

USING THE

2445

AND

2465

OSCILLOSCOPES

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Tektronix[®]
COMMITTED TO EXCELLENCE

TRIGGER LEVEL

TRIGGER SOURCE

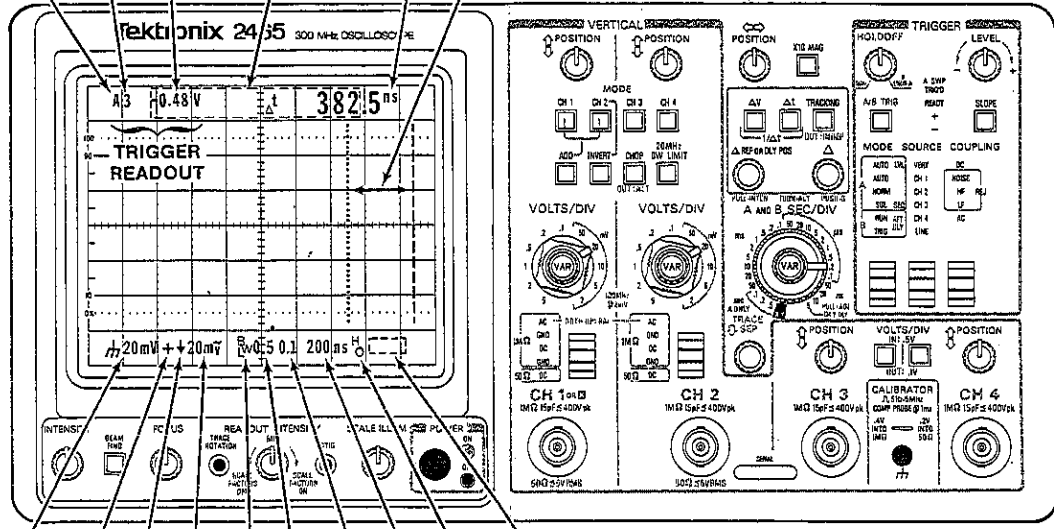
TRIGGER AFFECTED (A OR B)

50 Ω OVERLOAD INDICATOR*

CURSORS

DELTA VOLTS, DELAY TIME, DELTA TIME, 1/DELTA TIME, PHASE OR RATIO READOUT

SEE MEASUREMENT READOUTS



CH 1 SCALE FACTOR

CH 2 SCALE FACTOR

CH 3 SCALE FACTOR

A SWP RATE

B SWP RATE

ADD INDICATOR*

INVERT INDICATOR*

BANDWIDTH LIMIT INDICATOR*

CH 4 SCALE FACTOR

HOLD OFF INDICATOR*

*SEE DESCRIPTION OF "INDICATORS"

CRT READOUT

NOTE: All readouts except ΔV , Δt , $1/\Delta t$, RATIO, PHASE, and 50 Ω OVERLOAD are turned off when READOUT INTENSITY is CCW from center.

• **Trigger Readout** — Indicates that a single, dc-coupled trigger source is selected with VOLTS/DIV VARIABLE in detent and with DC or NOISE REJ COUPLING.

• **Trigger Affected** — Trigger controls affect only the indicated trigger.

A — if SEC/DIV knobs are locked.

B — if SEC/DIV knobs are unlocked and B TRIGGER MODE is TRIG AFT DLY.

The A/B TRIG button momentarily directs control to the opposite trigger.

With B TRIGGER MODE set to RUN AFT DLY and SEC/DIV knobs unlocked, the A/B TRIG button alternately directs control to the A and B triggers. There is no B readout in RUN AFT DLY.

• **Trigger Source** — Indicates CH 1 - CH 4.

• **Trigger Level** — Signal voltage required to initiate sweep.

• **Measurement Readouts** — Values of the Delay Time, Δ Time, $1/\Delta$ Time, Δ Volts, Phase, and Ratio measurements. The following tables show the control settings required to invoke the various measurement modes. To turn off a measurement readout, push the button(s) indicated in the readout.

AMPLITUDE MEASUREMENTS WITH ΔV CURSORS

TO GET	SET	
	VERTICAL MODE	VOLTS/DIV VAR
$\Delta V1$	CH 1	detent
	ADD only, CH 1 V/div = CH 2 V/div	detent
$\Delta V2$	CH 2 w/o CH 1	detent
$\Delta V3^a$	CH 3, w/o CH 1 or 2	X
$\Delta V4^a$	CH 4, w/o CH 1, 2, or 3	X
RATIO	CH 1 or CH 2 w/o CH 1	5 div = 100%
	ADD only, CH 1 V/div \neq CH 2 V/div	X

^a“?” indicates measurement accuracy is more uncertain than with CH 1 or CH 2.

TIMING MEASUREMENTS

TO GET	SET		
	ΔV , Δt	HORIZ ^b MODE	SEC/DIV VAR
DLY ^c	neither	INTEN, ALT, or B	X
Δt	Δt	A, with cursors	detent
Δt^d	Δt	INTEN, ALT, or B	X
RATIO	Δt	A, with cursors	5 div = 100%
$1/\Delta t$ (freq)	both	A, with cursors	detent
$1/\Delta t^{cd}$ (freq)	both	INTEN, ALT, or B	X
PHASE	both	A, with cursors	5 div = 360°
NO ΔV W/ DELAY	ΔV	INTEN, ALT, or B	X

^bA and B SEC/DIV switch settings: A (in, equal), INTEN (out, equal), ALT (out, unequal), B (in, unequal).

^c“?” indicates B MODE is in TRIG AFT DLY or delay is < 0.5% of maximum.

^d“?” indicates delay difference or cursor separation is < 1% of maximum.

• **CH 1 - CH 4 Scale Factors** — Numerical deflection factors and supplementary symbols. CH 3 and CH 4 deflection factors are shown in volts. The supplementary symbols for CH 1 and CH 2 are as follows:

\triangleright Variable out of detent

\perp Input grounded

V Dc coupling

\sim Ac coupling

TRIGGER OPERATION

• **Indicators** — Symbolic indicators of oscilloscope modes.

+	ADD vertical mode
↓	CH 2 INVERT mode
B LW	20 MHz BW Limit
H O	HOLDOFF is not set at minimum
50 Ω OVERLOAD	CH 1 or CH 2 input power limit has been exceeded

• **A and B SWP RATES** — Calibrated A and B SEC/DIV scale factors. With the SEC/DIV switches unlocked (INTENS, ALT, or B display), only the B sweep rate will be affected by the SEC/DIV VARIABLE control.

**NUMBER OF TRACES DISPLAYED
AS FUNCTION OF DISPLAY MODES AND Δt***

Total Vertical Channels Selected (from CH 1, CH 2, ADD, CH 3, and CH 4)	Horizontal Display				
	A	B		A-B ALT	
		Δt off	Δt on	Δt off	Δt on
1 (or CHOP)	1	1	2	2	4
2	2	2	2'	4	4'
3	3	3	4	6	8
4	4	4	6	8	12
5	5	5	8	10	16

*Intensified trace with 2 intensified zones is actually 2 traces.

† With ALT VERTICAL MODE and Δt, the ΔREF delay operates on the first channel selected and the Δ delay on the second channel.

• **TRIGGER MODE, SOURCE, and COUPLING Switches** — Automatically increment (up or down) when held in the associated position.

TRIGGER MODE

AUTO LVL — Range of TRIGGER LEVEL control is limited within signal peaks. Range limits are reestablished when;

- triggering ceases,
- LEVEL control is moved to either extreme, or
- MODE switch is pushed up when in AUTO LVL.

The initially established level is near the midpoint between signal peaks except as follows;

- If the LEVEL control is set near the CCW limit, the trigger level is set just above the negative signal peak.
- If the control is set near the CW limit, the level is set just below the positive peak.

AUTO — Sweep freeruns in absence of trigger signal. Trigger level changes only when LEVEL control is moved.

NORM — Sweep runs when trigger requirements are met. With input coupling of the selected trigger source at GND, sweep freeruns.

SGL SEQ — Sweep is triggerable once for each selected trace. READY is illuminated until final trace is completed, then readout and scale illumination flash.

TRIGGER SOURCE — Trigger source selection is independent from vertical display selection. With SOURCE at VERT, each vertical displayed provides a trigger in turn except as follows:

ADD VERTICAL MODE — VERT SOURCE is sum of CH 1 and CH 2.

CHOP VERTICAL MODE or AUTO LVL TRIGGER MODE — VERT SOURCE is lowest numbered channel displayed (or ADD if displayed).

TRIGGER COUPLING — Operates as follows:

DC	- normal, unrestricted triggering.
NOISE REJ	- blocks signals < approx 0.5 div.
HF REJ	- attenuates signals > 50 kHz,
LF REJ	- attenuates signals < 50 kHz,
AC	- blocks dc component of signal.

• **Period of an Expanded Burst**

1. Display burst with A-B Alternate or B Delayed setup.
2. If necessary, use B trigger to stabilize display.
3. Set B SEC/DIV and VAR for 1 burst cycle/division.
4. Read period of burst from B Sweep Rate readout.

ACCURACY ASSURANCE TECHNIQUES

• **DC Balance** — Minimize trace shift when changing VOLTS/DIV and maintain trigger level readout accuracy.

1. Set both CH 1 and CH 2 input coupling to AC.
2. Push up on both CH 1 and CH 2 input coupling switches.

• **Vertical Amplitude Verification**

1. With A and B SEC/DIV set at 1 ms (knobs locked), use the ΔV cursors to measure the amplitude of the CALIBRATOR signal on each of the four vertical channels. CH 1 and CH 2 should measure between 388 mV and 412 mV, while CH 3 and CH 4 should be between 360 mV and 440 mV.

• **Timing Verification**

1. With the CALIBRATOR signal displayed on CH 1, set the VOLTS/DIV switch to 100 mV.
2. Verify timing using table below. With any SEC/DIV faster than 1 μs, set TRIGGER SLOPE to + and observe low-to-high transitions.

HORIZONTAL TIMING

SEC/DIV	Display
1 ms w/X10 MAG	1/2 cycle / 10 div
100 ms - 100 ns	5 cycles / 10 div
50 ns	2 cycles / 8 div
20 ns	1 cycle / 10 div
10 ns	proportional stretching of CALIBRATOR signal
5 ns (2465 only)	

3. Measure 4 cycles of the CALIBRATOR waveform at sweep speeds from 100 ms/div to 100 ns/div. Results should be 8 times the A SEC/DIV setting within 0.9% using Δt cursors or within 0.5% using B Delayed sweep. Displays from above table should match the graticule within 1/2 minor division, 1 minor division with X10 MAG.

• **Probe Compensation**

1. Obtain a 4-division, 1 kHz CALIBRATOR display on both CH 1 and CH 2 using the probes to be compensated (VOLTS/DIV = 100 mV, A and B SEC/DIV = 1 ms).
2. Adjust the probe-compensation caps for optimum (flat) front corner.
3. Probes used on CH 3 or CH 4 should be compensated on CH 1 or CH 2, then moved to channel of use.

• **CH 2 Delay Adjust** — Match vertical delays, including probes.

1. Connect both CH 1 and CH 2 inputs to a fast-rise pulse generator. Use the probes that will be used for measurements.
2. Set A and B SEC/DIV controls to 5 ns (10 ns for 2445).
3. With both channels displayed, vertically superimpose the signals.
4. Pull out the B SEC/DIV knob and push in the X10 MAG button.
5. Adjust the Δ control until the two signals are superimposed horizontally.

ACCURACY SPECIFICATIONS

+15° C TO +35° C

ΔV:	±(1.25% of measurement +0.4% of full scale)
V/DIV on graticule:	±2%
Δt with cursors ² :	±(0.5% of measurement +0.3% of full scale)
—with X10 MAG on:	±(1% of measurement +0.3% of full scale)
Δt with delayed sweep:	±(0.3% of measurement +0.1% of maximum delay)
SEC/DIV on graticule:	±(0.7% of measurement +0.6% of full scale)
—with X10 MAG on:	±(1.2% of meas. +0.6% of full scale)
—with VAR (or at 1 sec/div with 2445):	Add ±2%

²Δt with cursors provides better accuracy than Δt with delayed sweep for intervals shorter than 10 ns (20 ns with 2445).

- **Frequency**

1. Press both ΔV and Δt together to enable $1/\Delta t$ mode.
2. Separate the cursors by exactly one cycle on the waveform and read frequency.

- **Slew Rate**

1. Press both ΔV and Δt together to enable $1/\Delta t$ mode.
2. Position cursors to points on signal transition separated by 1 volt (other voltages require scaling of the readings).
3. Read slew rate, interpreting "Hz" as "volts/second".

- **Rise Time**

1. Set step amplitude to 5 divisions and align 0% and 100% levels with corresponding graticule lines.
2. Position Δt cursors to the points on the transition that intersect the 10% and 90% graticule lines and read rise time.

- **Time Ratio**

1. Set A SEC/DIV VAR for one cycle over 5 horizontal divisions.
2. Push the Δt button to enable Δt RATIO.
3. Move the cursors to the points of interest on the waveform.
4. Read RATIO in percent (e.g., duty factor).

- **Phase Difference**

1. Set A SEC/DIV VAR for one cycle over 5 horizontal divisions.
2. Press both Δt and ΔV simultaneously to enable PHASE.
3. Place the cursors at identical points on two waveforms displayed with a single trigger source.
4. Read PHASE shift (in degrees).

- **Small-Angle Phase Differences or Low Duty Factors**

1. Set A SEC/DIV VAR for one cycle over 5 horizontal divisions.
2. Press X10 MAG to expand phase difference or pulse width.
3. Measure magnified PHASE or time RATIO with cursors.
4. Divide reading by 10.

- **Horizontal Display Modes and Timing Measurements**

- A Sweep**

1. Lock the SEC/DIV knobs together. This enables cursors. The VAR SEC/DIV control will affect A Sweep.

- A Intensified**

1. Pull out the B SEC/DIV knob (PULL-INT).
2. Set B TRIG MODE to RUN AFT DLY.
3. Position the intensified zone using the DLY POS control.
4. Read time interval (delay) from start of A Sweep.

- A - B Alternate**

1. Perform steps in A Intensified.
2. Rotate the B SEC/DIV control to a faster sweep speed to expand the point of interest. Readjust DLY POS as required to keep point of interest on screen.
3. Adjust TRACE SEP to vertically position B Sweep.

NOTE: X10 MAG will affect B Sweep only.

- B Delayed**

1. Perform steps in A - B Alternate (above).
2. Push in the B SEC/DIV control to display the B Sweep alone.

NOTE: If Δt or $1/\Delta t$ is active, TRACE SEP positions the trace associated with the Δ control.

- Delayed Sweep - Δt , $1/\Delta t$**

1. Set up A Intensified, A - B Alternate, or B Delayed display (explained above).
2. Press Δt button to activate Δt measurement or both ΔV and Δt together to activate $1/\Delta t$ measurement.
3. Set Δ REF and Δ to intensify and expand the points on the waveform that define the time interval. Superimpose the expanded points.
4. Read time interval or frequency.

NOTE: This method is more accurate than cursors for intervals greater than 10 ns with the 2465 (or 20 ns with the 2445) if the B SEC/DIV is at least 20 times faster than A SEC/DIV.

MEASUREMENT TECHNIQUES

In order to obtain the best measurement accuracies, set the VOLTS/DIV and SEC/DIV controls for the largest convenient display of the waveform. Set VAR controls in their fully CW, detented positions except where otherwise noted.

• Voltage

1. Push the ΔV button to enable Delta Volts cursors.
2. Position cursors to desired measurement points of waveform using Δ REF and Δ controls and read voltage difference.

• Voltage From Ground

1. Set input coupling to GND.
2. Superimpose the ΔV reference cursor on the GND trace.
3. Set the input coupling to DC.
4. Set the Δ cursor to the point of interest and read voltage.

• Voltage Ratio

1. Set CH 1 or CH 2 VOLTS/DIV and VARIABLE for exactly 5 divisions of amplitude.
2. Align ΔV cursors with points of interest on waveform and read RATIO.

• Differential Voltage

1. Apply signal of interest to CH 1 input.
2. Apply component to be subtracted to CH 2.
3. Set CH 1, CH 2, and INVERT VERTICAL MODE.
4. Set both VOLTS/DIV equally with less than 8 divisions of signal displayed on either channel.
5. Select ADD and release the CH 1 and CH 2 buttons.
6. Perform Voltage measurement as described above.

• Time Interval

1. Push Δt button to display Delta Time cursors.
2. Position cursors to points of interest and read time difference.