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Algebraic Addition

With the VERTICAL MODE switches set to BOTH and ADD, the waveform displayed is the algebraic sum of the signals applied to the Channel 1 and Channel 2 inputs (CH 1 + CH 2). If the Channel 2 INVERT push button is pressed in, the waveform displayed is the difference between the signals applied to the Channel 1 and Channel 2 inputs (CH 1 − CH 2). The total deflection factor in the ADD mode is equal to the deflection factor indicated by either VOLTS/DIV switch (when both VOLTS/DIV switches are set to the same deflection factor). A common use for the ADD mode is to provide a dc offset for a signal riding on top of a high dc level.

The following general precautions should be observed when using the ADD mode.

a. Do not exceed the input voltage rating of the oscilloscope.

b. Do not apply signals that exceed the equivalent of about eight times the VOLTS/DIV switch settings, since large voltages may distort the display. For example, with a VOLTS/DIV switch setting of 0.5, the voltage applied to that channel should not exceed approximately 4 volts.

c. Use Channel 1 and Channel 2 POSITION control settings which most nearly position the signal on each channel to midscreen, when viewed in either CH 1 or CH 2 VERTICAL MODE. This ensures the greatest dynamic range for ADD mode operation.

d. To attain similar response from each channel, set both the Channel 1 and Channel 2 AC-GND-DC switches to the same position.

EXAMPLE: Using the graticule center line as 0 V, the Channel 1 signal is at a 3-division, positive dc level (see Figure 13A).

1. Multiply 3 divisions by the VOLTS/DIV switch setting to determine the dc-level value.

2. To the Channel 2 input connector, apply a negative dc level (or positive level, using the Channel 2 INVERT switch) whose value was determined in step 1 (see Figure 13B).

3. Select ADD and BOTH VERTICAL MODE to place the resultant display within the operating range of the vertical POSITION controls (see Figure 13C).

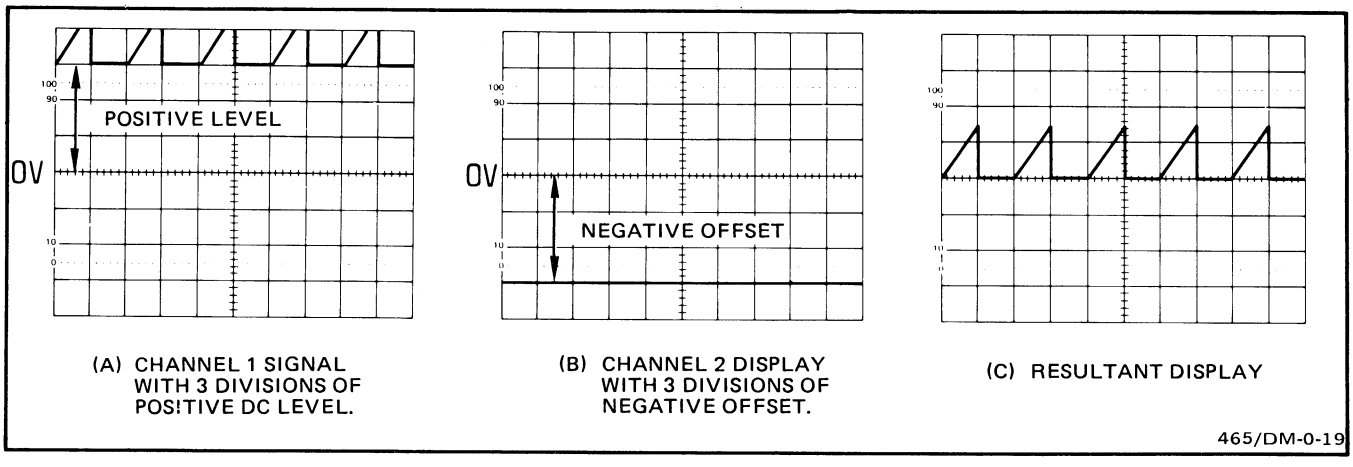


Figure 13. Algebraic addition.

Common-Mode Rejection

The ADD mode can also be used to display signals that contain undesirable frequency components. The undesirable components can be eliminated through common-mode rejection. The precautions given under the preceding "Algebraic Addition" procedure should be observed.

EXAMPLE: The signal applied to the Channel 1 input connector contains unwanted ac-input-power-source frequency components (see Figure 14A). To remove the undesired components, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal containing the unwanted line-frequency components to the Channel 1 input.

3. Apply a line-frequency signal to the Channel 2 input.

4. Select BOTH and ALT VERTICAL MODE and press in the Channel 2 INVERT push button.

5. Adjust the Channel 2 VOLTS/DIV switch and Variable control so that the Channel 2 display is approximately the same amplitude as the undesired portion of the Channel 1 display (see Figure 14A).

6. Select ADD VERTICAL MODE and slightly readjust the Channel 2 VOLTS/DIV Variable control for maximum cancellation of the undesired signal component (see Figure 14B).

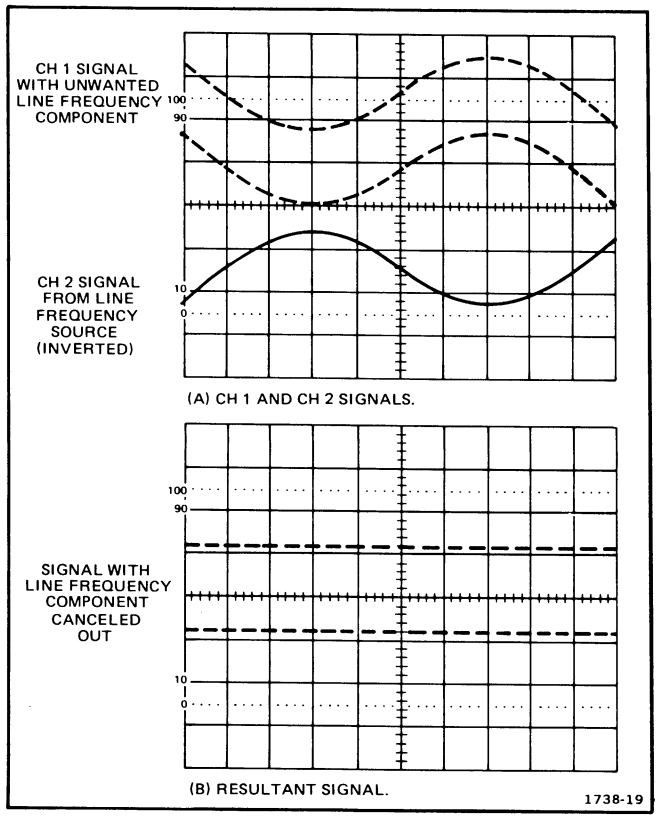


Figure 14. Common-mode rejection.

Time Duration

To measure time between two points on a waveform, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used.

3. Adjust the A TRIGGER LEVEL control to obtain a stable display.

4. Set the A SEC/DIV switch to display one complete period of the waveform. Ensure that the A and B SEC/DIV Variable control is in the CAL detent.

5. Position the display to place the time-measurement points on the center horizontal graticule line (see Figure 15).

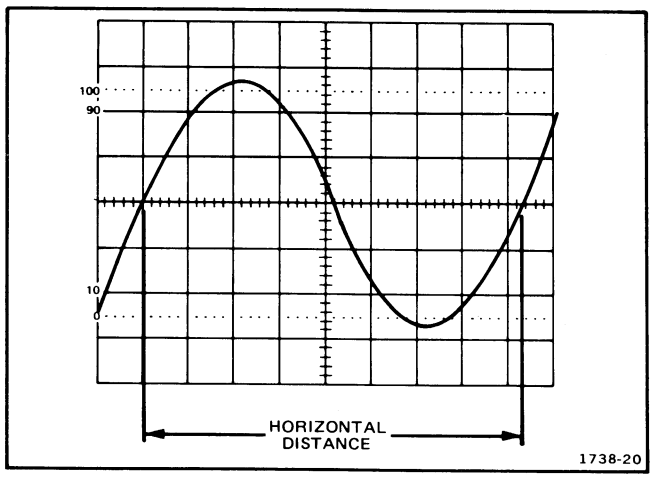


Figure 15. Time duration.

6. Measure the horizontal distance between the time-measurement points.

7. Calculate time duration, using the following formula:

$$\text{Time Duration} = \frac{\text{horizontal distance (divisions)} \times \text{A SEC/DIV switch setting}}{\text{magnification factor}}$$

EXAMPLE: The distance between the time-measurement points is 8.3 divisions (see Figure 15), and the A SEC/DIV switch is set to 2 ms. The X10 Magnifier switch is pushed in (1X magnification).

Substituting the given values:

Time Duration = 8.3 div x 2 ms/div = 16.6 ms

Frequency

The frequency of a recurrent signal can be determined from its time-duration measurement as follows:

1. Measure the time duration of one waveform cycle using the preceding "Time Duration" measurement procedure.

2. Calculate the reciprocal of the time-duration value to determine the frequency of the waveform.

EXAMPLE: The signal in Figure 15 has a time duration of 16.6 ms.

Calculating the reciprocal of time duration:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{16.6\ \text{ms}} = 60\ \text{Hz}$$

Rise Time

Rise-time measurements use the same methods as time duration, except that the measurements are made between the 10% and 90% points on the leading edge of the waveform (see Figure 16). Fall time is measured between the 90% and 10% points on the trailing edge of the waveform.

1. Preset instrument controls and obtain a baseline trace.

2. Apply an exact 5-division signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used. Ensure that the VOLTS/DIV Variable control is in the CAL detent.

NOTE

For rise time greater than 0.2 μs, the VOLTS/DIV Variable control may be used to obtain an exact 5-division display.

3. Set the A TRIGGER SLOPE switch to ⎍ (plus). Use a sweep-speed setting that displays several complete cycles or events (if possible).

4. Adjust vertical positioning so that the zero reference of the waveform touches the 0% graticule line and the top of the waveform touches the 100% graticule line (see Figure 16).

5. Set the A SEC/DIV switch for a single-waveform display, with the rise time spread horizontally as much as possible.

6. Horizontally position the display so the 10% point on the waveform intersects the second vertical graticule line (see Figure 16, Point A).

7. Measure the horizontal distance between the 10% and 90% points and calculate the time duration using the following formula:

$$\text{Rise Time} = \frac{\text{horizontal distance (divisions)} \times \text{A SEC/DIV switch setting}}{\text{magnification factor}}$$

EXAMPLE: The horizontal distance between the 10% and 90% points is 5 divisions (see Figure 16), and the A SEC/DIV switch is set to 1 μs. The X10 magnifier knob is pushed in (1X magnification).

Substituting the given values in the formula:

$$\text{Rise Time} = \frac{5\ \text{div} \times 1\ \mu\text{s/div}}{1} = 5\ \mu\text{s}$$

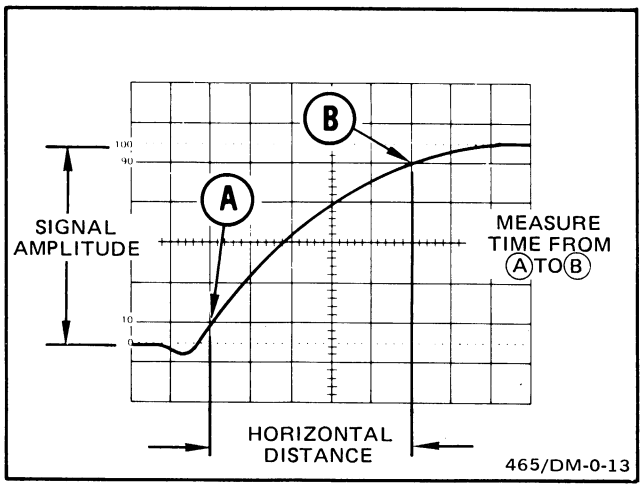


Figure 16. Rise time.

Time Difference Between Two Time-Related Pulses

The calibrated sweep speed and dual-trace features of the 2215 allow measurement of the time difference between two separate events. To measure time difference, use the following procedure:

1. Preset instrument controls and obtain a baseline trace.

2. Set the A TRIGGER SOURCE switch to CH 1.

3. Set both AC-GND-DC switches to the same position, depending on the type of input coupling desired.

4. Using either probes or cables with equal time delays, connect a known reference signal to the Channel 1 input and the comparison signal to the Channel 2 input.

5. Set both VOLTS/DIV switches for 4- or 5-division displays.

6. Select BOTH VERTICAL MODE; then select either ALT or CHOP, depending on the frequency of input signals.

7. If the two signals are of opposite polarity, press in the Channel 2 INVERT push button to invert the Channel 2 display (signals may be of opposite polarity due to 180° phase difference; if so, note this for use later in the final calculation).

8. Adjust the A TRIGGER LEVEL control for a stable display.

9. Set the A SEC/DIV switch to a sweep speed which provides three or more divisions of horizontal separation between the reference points on the two displays. Center each of the displays vertically (see Figure 17).

10. Measure the horizontal difference between the two signal reference points and calculate the time difference using the following formula:

$$\text{Time Difference} = \frac{\text{A SEC/DIV switch setting} \times \text{horizontal difference (divisions)}}{\text{magnification factor}}$$

EXAMPLE: The A SEC/DIV switch is set to 50 μs, the X10 magnifier knob is pulled out, and the horizontal difference between waveform measurement points is 4.5 divisions.

Substituting the given values in the formula:

$$\text{Time Difference} = \frac{50\ \mu\text{s/div} \times 4.5\ \text{div}}{10} = 22.5\ \mu\text{s}$$

Phase Difference

In a similar manner to "Time Difference," phase comparison between two signals of the same frequency can be made using the dual-trace feature of the 2215. This method of phase difference measurement can be used up to the frequency limit of the vertical system. To make a phase comparison, use the following procedure:

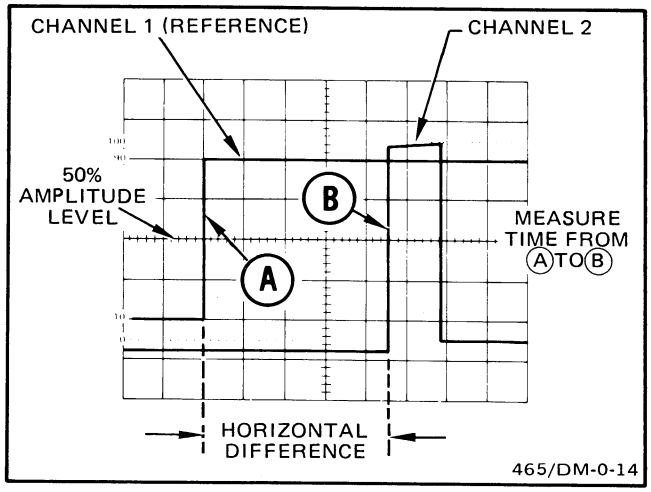


Figure 17. Time difference between two time-related pulses.

1. Preset instrument controls and obtain a baseline trace, then set the A TRIGGER SOURCE switch to CH 1.

2. Set both AC-GND-DC switches to the same position, depending on the type of input coupling desired.

3. Using either probes or coaxial cables with equal time delays, connect a known reference signal to the Channel 1 input and the unknown signal to the Channel 2 input.

4. Select BOTH VERTICAL MODE; then select either ALT or CHOP, depending on the frequency of the input signals. The reference signal should precede the comparison signal in time.

5. If the two signals are of opposite polarity, press in the Channel 2 INVERT push button to invert the Channel 2 display.

6. Set both VOLTS/DIV switches and both Variable controls so the displays are equal in amplitude.

7. Adjust the A TRIGGER LEVEL control for a stable display.

8. Set the A SEC/DIV switch to a sweep speed which displays about one full cycle of the waveforms.

9. Position the displays and adjust the A and B SEC/DIV Variable control so that one reference-signal cycle occupies exactly 8 horizontal graticule divisions at the 50% rise-time points (see Figure 18). Each division of the graticule now represents 45° of the cycle (360° ÷ 8 divisions), and the horizontal graticule calibration can be stated as 45° per division.

10. Measure the horizontal difference between corresponding points on the waveforms at a common horizontal graticule line (50% of rise time) and calculate the phase difference using the following formula:

$$\text{Phase Difference} = \text{horizontal difference (divisions)} \times \text{horizontal graticule calibration (deg/div)}$$

EXAMPLE: The horizontal difference is 0.6 division with a graticule calibration of 45° per division as shown in Figure 18.

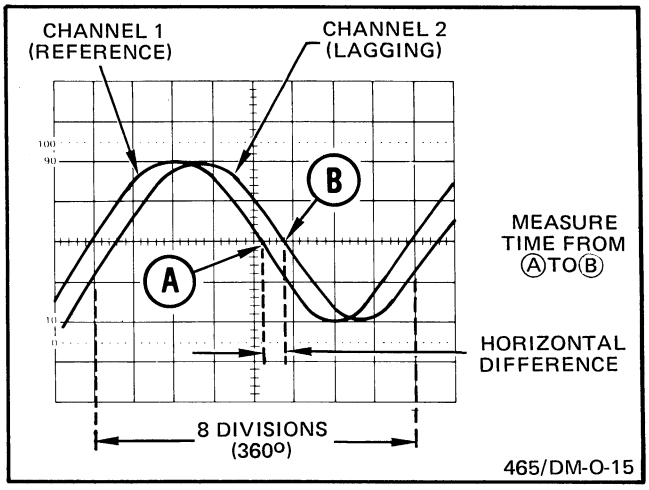


Figure 18. Phase difference.

Substituting the given values into the phase difference formula:

Phase Difference = 0.6 div x 45°/div = 27°

More accurate phase measurements can be made by using the X10 Magnifier function to increase the sweep speed without changing the A and B SEC/DIV Variable control setting.

EXAMPLE: If the sweep speed were increased 10 times with the magnifier (X10 Magnifier out), the magnified horizontal graticule calibration would be 45°/division divided by 10 (or 4.5°/division). Figure 19 shows the same signals illustrated in Figure 18, but magnifying the displays results in a horizontal difference of 6 divisions between the two signals.

Substituting the given values in the phase difference formula:

Phase Difference = 6 div x 4.5°/div = 27°

Amplitude Comparison

In some applications it may be necessary to establish a set of deflection factors other than those indicated by the VOLTS/DIV switch settings. This is useful for comparing unknown signals to a reference signal of known amplitude. To accomplish this, a reference signal of known amplitude is first set to an exact number of vertical divisions by adjusting the VOLTS/DIV switch and Variable control. Unknown signals can then be quickly and accurately compared with the reference signal without disturbing the setting of the VOLTS/DIV Variable control. The procedure is as follows.

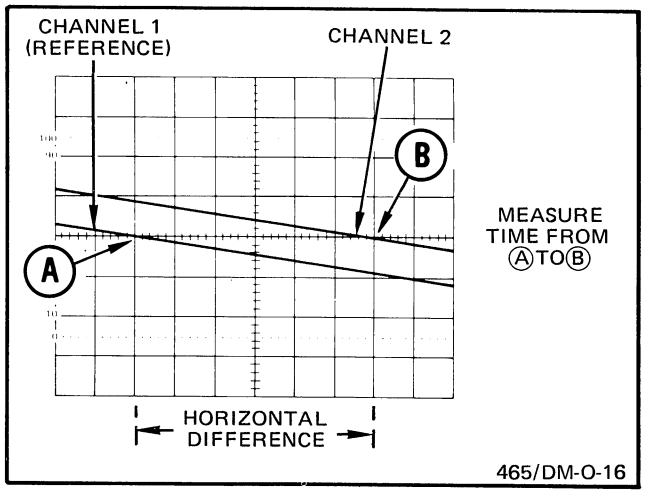


Figure 19. High-resolution phase difference.

1. Preset instrument controls and obtain a baseline trace.

2. Apply the reference signal to either vertical channel input and set the VERTICAL MODE switch to display the channel used.

3. Set the amplitude of the reference signal to an exact number of vertical divisions by adjusting the VOLTS/DIV switch and VOLTS/DIV Variable control.

4. Establish a vertical conversion factor, using the following formula (reference signal amplitude must be known):

$$\text{Vertical Conversion Factor} = \frac{\text{reference signal amplitude (volts)}}{\text{vertical deflection (divisions)} \times \text{VOLTS/DIV switch setting}}$$

5. Disconnect the reference signal and apply the unknown signal to be measured to the same channel input. Adjust the VOLTS/DIV switch to a setting that provides sufficient vertical deflection to make an accurate measurement. Do not readjust the VOLTS/DIV Variable control.

6. Establish an arbitrary deflection factor, using the following formula:

$$\text{Arbitrary Deflection Factor} = \text{vertical conversion factor} \times \text{VOLTS/DIV switch setting}$$

7. Measure the vertical deflection of the unknown signal in divisions and calculate its amplitude using the following formula:

$$\text{Unknown Signal Amplitude} = \frac{\text{arbitrary deflection factor} \times \text{vertical deflection (divisions)}}{}$$

EXAMPLE: The reference signal amplitude is 30 V, with a VOLTS/DIV switch setting of 5 and the VOLTS/DIV Variable control adjusted to provide a vertical deflection of exactly 4 divisions.

Substituting these values in the vertical conversion factor formula:

$$\text{Vertical Conversion Factor} = \frac{30\text{ V}}{4\text{ div} \times 5\text{ V/div}} = 1.5$$

Continuing, for the unknown signal the VOLTS/DIV switch setting is 1, and the peak-to-peak amplitude spans five vertical divisions. The arbitrary deflection factor is then determined by substituting values in the formual:

$$\text{Arbitrary Deflection Factor} = 1.5 \times 1\text{ V/div} = 1.5\text{ V/div}$$

The amplitude of the unknown signal can then be determined by substituting values in the unknown signal amplitude formula:

$$\text{Amplitude} = 1.5\text{ V/div} \times 5\text{ div} = 7.5\text{ V}$$

Time Comparison

In a similar manner to "Amplitude Comparison," repeated time comparisons between unknown signals and a reference signal (e.g., on assembly line test) may be easily and accurately measured with the 2215. To accomplish this, a reference signal of known time duration is first set to an exact number of horizontal divisions by adjusting the A SEC/DIV switch and the A and B SEC/DIV Variable control. Unknown signals can then be compared with the reference signal without disturbing the setting of the A and B SEC/DIV Variable control. The procedure is as follows:

1. Set the time duration of the reference signal to an exact number of horizontal divisions by adjusting the A SEC/DIV switch and the A and B SEC/DIV Variable control.

2. Establish a horizontal conversion factor, using the following formula (reference signal time duration must be known):

$$\text{Horizontal Conversion Factor} = \frac{\text{reference signal time duration (seconds)}}{\text{horizontal distance (divisions)} \times \text{A SEC/DIV switch setting}}$$

3. For the unknown signal, adjust the A SEC/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the A and B SEC/DIV Variable control.

4. Establish an arbitrary deflection factor, using the following formula:

$$\text{Arbitrary Deflection Factor} = \text{horizontal conversion factor} \times \text{A SEC/DIV switch setting}$$

5. Measure the horizontal distance of the unknown signal in divisions and calculate its time duration using the following formula:

$$\text{Time Duration} = \text{arbitrary deflection factor} \times \text{horizontal distance (divisions)}$$

6. Frequency of the unknown signal can then be determined by calculating the reciprocal of its time duration.

EXAMPLE: The reference signal time duration is 2.19 ms, the A SEC/DIV switch setting is 0.2 ms, and the A and B SEC/DIV Variable control is adjusted to provide a horizontal distance of exactly 8 divisions.

Substituting the given values in the horizontal conversion factor formula:

$$\text{Horizontal Conversion Factor} = \frac{2.19\ \text{ms}}{8\ \text{div} \times 0.2\ \text{ms/div}} = 1.37$$

Continuing, for the unknown signal the A SEC/DIV switch setting is 50 μs, and one complete cycle spans 7 horizontal divisions. The arbitrary deflection factor is then determined by substituting values in the formula:

$$\text{Arbitrary Deflection Factor} = 1.37 \times 50\ \mu\text{s/div} = 68.5\ \mu\text{s/div}$$

The time duration of the unknown signal can then be computed by substituting values in the formula:

$$\text{Time Duration} = 68.5\ \mu\text{s/div} \times 7\ \text{div} = 480\ \mu\text{s}$$

The frequency of the unknown signal is then calculated:

$$\text{Frequency} = \frac{1}{480\ \mu\text{s}} = 2.083\ \text{kHz}$$

DELAYED-SWEEP MAGNIFICATION

The delayed-sweep feature of the 2215 can be used to provide higher apparent magnification than is provided by the X10 Magnifier switch. Apparent magnification occurs as a result of displaying a selected portion of the A trace at a faster sweep speed (B Sweep speed). The A SEC/DIV switch setting determines how often the B trace will be displayed. Since the B Sweep can occur only once for each A Sweep, the A Sweep time duration sets the amount of time elapse between succeeding B Sweeps.

The intensified zone is an indication of both the location and length of the B Sweep interval within the A Sweep interval. Positioning of the intensified zone (i.e., setting the amount of time between start of the A Sweep and start of the B Sweep) is accomplished with the B DELAY TIME POSITION control. With either ALT or B HORIZONTAL MODE selected, the B DELAY TIME POSITION control provides continuously variable positioning of the start of the B Sweep. The range of this control is sufficient to place the B Sweep interval at any location within the A Sweep interval. When ALT HORIZONTAL MODE is selected, the B SEC/DIV switch setting determines the B Sweep speed and concurrently sets the length of the intensified zone on the A trace.

Using delayed-sweep magnification may produce a display with some slight horizontal movement (pulse jitter). Pulse jitter includes not only the inherent uncertainty of triggering the delayed sweep at exactly the same trigger point each time, but also jitter that may be present in the input signal. If pulse jitter needs to be measured, use the "Pulse Jitter Time Measurement" procedure which follows the discussion of "Magnified Sweep Runs After Delay."

Magnified Sweep Runs After Delay

The following procedure explains how to operate the B Sweep in a nontriggered mode and to determine the resulting apparent magnification factor.

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal to either vertical channel input connector and set the VERTICAL MODE switch to display the channel used.

3. Set the appropriate VOLTS/DIV switch to produce a display of approximately 2 or 3 divisions in amplitude and center the display.

4. Set the A SEC/DIV switch to a sweep speed which displays at least one complete waveform cycle.

5. Select ALT HORIZONTAL MODE. Adjust both the appropriate channel POSITION control and the A/B SWP SEP control to display the A trace above the B trace.

6. Adjust the B DELAY TIME POSITION control to position the start of the intensified zone to the portion of the display to be magnified (see Figure 20).

7. Set the B SEC/DIV switch to a setting which intensifies the full portion of the A trace to be magnified. The intensified zone will be displayed as the B trace (see Figure 20). The B HORIZONTAL MODE may also be used to magnify the intensified portion of the A Sweep.

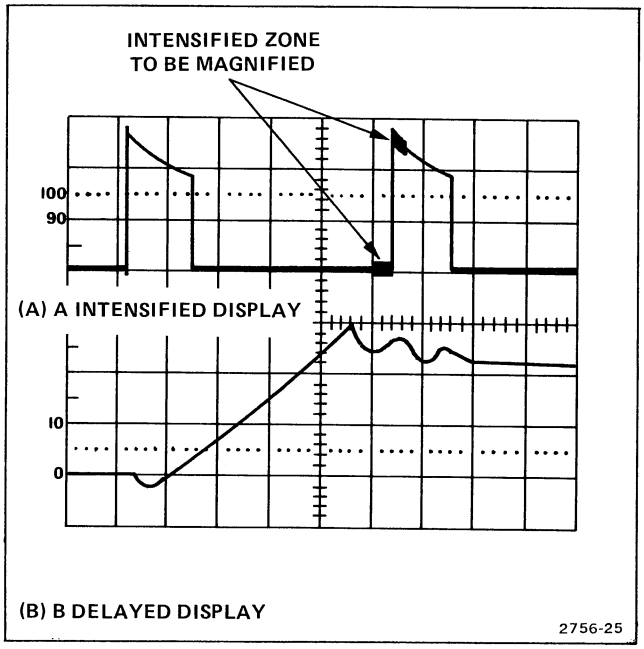


Figure 20. Delayed-sweep magnification.

8. The apparent sweep magnification can be calculated from the following formula:

$$\text{Apparent Delayed Sweep Magnification} = \frac{\text{A SEC/DIV switch setting}}{\text{B SEC/DIV switch setting}}$$

EXAMPLE: Determine the apparent magnification of a display with an A SEC/DIV switch setting of 0.1 ms and a B SEC/DIV switch setting of 1 μs.

Substituting the given values:

$$\text{Apparent Magnification} = \frac{1 \times 10^{-4}\ \text{s}}{1 \times 10^{-6}\ \text{s}} = 10^2 = 100$$

Pulse Jitter Time Measurement

To measure pulse jitter time:

1. Perform steps 1 through 7 of the preceding "Magnified Sweep Runs After Delay" procedure.

2. Referring to Figure 21, measure the difference between Point A and Point B in divisions and calculate the pulse jitter time using the following formula:

$$\text{Pulse Jitter Time} = \text{horizontal difference (divisions)} \times \text{B SEC/DIV switch setting}$$

Triggered Magnified Sweep

The following procedure explains how to operate the B Sweep in a triggered mode and to determine the resulting apparent magnification factor. Operating the B Sweep in a triggered mode provides a more stable display, since the delayed display is triggered at the same point each time.

1. Perform steps 1 through 7 of the preceding "Magnified Sweep Runs After Delay" procedure.

NOTE

The intensified zone seen in the ALT HORIZONTAL MODE display will move from trigger point to trigger point as the B DELAY TIME POSITION control is rotated.

2. Adjust the B TRIGGER LEVEL control so the intensified zone on the A trace is stable.

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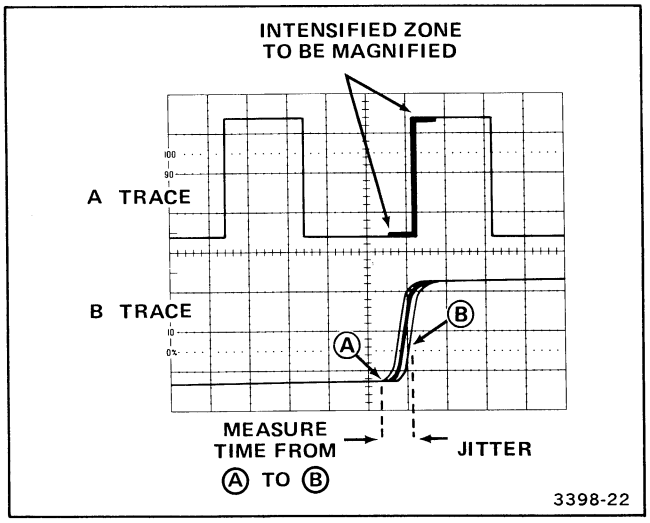


Figure 21. Pulse jitter.

3. The apparent magnification factor can be calculated from the formula shown in step 8 of the "Magnified Sweep Runs After Delay" procedure.

DELAYED-SWEEP TIME MEASUREMENTS

Operating the 2215 Oscilloscope with HORIZONTAL MODE set to either ALT or B will permit time measurements to be made with a greater degree of accuracy than attained with HORIZONTAL MODE set to A. The following procedures describe how these measurements are accomplished.

Time Difference Between Repetitive Pulses

1. Preset instrument controls and obtain a baseline trace.

2. Apply the signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used.

3. Set the appropriate VOLTS/DIV switch to produce a display of approximately 2 or 3 divisions in amplitude.

4. Set the A SEC/DIV switch to display the measurement points of interest within the graticule area.

5. Select ALT HORIZONTAL MODE and adjust both the appropriate channel POSITION control and A/B SWP SEP control to display the A trace above the B trace.

6. For the most accurate measurement, set the B SEC/DIV switch to the fastest sweep speed that provides a useable (visible) intensified zone.

7. Adjust the B DELAY TIME POSITION control to move the intensified zone to the leading edge of the first pulse (on the A trace); then fine adjust until the rising portion (on the B trace) is centered at any convenient vertical graticule line (see Figure 22).

8. Record the B DELAY TIME POSITION control dial setting.

9. Adjust the B DELAY TIME POSITION control clockwise to move the intensified zone to the leading edge of the second pulse (on the A trace); then fine adjust until the rising portion (on the B trace) is centered at the same convenient vertical graticule used in preceding step 7.

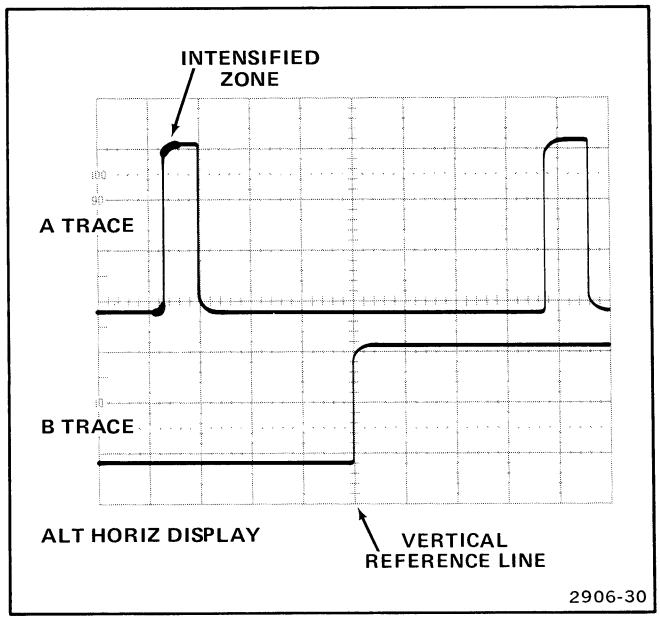


Figure 22. Time difference between repetitive pulses.

10. Record the B DELAY TIME POSITION control dial setting.

11. Calculate the time difference between repetitive pulses using the following formula.

$$\text{Time Difference (Duration)} = \begin{pmatrix}\text{second dial setting} - \text{first dial setting}\end{pmatrix} \begin{pmatrix}\text{A SEC/DIV switch setting}\end{pmatrix}$$

EXAMPLE: With the A SEC/DIV switch set to 0.2 ms, the first B DELAY TIME POSITION dial setting is 1.20 and the second B DELAY TIME POSITION dial setting is 9.53 (see Figure 23).

Substituting the given values in the time difference formula:

Time Difference = (9.53 – 1.20) (0.2 ms) = 1.666 ms

Rise Time

The measurement method for rise time is the same as for time difference between repetitive pulses, except that the measurements are made between the 10% and 90% points on the leading edge of the waveform. Fall time is measured between the 90% and 10% points on the trailing edge of the waveform.

1. Preset instrument controls and obtain a baseline trace.

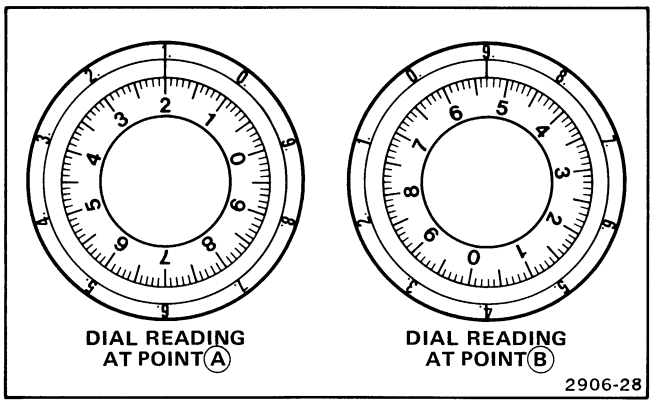


Figure 23. B DELAY TIME POSITION control settings.

2. Apply a 5-division signal to either vertical-channel input connector and set the VERTICAL MODE switch to display the channel used. Ensure that the VOLTS/DIV Variable control is in the CAL detent.

NOTE

For rise time less than 0.2 µs per division, the VOLTS/DIV Variable control may be used to obtain an exact 5-division display.

3. Vertically position the trace so that the zero reference of the waveform touches the 0% graticule line and the top of the waveform touches the 100% graticule line (see Figure 24).

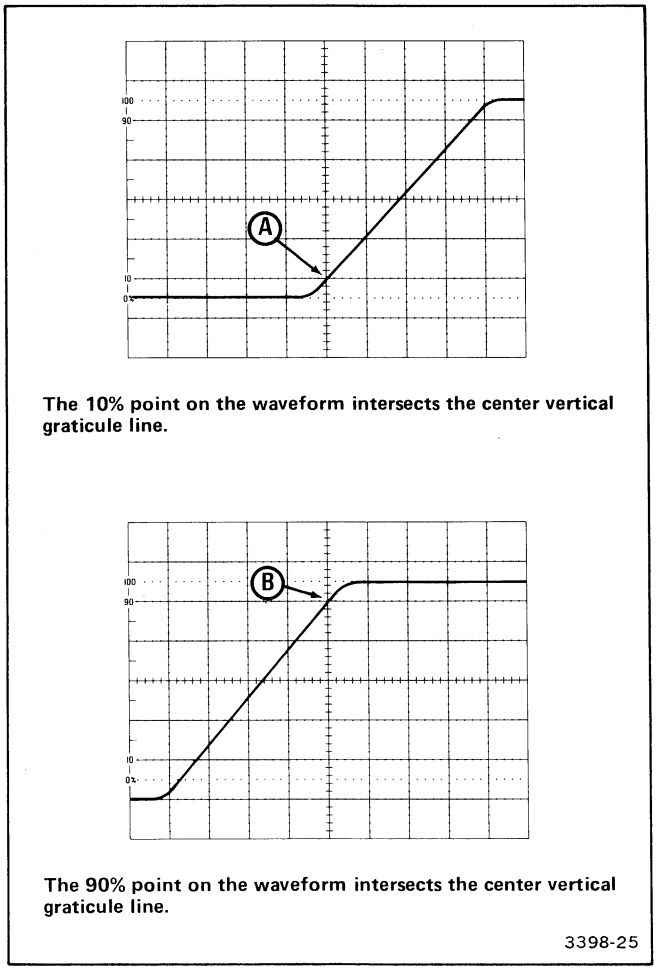


Figure 24. Rise time, differential time method.

4. Set the A SEC/DIV switch for a single-waveform display. Ensure that the A and B SEC/DIV Variable control is in the CAL detent.

5. Select ALT HORIZONTAL MODE and set the B SEC/DIV switch to spread the rise-time-measurement portion of the display as much as possible.

6. Select the B HORIZONTAL MODE. Adjust the B DELAY TIME POSITION control until the display intersects the 10% point at the center vertical graticule line (see Figure 24, Point A).

7. Record the B DELAY TIME POSITION control dial setting.

8. Adjust the B DELAY TIME POSITION control until the display intersects the 90% point at the center vertical graticule line (see Figure 24, Point B).

9. Record the B DELAY TIME POSITION control dial setting.

10. Calculate rise time using the same formula listed in the "Time Difference Between Repetitive Pulses" measurement procedure.

EXAMPLE: With the A SEC/DIV switch set to 1 μs, the first B DELAY TIME POSITION dial setting (Point A) is 2.50 and the second B DELAY TIME POSITION dial setting (Point B) is 7.50.

Substituting the given values in the time difference formula:

Rise Time = (7.50 – 2.50) (1 μs) = 5 μs

Time Difference Between Two Time-Related Pulses

1. Preset instrument controls and obtain a baseline trace.

2. Using probes or cables having equal time delays, apply the reference signal to the Channel 1 input and apply the comparison signal to the Channel 2 input.

3. Set both VOLTS/DIV switches to produce a display of either 2 or 3 divisions in amplitude.

4. Select BOTH VERTICAL MODE and either ALT or CHOP, depending on the frequency of the input signals.

5. Set the A SEC/DIV switch to display the measurement points of interest within the graticule area.

6. Select ALT HORIZONTAL MODE and CH 1 VERTICAL MODE. Adjust both the Channel 1 POSITION control and the A/B SWP SEP control so that the A trace is displayed above the B trace.

7. Rotate the B DELAY TIME POSITION control to move the intensified zone to the rising edge of the reference pulse (on the A trace); then fine adjust until the rising portion (on the B trace) is centered at any convenient vertical graticule line (see Figure 25, point A).

8. Record the B DELAY TIME POSITION control dial setting.

9. Select CH 2 VERTICAL MODE and adjust both the Channel 2 POSITION control and the A/B SWP SEP control as necessary to display the A trace above the B trace.

10. Rotate the B DELAY TIME POSITION control to set the rising portion of the Channel 2 pulse (on the B trace) to the same vertical reference point as used in preceding step 7 (see Figure 25, Point B). Observe the A trace to position the intensified zone to the correct pulse (if more than one pulse is displayed). Do not change the setting of the Horizontal POSITION control.

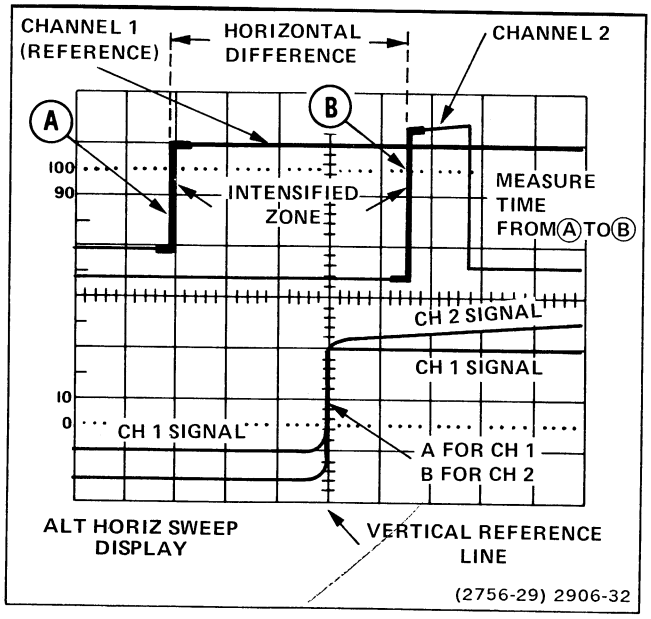


Figure 25. Time difference between two time-related pulses, differential time method.

11. Record the B DELAY TIME POSITION control dial setting.

12. Calculate the time difference between the Channel 1 and Channel 2 pulses as in the preceding "Time Difference Between Repetitive Pulses" measurement procedure.

EXAMPLE: With the A SEC/DIV switch set to 50 μs, the dial reading for the reference pulse (Channel 1) is 2.60 and the dial reading for the comparison pulse (Channel 2) is 7.10.

Substituting the given values into the time difference (or duration) formula:

Time Difference = (7.10 − 2.60) (50 μs) = 225 μs

SPECIFICATION

The following electrical characteristics (Table 2) are valid for the 2215 when it has been adjusted at an ambient temperature between +20°C and +30°C, has had a warm-up period of at least 20 minutes, and is operating at an ambient temperature between 0°C and +50°C (unless otherwise noted).

Item listed in the "Performance Requirements" column are verifiable qualitative or quantitative limits, while items listed in the "Supplemental Information" column are either explanatory notes, calibration setup descriptions, performance characteristics for which no absolute limits are specified, or characteristics that are impractical to check.

Environmental characteristics are given in Table 3. The 2215 meets the requirements of MIL-T-28800B, Class 5 equipment, except where otherwise noted.

Physical characteristics of the instrument are listed in Table 4.

@

Table 2

Electrical Characteristics

Characteristics	Performance Requirements	Supplemental Information
VERTICAL DEFLECTION SYSTEM		
Deflection Factor		1X gain adjusted with VOLTS/DIV switch set to 20 mV per division. 10X gain adjusted with VOLTS/DIV switch set to 2 mV per division.
Range	2 mV per division to 10 V per division in a 1-2-5 sequence.	
Accuracy		
+20°C to +30°C	±3%.	
0°C to +50°C	±4%.[a]	
Range of VOLTS/DIV Variable Control.	Continuously variable between settings. Increases deflection factor by at least 2.5 to 1.	
Step Response		Measured with a vertically centered 5-division reference signal from a 50-Ω source driving a 50-Ω coaxial cable that is terminated in 50 Ω at the input connector, with the VOLTS/DIV Variable control in its CAL detent.
Rise Time		5.8 ns or less. Rise time is calculated from the formula: $\text{Rise Time} = \frac{0.35}{\text{BW (in MHz)}}$
Bandwidth		Measured with a vertically centered 6-division reference signal from a 50-Ω source driving a 50-Ω coaxial cable that is terminated in 50 Ω, both at the input connector and at the P6120 probe input, with the VOLTS/DIV Variable control in its CAL detent.
0°C to +40°C		
20 mV to 10 V per Division	Dc to at least 60 MHz.	
2 mV to 10 mV per Division	Dc to at least 50 MHz.	
+40°C to +50°C		
2 mV to 10 V per Division	Dc to at least 50 MHz.[a]	
Chop Mode Repetition Rate		250 kHz ±30%.

[a]Performance Requirement not checked in Service Manual.

Table 2 (cont)

Characteristics	Performance Requirements	Supplemental Information
VERTICAL DEFLECTION SYSTEM (cont)		
Input Characteristics Resistance	1 MΩ ±2%.[a]	
Capacitance	30 pF ±3 pF.[a]	
Maximum Safe Input Voltage ⚠ DC Coupled	400 V (dc + peak ac) or 800 V p-p ac to 1 kHz or less.[a]	
AC Coupled	400 V (dc + peak ac) or 800 V p-p ac to 1 kHz or less.[a]	
Common-Mode Rejection Ratio (CMRR)	At least 10 to 1 at 10 MHz.	Checked at 20 mV per division for common-mode signals of 8 divisions or less, with VOLTS/DIV Variable control adjusted for best CMRR at 50 kHz.
TRIGGER SYSTEM		
A Trigger Sensitivity AUTO and NORM	0.4 division internal or 50 mV external to 2 MHz, increasing to 1.5 divisions internal or 250 mV external at 60 MHz.	External trigger signal from a 50-Ω source driving a 50-Ω coaxial cable that is terminated in 50 Ω at the input connector. Will trigger on tv line sync components in NORM only: ⩾ 0.4 division internal or 50 mV p-p external.
AUTO Lowest Usable Frequency	20 Hz.[a]	
TV FIELD	2.0 divisions of composite video or composite sync.[a]	
B Trigger Sensitivity Internal	0.4 division to 2 MHz, increasing to 2.0 divisions at 60 MHz.	
External Input Maximum Input Voltage ⚠	400 V (dc + peak ac) or 800 V p-p ac at 1 kHz or less.[a]	
Input Resistance	1 MΩ ±2%.[a]	
Input Capacitance	30 pF ±3 pF.[a]	
AC Coupled	10 Hz or less at lower −3 dB point.[a]	

[a]**Performance Requirement not checked in Service Manual.**

Table 2 (cont)

Characteristics	Performance Requirements		Supplemental Information
TRIGGER SYSTEM (cont)			
LEVEL Control Range			
A Trigger (NORM)			
INT	On screen limits.[a]		
EXT and DC	At least ±2 V (4 V p-p).[a]		
EXT and DC ÷ 10	At least ±20 V (40 V p-p).[a]		
B Trigger			
Internal	On screen limits.[a]		
VAR HOLDOFF Control Range	Increases the A Sweep holdoff time by at least a factor of four.[a]		
HORIZONTAL DEFLECTION SYSTEM			
Sweep Rate			
Calibrated Range			
A Sweep	0.5 s per division to 0.05 μs per division in a 1-2-5 sequence. X10 Magnifier extends maximum sweep speed to 5 ns per division.		
B Sweep	50 ms per division to 0.05 μs per division in a 1-2-5 sequence. X10 Magnifier extends maximum sweep speed to 5 ns per division.		
Accuracy	**Unmagnified**	**Magnified**	Sweep accuracy applies over the center 8 divisions. Exclude the first 50 ns of the sweep for both magnified and unmagnified sweep speeds and exclude anything beyond the 100th magnified division.
+20°C to +30°C	±3%	±5%	
0°C to +50°C	±4%[a]	±6%[a]	
POSITION Control Range	Start of sweep to 100th division will position past the center vertical graticule line with X10 Magnifier.		
Variable Control Range	Continuously variable between calibrated settings. Extends both the A and B sweep speeds by at least a factor of 2.5.		
Delay Time	Applies to sweep-speed settings of 0.5 μs per division and slower.		Delay time is functional but is not calibrated at sweep-speed settings above 0.5 μs per division.
B DELAY TIME POSITION Control Range	Less than 0.5 division to more than 10 divisions.		

[a]**Performance Requirement not checked in Service Manual.**

Table 2 (cont)

Characteristics	Performance Requirements		Supplemental Information
HORIZONTAL DEFLECTION SYSTEM (cont)			
Delay Time (cont)			
Jitter	One part, or less, in 10,000 (0.01%) of the maximum available delay time.		
Dial Accuracy	±1.5% of full scale.		
X-Y OPERATION (X1 MAGNIFICATION)			
Deflection Factors			
Range	Same as Vertical Deflection System, with both VOLTS/DIV Variable controls in CAL detent.		
Accuracy	**X-Axis**	**Y-Axis**	Measured with a dc-coupled, 5-division reference signal.
+20°C to +30°C	±5%	±3%	
0°C to +50°C	±6%[a]	±4%[a]	
Bandwidth			Measured with a 5-division reference signal.
X-Axis	Dc to at least 2 MHz.		
Y-Axis	Same as Vertical Deflection System.		
Phase Difference Between X- and Y-Axis Amplifiers	±3° from dc to 50 kHz.[a]		With dc-coupled inputs.
PROBE ADJUST			
Signal at PROBE ADJUST Jack			
Voltage	0.5 V ±20%.		
Repetition Rate	1 kHz ±20%.[a]		
Z-AXIS INPUT			
Sensitivity	5 V causes noticeable modulation. Positive-going input signal decreases intensity.		
Usable Frequency Range	Dc to 5 MHz.[a]		
Maximum Safe Input Voltage	30 V (dc + peak ac) or 30 V p-p ac at 1 kHz or less.[a]		
Input Impedance	10 kΩ ±10%.[a]		

[a]**Performance Requirement not checked in Service Manual.**

Table 2 (cont)

Characteristics	Performance Requirements	Supplemental Information
POWER SOURCE		
Line Voltage Range	90 V to 250 V.[a]	
Line Frequency Range	48 Hz to 62 Hz.[a]	
Maximum Power Consumption	50 W.[a]	
Line Fuse	2 A, 250 V, fast.	
CATHODE-RAY TUBE		
Display Area	80 by 100 mm.[a]	
Standard Phosphor	P31.[a]	
Nominal Accelerating Voltage	10,000 V.[a]	

[a]**Performance Requirement not checked in Service Manual.**

Table 3

Environmental Characteristics

Characteristics	Description
	NOTE *The instrument meets all of the following MIL-T-28800B requirements for Class 5 equipment.*
Temperature	
Operating	0°C to +50°C (+32°F to +122°F).
Nonoperating	−55°C to +75°C (−67°F to +167°F).
Altitude	
Operating	To 4,500 m (15,000 ft). Maximum operating temperature decreased 1°C per 300 m (1,000 ft) above 1,500 m (5,000 ft).
Nonoperating	To 15,000 m (50,000 ft).
Humidity (Operating and Nonoperating)	5 cycles (120 hours) referenced to MIL-T-28800B, Class 5 instruments.
Vibration (Operating)	15 minutes along each of 3 major axes at a total displacement of 0.015 inch p-p (2.4 g at 55 Hz), with frequency varied from 10 Hz to 55 Hz to 10 Hz in 1-minute sweeps. Hold for 10 minutes at 55 Hz. All major resonances must be above 55 Hz.
Shock (Operating and Nonoperating)	30 g, half-sine, 11-ms duration; 3 shocks per axis each direction, for a total of 18 shocks.

Table 4

Physical Characteristics

Characteristics	Description
Weight	
With Front-Panel Cover, Accessories, and Pouch	7.6 kg (16.8 lb).
Without Front-Panel Cover, Accessories, and Pouch	6.1 kg (13.5 lb).
Domestic Shipping	8.2 kg (18.0 lb).
Height With Feet and Handle	137 mm (5.4 in).
Width	
With Handle	361 mm (14.2 in).
Without Handle	328 mm (12.9 in).
Depth	
With Front-Panel Cover	445 mm (17.5 in).
Without Front-Panel Cover	439 mm (17.3 in).
With Handle Extended	511 mm (20.1 in).

ACCESSORIES

STANDARD ACCESSORIES INCLUDED

2 Probes, 10X, 1.5-m length with accessories. 010-6120-01

2 Probe accessories, Grabber Tips 013-0191-00

1 Operators Manual 070-3398-00

1 Service Manual 070-3826-00

OPTIONAL ACCESSORIES

Protective Front-Panel Cover 200-2520-00

Cord Wrap and Storage Pouch 016-0677-00

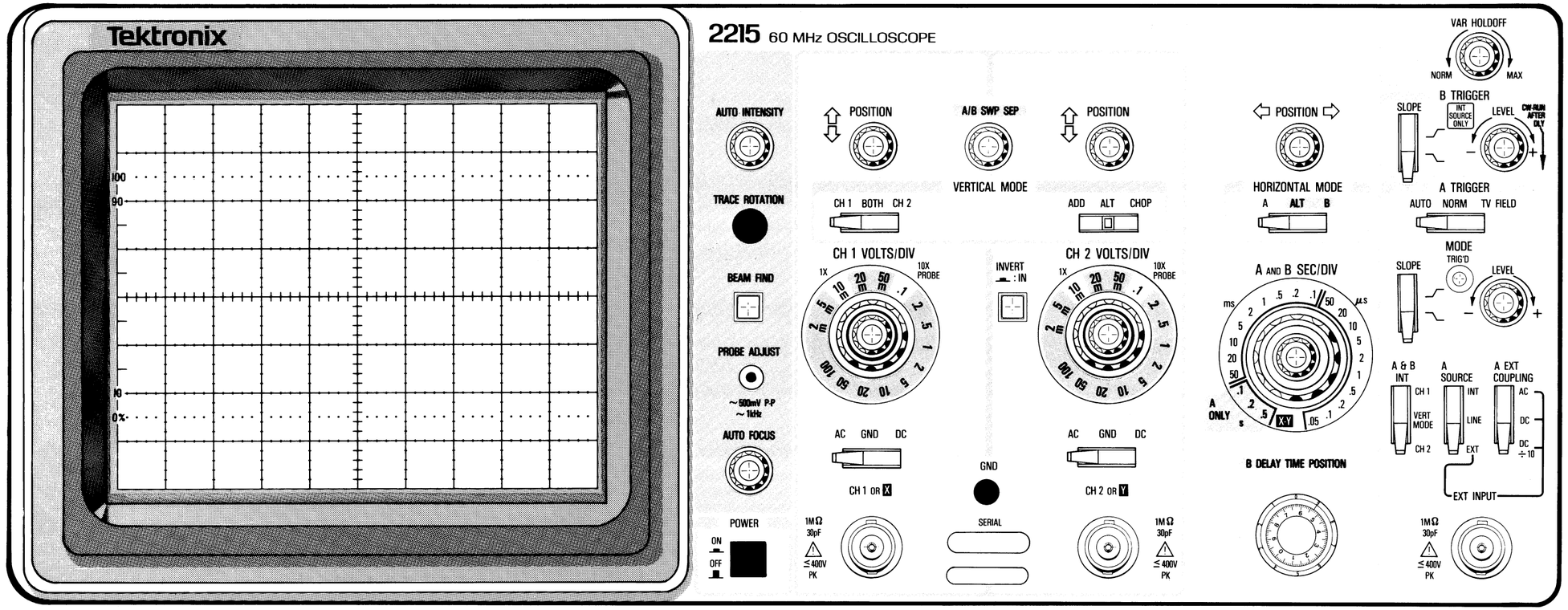
Protective Front-Panel Cover, Cord Wrap, and Storage Pouch. 020-0672-00

Low-Cost, General-Purpose Camera. . . . . Order C-5C Option 04

SCOPE-MOBILE Cart—Occupies less than 18 inches of aisle space, with storage area in base . . . . . Order 200C

Rack-Mount Adapter Kit 016-0466-00

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MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

SERVICE NOTE

Because of the universal parts procurement problem, some electrical parts in your instrument may be different from those described in the Replaceable Electrical Parts List. The parts used will in no way alter or compromise the performance or reliability of this instrument. They are installed when necessary to ensure prompt delivery to the customer. Order replacement parts from the Replaceable Electrical Parts List.

CALIBRATION TEST EQUIPMENT REPLACEMENT

Calibration Test Equipment Chart

This chart compares TM 500 product performance to that of older Tektronix equipment. Only those characteristics where significant specification differences occur, are listed. In some cases the new instrument may not be a total functional replacement. Additional support instrumentation may be needed or a change in calibration procedure may be necessary.

Comparison of Main Characteristics

DM 501 replaces 7D13		
PG 501 replaces 107	PG 501 - Risetime less than 3.5 ns into 50 Ω.	107 - Risetime less than 3.0 ns into 50 Ω.
108	PG 501 - 5 V output pulse; 3.5 ns Risetime	108 - 10 V output pulse 1 ns Risetime
PG 502 replaces 107		
108	PG 502 - 5 V output	108 - 10 V output
111	PG 502 - Risetime less than 1 ns; 10 ns Pretrigger pulse delay	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger pulse delay
PG 508 replaces 114	Performance of replacement equipment is the same or better than equipment being replaced.	
115		
2101		
PG 506 replaces 106	PG 506 - Positive-going trigger output signal at least 1 V; High Amplitude output, 60 V.	106 - Positive and Negative-going trigger output signal, 50 ns and 1 V; High Amplitude output, 100 V.
067-0502-01	PG 506 - Does not have chopped feature.	0502-01 - Comparator output can be alternately chopped to a reference voltage.
SG 503 replaces 190, 190A, 190B	SG 503 - Amplitude range 5 mV to 5.5 V p-p.	190B - Amplitude range 40 mV to 10 V p-p.
191		
067-0532-01	SG 503 - Frequency range 250 kHz to 250 MHz.	0532-01 - Frequency range 65 MHz to 500 MHz.
SG 504 replaces 067-0532-01	SG 504 - Frequency range 245 MHz to 1050 MHz.	0532-01 - Frequency range 65 MHz to 500 MHz.
067-0650-00		
TG 501 replaces 180, 180A	TG 501 - Trigger output-slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	180A - Trigger pulses 1, 10, 100 Hz; 1, 10, and 100 kHz. Multiple time-marks can be generated simultaneously.
181		181 - Multiple time-marks
184	TG 501 - Trigger output-slaved to market output from 5 sec through 100 ns. One time-mark can be generated at a time.	184 - Separate trigger pulses of 1 and 0.1 sec; 10, 1, and 0.1 ms; 10 and 1 μs.
2901	TG 501 - Trigger output-slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	2901 - Separate trigger pulses, from 5 sec to 0.1 μs. Multiple time-marks can be generated simultaneously.

NOTE: All TM 500 generator outputs are short-proof. All TM 500 plug-in instruments require TM 500-Series Power Module.

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MANUAL CHANGE INFORMATION

Date: 8-21-81 Change Reference: C1/881

Product: 2215 OSCILLOSCOPE OPERATORS ALL SN Manual Part No.: 070-3398-00

DESCRIPTION

TEXT CHANGES

Page 4 Callout 13, at end of existing text

ADD: ...Extends maximum uncalibrated deflection factor to 25 volts per division with IX probe (a range of at least 2.5:1).

Page 7 Callout 30 at end of second line

ADD: (also refer to TV Signal Displays at the end of "Instrument Familiarization".

Page 7 Callout 31, TV FIELD

CHANGE TO:

TV FIELD- permits triggering on television field-rate signals (refer to TV Signal Displays at the end of "Instrument Familiarization".

Page 15 At the end of existing text

ADD:

TV SIGNAL DISPLAYS

Displaying a TV Line-rate Signal

1. Perform the steps and set the controls as outlined under Baseline Trace and Signal Display to obtain a basic display of the desired TV signal.

2. Set A SEC/DIV to 10 µs, and A & B INT to CH 1 or CH 2 as appropriate for applied signal.

3. Set A TRIGGER SLOPE for a positive-going signal (lever up) if the applied TV signal sync pulses are positive-going, or for a negative-going signal (lever down) if the TV sync pulses are negative-going.

4. Adjust the A TRIGGER LEVER control for a stable display, and AUTO INTENSITY for desired display brightness.

DESCRIPTION

Page 15 (cont.)

Displaying a TV Field-rate Signal

1. Perform Step 1 under Displaying a TV Line-rate Signal.

2. Set A SEC/DIV to 2 ms, A TRIGGER MODE to TV FIELD and A & B INT to CH 1 or CH 2 as appropriate for the applied signal.

3. Perform Step 3 and and 4 under Displaying a TV Line-rate Signal.

4. To display either Field 1 or Field 2 individually at faster sweep rates (displays of less than one full field), set VERTICAL MODE to BOTH and ALT simultaneously. This synchronizes the Channel 1 display to one field and the Channel 2 display to the other field.

To change the field that is displayed, interrupt the triggering by repeatedly setting the AC GND DC switch to GND or disconnecting the signal from the applied signal input until the other field is displayed. To display both fields simultaneously, apply the input signal to both the CH 1 and CH 2 inputs via two probes, two cables, or through a dual-input coupler.

To examine either a TV Field-rate or Line-rate signal in more detail, either the X10 Magnifier or HORIZONTAL MODE functions may be employed as described for other signals elsewhere in this manual.

5. To display a selected horizontal line, first trigger the sweep on a vertical (field-rate) sync pulse, then use the delayed sweep to delay out to that line for close examination. This procedure is useful for examining VITS signals.

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