GATE
        DISPLAY TIME  . . . . . . . . . . . . . ∞
        B TRIGGER SOURCE  . . . . . . . INPUT B
        SENSITIVITY  . . . . . . . . . . . . . AS REQUIRED
        LEVEL  . . . . . . . . . . . . . . . . . AS REQUIRED
```

Using a "Tee", connect the higher frequency signal to the B TRIGGER (FREQ IN) input of the 7D15, and to CH 2 of the dual trace vertical amplifier. Using another "Tee" connector and the Sealectro to BNC cable provided with the instrument, connect the lower frequency signal to the EXT CLOCK IN of the 7D15 and to CH 1 of the dual trace vertical amplifier.

Trigger the time base from LEFT VERT CH 1. With the mainframe VERT MODE switch in LEFT a display similar to Figure 13 should be present. If it is not necessary to view the two signals, Tee connecting to the vertical amplifier is not necessary.

Make sure the internal slide switch is in the INT position for all measurements that do not utilize the EXT CLOCK IN connector.

# 7D15 Displayed Waveforms

Since the DISPLAYED WAVEFORM changes with the selection of the TIME/AVERG push buttons in the various MODES of operation, an attempt will be made to distinguish between the three selectable displays of PSEUDO GATE, CH B, and TRUE GATE.

The CH B display is the easiest to explain, so that position will be discussed first. The display obtained in the CH B position is the output of the B trigger shaper circuit. This display is most useful in the FREQUENCY MODE to show exactly which cycles are being counted.

On a waveform such as the one shown in Figure 14, the CH B display allows you to determine if the counter is triggering on an unwanted signal. Such an unwanted count can cause a frequency error as high as 100%. By viewing the CH B trigger shaper output, the trigger LEVEL control can be adjusted to eliminate the unwanted count.



**Figure 15**
TRUE GATE display with 7D15 in PERIOD mode, 1x average.
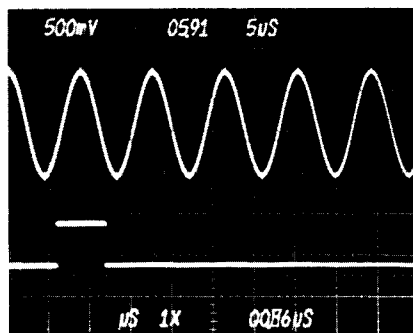


**Figure 16**
TRUE GATE displays with 7D15 in TIM WIDTH A mode, 1x average.



**Figure 14**
CH B display showing a double count caused by ringing on the waveform. Error is easily detected visually and can be corrected using trigger LEVEL control.
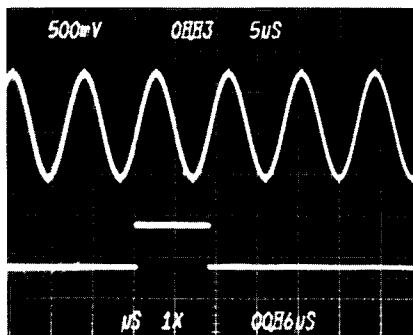
In the FREQUENCY MODE, the TRUE GATE and the PSEUDO GATE are exactly the same. Gate widths are controlled by the TIME selector switches and can be varied in decade steps from 10 ms to 10 seconds. The gates are derived from the crystal oscillator through decade dividing units and are very accurate.

The repetition rates of the TRUE GATE and PSEUDO GATE are determined by the setting of the DISPLAY TIME control in the FREQUENCY MODE and can be varied from 0.1 second to 5 seconds. They are non-synchronous with the incoming signal unless the counter gate is forced with a reset pulse, as previously described in the burst measurement application.

Figures 15 and 16 show TRUE GATE display in the PERIOD and WIDTH modes with an AVERG of X1 selected. The repetition rate is still determined by the DISPLAY TIME control, as it was in the FREQUENCY MODE, but the gate is now synchronous with the displayed waveform.
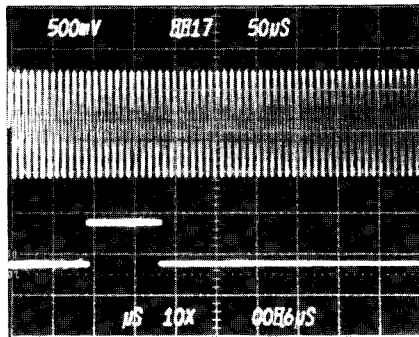
**Figure 17**
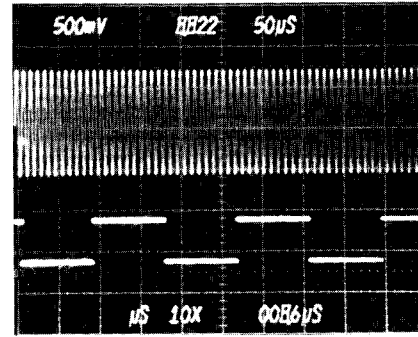TRUE GATE display with 7D15 in
PERIOD mode, 10x averages.



**Figure 19**
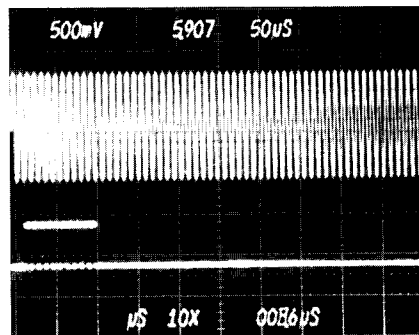PSEUDO GATE display with 7D15 in
PERIOD mode, 10x averages.



**Figure 18**
TRUE GATE display with 7D15 in
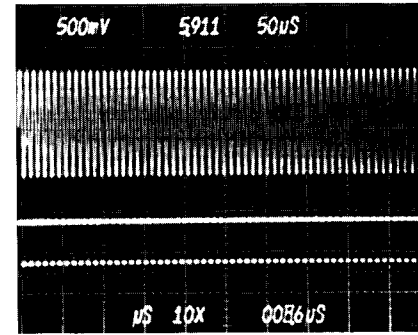TIM WIDTH A mode, 10x averages.



**Figure 20**
PSEUDO GATE displays with 7D15 in
TIM WIDTH A mode, 10x averages.

**All displays shown were gener-
ated with the 7D15 in the RIGHT
VERT compartment.**

Figures 17 and 18 again show a
TRUE GATE display, but this time
an AVERG of X10 was selected. In
the PERIOD mode the gate is 10
cycles wide. The measurement
time displayed on the CRT readout
would be the average cycle time of
the 10 cycles measured. In the
WIDTH mode, note that 10 discrete
pulse widths are measured. In this
case the measurement time
displayed on the CRT would be the
average of those 10 discrete pulse
width measurements.

The primary difference between
the TRUE GATE and the PSEUDO
GATE is one of repetition rate. The
PSEUDO GATE is merely a high
repetition rate replica of the TRUE
GATE. A comparison of Figures
17-18 with Figures 19-20 shows
the difference in the PERIOD and
the WIDTH modes. Increasing the
number of averages by a factor of
10 also increases the TRUE GATE
and PSEUDO GATE widths by a
factor of 10.

17

# 7D15 Pseudo Gate Delay Compensation

Propagation time of a fast rise signal through the various 7000 Series vertical amplifiers can vary significantly from the propagation time through the 7D15, depending on which vertical amplifier is being used. Waveform displays on the CRT will show a delay in the Pseudo Gate display as it compares to the step function of a fast rise input signal at fast sweep speeds. The propagation time will usually be longer through the 7D15 than through any of the vertical amplifiers except the 7A11. The signal path of the 7A11 is through a 6-foot FET probe, providing enough delay to equalize the propagation time through both plug-ins as shown in Figure 21.
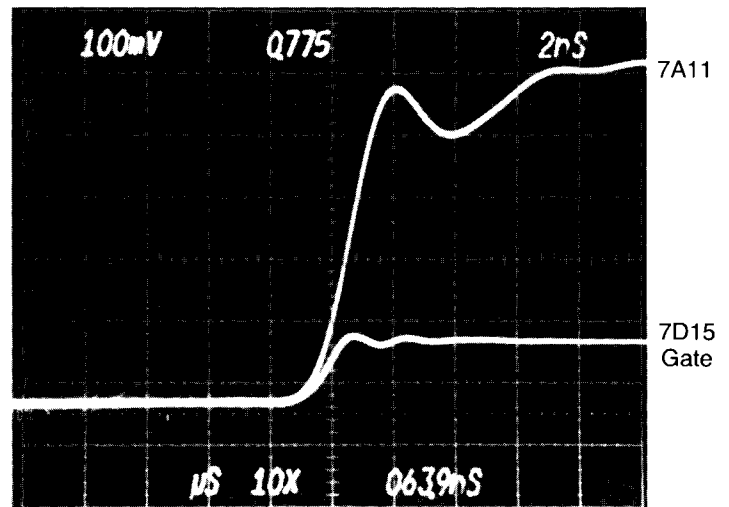


**Figure 21**
Typical 7D15 PSEUDO GATE delay coincides with rise signal of 7A11 display. No equalization is necessary.
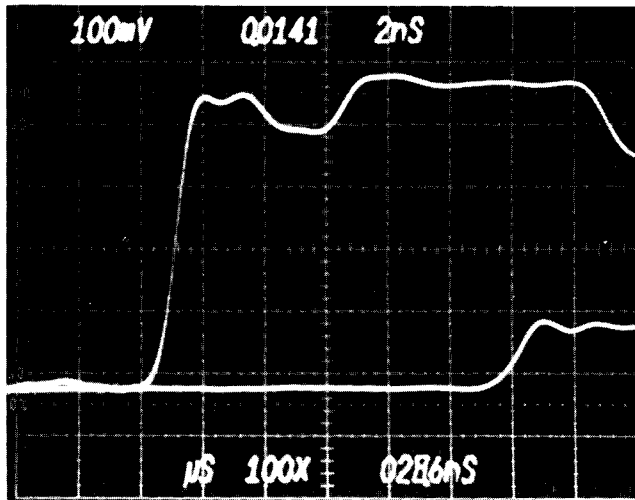


**Figure 22**
Typical uncompensated 7D15 PSEUDO GATE delay relative to rise signal of 7A26 display. Equalization is necessary in this case.
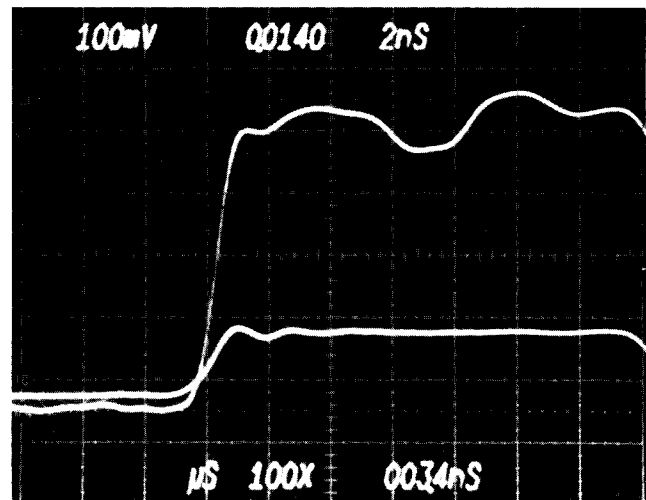


**Figure 23**
7A26/7D15 delay equalized with a 3 meter, P6106 probe added to the 7A26 signal path.

Figure 22 illustrates the unequal delay caused by the difference in propagation time of the 7D15 Pseudo Gate compared to the propagation time of the 7A26 Amplifier. Figure 23 shows the improvement which results by adding a 3 meter x 10 P6106 passive probe to the signal path through the 7A26. The additional delay added to the signal through the vertical amplifier allows the trigger points to be accurately aligned with the 7D15 Trigger Level control.
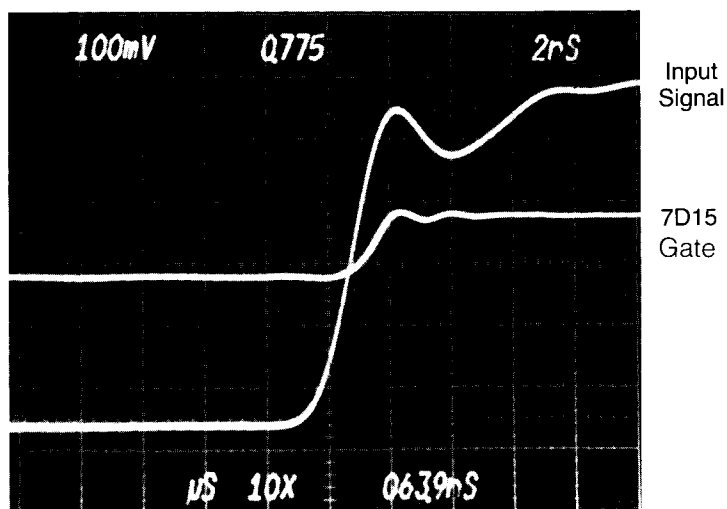
Input
Signal

7D15
Gate

**Figure 24**
7D15 triggered at the 50% point of the
input waveform.

Added delays should be such that further rotation of the 7D15 Trigger Level control in the CCW direction will cause the 7D15 Pseudo Gate display to drop out, thus insuring that the 7D15 is triggering at the start of the rising portion of the step function. Clockwise rotation of the 7D15 Trigger Level control would then allow the 7D15 to be triggered at any point along the rising portion of the step function as shown in Figure 24.

The important point is that by adding the proper amount of delay in the signal path to the vertical amplifier, the 7D15 Pseudo Gate trigger point can be correctly aligned with the displayed waveform to show the exact trigger point on that waveform. The added delays can be either through a probe or through a piece of BNC cable. If capacitive loading is critical, a probe should be used, if possible.

## Using the 7D15 TRIG LEVEL Monitor Jacks

Another method of determining the trigger point of the 7D15 is to monitor the TRIG LEVEL outputs with a DVM. This will allow the level ranges of the 7D15 trigger circuit to be determined. Once the level range is determined, then the level control can be adjusted to the desired trigger point. The 7D15 Trigger Level control range is ± 5 times the attenuator setting. Since the 1 V and 10 V attenuators are ahead of the TRIG LEVEL monitor jack, the DVM reading must be multiplied by the appropriate attenuator setting to obtain the correct trigger level.

# Accuracy Charts and 7D15 Specifications

Measurement averaging and selectable clock rates on the 7D15 allow you to select the amount of resolution and the maximum accuracy possible for a particular time measurement. This feature helps you prevent readout overflow when measuring long time intervals.

The CLOCK push buttons set the basic resolution of the counter. The 7D15's fastest clock rate 10 ns, which is the maximum resolution possible for a single shot time measurement. When measuring repetitive signals, resolution can be increased by using measure-ment averaging.

Measurement averaging is a statistical method of increasing resolution which involves making a number of measurements and averaging the results. When measuring period, for example, with the X1000 AVERG push button pressed, the counter measures the time for 100 cycles and divides the total by 1000 to obtain the average of one time period.

The three graphs show resolution vs. period, time interval, and frequency for the various settings of the CLOCK and AVERG push buttons. Note that for period measurements, resolution is increased 1000 times from the X1 to the X1000 AVERG setting.

For time interval measurements, the maximum resolution at the 10 ns clock rate is increased from 10 ns to 2 ns, an increase in resolution of 5 times.

The resolution you select also determines the maximum time interval you can measure without overflowing the 8 digit CRT readout. If a resolution of 10 ns is selected (10 ns clock rate and X1 measure-ment averaging), the longest time interval that can be measured before overflow occurs is .99999999 second. For a longer time interval, you must select less resolution, if the most significant

digit is of concern to you. If you are merely trying to resolve a small time difference, and do not care about the actual time interval, you can overflow the counter and still obtain the maximum resolution desired.

Accuracy is defined as the ratio (in percent) of the worst case error for a measurement to the actual measurement, and is a function of resolution and the accuracy of the crystal-controlled clock oscillator. The 7D15 clock oscillator has an accuracy of 0.5 ppm, which provides time measurement
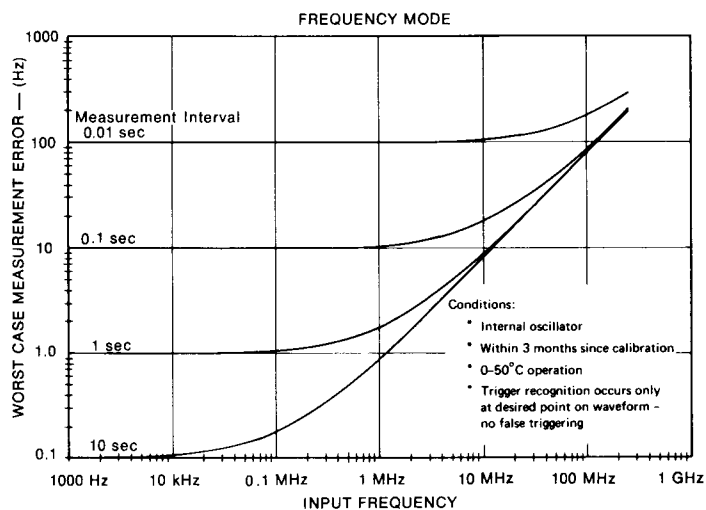
accuracies of up to 0.0001% on long time intervals - much greater than the 1% accuracy of an oscilloscope.

Measurement averaging and selectable clock rates on the 7D15 allow you to select the amount of resolution and the maximum accuracy possible for a particular time measurement. This feature helps you prevent readout overflow when measuring long time intervals.
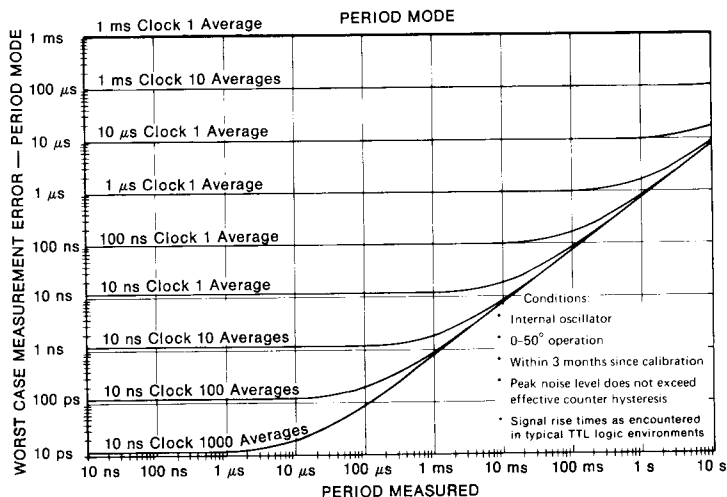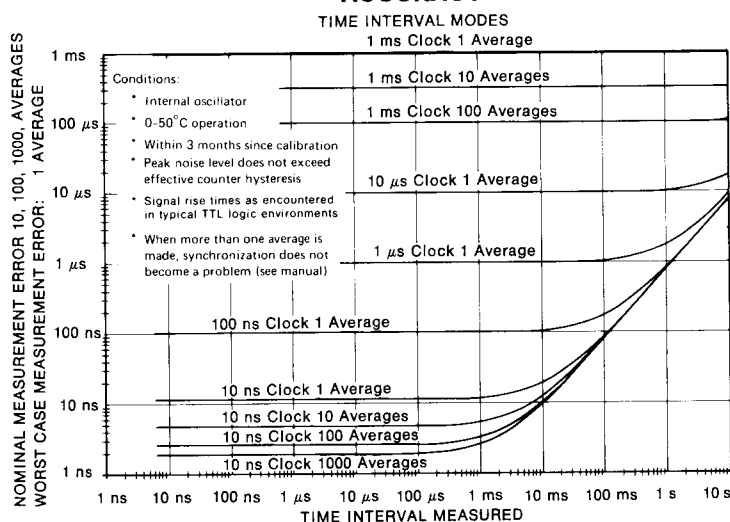
**Modes of Operation**

| | | |
|---|---|---|
| Frequency Mode | Range | Dc to 225 MHz<br>Resolution    0.1 Hz maximum |
| | Accuracy | $\epsilon_{freq(Hz)} = \pm\, TB \cdot f_{in} \pm \frac{1}{T}$ |
| Period and Multi-Period Mode | Range | 10 ns to $10^5$ seconds with averaging times of X1 to X1000 in decade steps.<br>Resolution: 10 picoseconds maximum |
| | Accuracy | $\epsilon_{period(s)} = \pm\, TB \cdot P_{in} \pm \frac{10^{-9}}{M} \pm \frac{2E_{npk}}{\frac{dv}{dt} \cdot M} \pm \frac{P_{ck}}{M}$ |
| Time Interval TI and (TI Average) Mode | Range | 6 ns to $10^5$ seconds with averaging times of X1 to X1000.<br>0.1 ns resolution (usable) |
| | Accuracy Worst Case (Nominal) | $\epsilon_{TI(s)} = \pm\, TB \cdot P_{in} \pm \frac{P_{ck}}{\sqrt{M}} \pm 10^{-9} \pm \frac{2E_{npk}}{\frac{dv}{dt}}$ |
| Frequency Ratio, CH B/Ext Clock | Range | $10^{-7}$ to $10^4$ |
| Manual Stop Watch | Range | 0 to $10^5$ seconds |
| Totalize, Ch B | Range | 0 to $10^8$ counts |

NOTE: Formulas given where $\epsilon$ is the error; TB (expressed as a decimal) is the time base accuracy; $P_{in}$ is the period or time interval of unknown signal; $M$ is the number of averages given; $P_{ck}$ is the measurement clock period; $T$ is the gate time; $f_{in}$ is the frequency of the unknown signal; $E_{npk}$ equals peak noise pulse amplitude as presented to Schmitt trigger circuit; $dv/dt$ equals signal slope at input to Schmitt trigger (volts per second). These formulas were used to develop the associated charts.



FREQUENCY MODE

## ACCURACY

### TIME INTERVAL MODES



Conditions:
- Internal oscillator
- 0-50°C operation
- Within 3 months since calibration
- Peak noise level does not exceed effective counter hysteresis
- Signal rise times as encountered in typical TTL logic environments
- When more than one average is made, synchronization does not become a problem (see manual)

(Curves labeled: 1 ms Clock 1 Average, 1 ms Clock 10 Averages, 1 ms Clock 100 Averages, 10 μs Clock 1 Average, 1 μs Clock 1 Average, 100 ns Clock 1 Average, 10 ns Clock 1 Average, 10 ns Clock 10 Averages, 10 ns Clock 100 Averages, 10 ns Clock 1000 Averages)

Y-axis: NOMINAL MEASUREMENT ERROR 10, 100, 1000, AVERAGES / WORST CASE MEASUREMENT ERROR: 1 AVERAGE (1 ns to 1 ms)
X-axis: TIME INTERVAL MEASURED (1 ns to 10 s)

### PERIOD MODE



Conditions:
- Internal oscillator
- 0-50° operation
- Within 3 months since calibration
- Peak noise level does not exceed effective counter hysteresis
- Signal rise times as encountered in typical TTL logic environments

(Curves labeled: 1 ms Clock 1 Average, 1 ms Clock 10 Averages, 10 μs Clock 1 Average, 1 μs Clock 1 Average, 100 ns Clock 1 Average, 10 ns Clock 1 Average, 10 ns Clock 10 Averages, 10 ns Clock 100 Averages, 10 ns Clock 1000 Averages)

Y-axis: WORST CASE MEASUREMENT ERROR — PERIOD MODE (10 ps to 1 ms)
X-axis: PERIOD MEASURED (10 ns to 10 s)

---

The CLOCK push buttons set the basic resolution of the counter. The 7D15's fastest clock rate 10 ns, which is the maximum resolution possible for a single shot time measurement. When measuring repetitive signals, resolution can be increased by using measurement averaging.

Measurement averaging is a statistical method of increasing resolution which involves making a number of measurements and averaging the results. When measuring period, for example, with the X1000 AVERG push button pressed, the counter measures the time for 1000 cycles and divides the total by 1000 to obtain the average of one time period.

The three graphs show resolution vs. period, time interval, and frequency for the various settings of the CLOCK and AVERG push buttons. Note that for period measurements, resolution is increased 1000 times from the X1 to the X1000 AVERG setting.

For time interval measurements, the maximum resolution at the 10 ns clock rate is increased from 10 ns to 2 ns, an increase in resolution of 5 times.

The resolution you select also determines the maximum time interval you can measure without overflowing the 8 digit CRT readout. If a resolution of 10 ns is selected (10 ns clock rate and X1 measurement averaging), the longest time interval that can be measured

before overflow occurs is .99999999 second. For a longer time interval, you must select less resolution, if the most significant digit is of concern to you. If you are merely trying to resolve a small time difference, and do not care about the actual time interval, you can overflow the counter and still obtain the maximum resolution desired.

Accuracy is defined as the ratio (in percent) of the worst case error for a measurement to the actual measurement, and is a function of resolution and the accuracy of the crystal-controlled clock oscillator. The 7D15 clock oscillator has an accuracy of 0.5 ppm, which provides time measurement accuracies of up to 0.0001% on long time intervals - much greater than the 1% accuracy of an oscilloscope.

## SPECIFICATIONS

### INTERNAL TIME BASE

**Crystal Oscillator** — Accuracy: within 0.5 ppm (0°C to +50°C ambient). Long-term drift: 1 part or less in $10^7$ per month. Oscillator is temperature compensated; no warm up is required.

### OUTPUT SIGNALS

**Clock Out** — Logical 1 ⩾ +0.5 V into 50 Ω. Logical 0 ⩽0 V into 50 Ω. TTL compatible without 50 Ω load (1.6 mA current capacity).

**A and B Trigger Level** — $Z_{out}$ ≈1 kΩ, $V_{out}$ = ±0.5 V into 1 MΩ.

**Displayed Waveform (Internally Connected)** — Front-panel switch selects true gate, pseudo gate, or channel B signal out. Position controlled by front-panel screwdriver control.

**External Display** — Same as internal except position control has no effect.

**Display Mode Switch** — 0.1 to 5 s; also a preset position for infinite display time. Allows selection of readout "follow or store."

**Readout** — Eight-digit display; the four most significant have zero suppression. Overflow indicated by a greater than symbol.

### INPUT SIGNAL CH A & B

**Frequency Range (Ch B only** — Dc-coupled: dc to 225 MHz. Ac-coupled: 5 Hz to 225 MHz.

**Sensitivity (Ch A and B inputs)** — 100 mV p-p. Trigger source: 0.5 division to 100 MHz, 1.0 division to 225 MHz, or to the vertical system bandwidth, whichever is less.

**Input R and C** — 1 MΩ and 22 pF.

**Triggering (Preset Position)** — Automatically triggers at 0 V.

**Level Control Range (Ch A and B inputs)** — 100 mV range: ±500 mV. 1-V range: ±5 V. 10-V range: ±50 V.

**Arming Inputs** — Input R and C: 10 kΩ and 20 pF. Sensitivity arm A: logical 1 ⩾ +0.5 V, logical 0 ⩽ +0.2 V. Sensitivity arm B: logical 1 ⩽ +0.2 V, logical 0 ⩾ +0.5 V.

**External Clock-In** — 20 Hz to 5 MHz.

**Reset Front Panel** — Reset readies the instrument. All counters are affected, including averaging circuits.

**Included Accessories** — Two cables RF 44 in (012-0403-00, Sealectro to BNC connector).

# Delayed Sweep Gate Connections

The Delayed Sweep Gate used in
some of the 7D15 measurements is
available as noted below for
various 7000 Series mainframes.

| Mainframe | Delayed Sweep Gate |
|---|---|
| 7600 Series | Available at DLY'D TRIG IN with BNC connector on front panel of 7B53A time base. |
| 7704A | Available on + GATE output BNC on rear panel. Internal mainframe switch near BNC must be in DLY'D position. |
| 7834 | Available on + GATE OUT with BNC on rear panel. Internal mainframe switch near BNC must be in DLY'D position. |
| 7844 | Available on B GATE output BNC on rear panel. Rear panel switch must be in DLY'D position. |
| 7854 | Available on + GATE output BNC on rear panel. Internal mainframe switch must be in DLY'D position. |
| R7903 | Available on + GATE output BNC on rear panel. Mainframe switch near BNC must be in MAIN position. |
| 7904 | Available on + GATE output BNC on front panel. Internal mainframe switch must be in GATE B position. |
| 7104 | Available on + GATE output BNC on front panel. Position "B" must be selected on switch next to BNC. |

# Internally Wired Trigger Source Signal Paths

The wide selection of capabilities
provided by the diversified assort-
ment of vertical amplifier plug-ins
available for use in 7000 Series
Oscilloscope mainframes provides
the user of the 7D15 Universal
Counter/Timer with many unique
input possibilities for digital
counting.

Amplifier features available include
bandwidths up to 1 GHz, single
and multi-trace capabilities,
selectable polarity, magnification
for increased sensitivity, up to 5
operating modes, low frequency
bandwith limiting, differential and
differential comparator capabilities,
up to 100,000:1 CMRR, trace
identification, and remarkable ease
of use, dependability, and
accuracy.

Once the techniques and applica-
tions outlined and explained in this
handbook have been mastered,
engineers and technicians will
begin to discover for themselves
the almost limitless possibilities for
more advanced and sophisticated
uses and applications of the 7D15.

The ease, convenience, and
simplicity of the mainframe's
internally wired and selectable
TRIGGER SOURCE signal routing
allows the counter to be driven by
almost any 7000 Series vertical
plug-in available. This feature
facilitates set-up, saves time,
improves accuracy of measure-
ments, minimizes possibilities for
errors, and allows the user to
concentrate on the measurement
itself, rather than the hardware
involved.
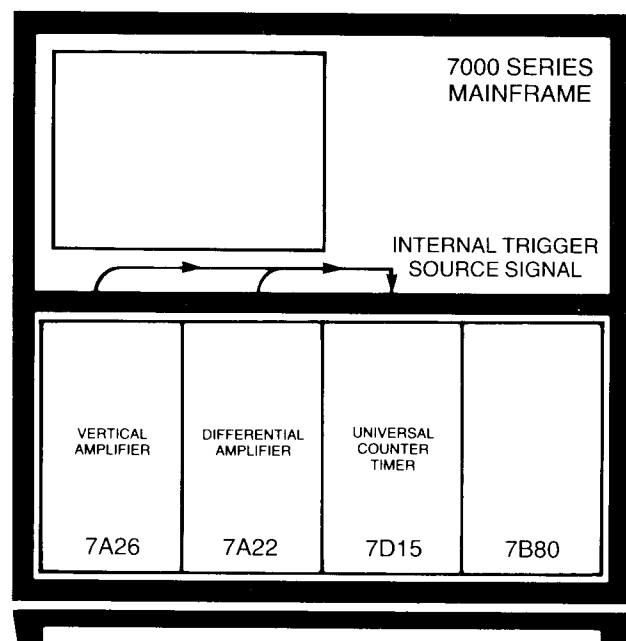
# The 7000 Series

## Versatile . . . Flexible . . . . . . Adaptable . . . Configurable

While the content of this applications handbook has focused on the technical measurements possible with the 7D15 Universal Counter/ Timer, don't let its amazing capabilities overshadow the other 30 plug-ins available for use in the 7000 Series. Nor should the use of the 7704A Oscilloscope to represent the mainframe for the set-ups and techniques described throughout these pages completely divert your attention from the many other mainframes available.

The state-of-the-art performance features incorporated into the 7000 Series modular oscilloscope systems are so varied and extensive that they cover virtually every facet of measurement technology. If your measurements require the ultimate in advanced technology available in an oscilloscope-based measurement system, the 7000 Series can provide the highest bandwidth, the fastest rise time, and the fastest writing speed available today.

Whatever your measurement requirement needs may be, there is a 7000 Series mainframe/plug-in combination which will provide you with exactly the capabilities which you need.

Plug-in features available, in addition to the large selection of vertical amplifiers and time bases, include all of the following:

### Digital Measurements

In addition to the 7D15 Universal Counter/Timer, which has been described in detail in this handbook, digital measurement plug-ins include:

A Digital Multimeter, with convenient voltage, current, resistance, and temperature measuring capabilities.

Digital delay trigger generator, delay by time to 1 second, or to $10^7$ events.

An oscilloscope-controlled Sampling DVM with CRT readout.

These plug-ins provide: scope-controlled digital measurements, measuring convenience and confidence, increased accuracy, easier and faster solutions to complex problems, and more bench space.

### Sampling/Time Domain Reflectometry

The 7000 Series sampling plug-in family provides unique measurement capabilities not ordinarily available in other oscilloscopes. These capabilities range from time-domain measurements up to 14 GHz to highly accurate measurements on microwave striplines and cabling. The unique 7000 Series modularity makes these possible.

### Spectrum Analysis

Unexcelled performance from 20 Hz to 60 GHz is provided by the 7L5, 7L14, and 7L18 Spectrum Analyzer plug-ins. Stable, sensitive, and free of spurious responses, these analyzers add accurate frequency-domain capability to your 7000 Series mainframe.

Some plug-in analyzers have microprocessor aided controls for easy operation, and digital storage and display capability for recalling and comparing signals. Others offer 30 Hz resolution for viewing close-together signals. Optional tracking generators are available for swept frequency measurements.

### Logic Analysis

7000 Series modular oscilloscopes have the additional capability of being transformed from a scope to a Logic Analyzer with the addition of a plug-in module.

You can combine the multiple channel acquisition, display formatting and complex triggering capabilities of a logic analyzer with the high-speed performance of a scope to tackle digital applications, with unprecedented triggering power in both the state and timing modes of data acquisition.

### Signal Processing Systems

GPIB-programmable waveform digitizers are an important extension of 7000 Series technology and are used as a central element in Tektronix Signal Processing Systems. These minicomputer-based systems offer wide ranging capabilities.

We suggest that you make a habit of periodically discussing and reviewing your measurement needs with your Tektronix Sales Representative. The 7000 Series scope and plug-ins recommended will not only provide the capabilities to fulfill your measurement requirements today, they will continue to expand and adapt to accommodate your future needs.

# Tektronix®

COMMITTED TO EXCELLENCE