**A-9(2).**

**Pulse Measurements**

**OBJECTIVES**

After performing this experiment, you will be able to:

1. Measure rise time, fall time, pulse repetition time, pulse width, and duty cycle for a pulse waveform.
2. Explain the limitations of instrumentation in making pulse measurements.
3. Compute the oscilloscope bandwidth necessary to make a rise time measurement with an accuracy of 3%.

**READING**

None

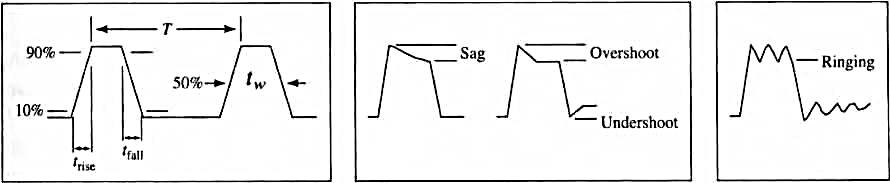
**MATERIALS NEEDED**

One 1000 pF capacitor

**SUMMARY OF THEORY**

A pulse is a signal that rises from one level to another, remains at the second level for some time, and then returns to the original level. Definitions for pulses are illustrated in Figure 1. The time from one pulse to the next is the period, T. This is often referred to as the pulse repetition time. The reciprocal of period is the frequency. The time required for a pulse to rise from 10% to 90% of its maximum level is called the rise time, and the time to return from 90% to 10% of the maximum level is called the fall time. Pulse width, abbreviated tw, is measured at the 50% level, as illustrated. The duty cycle is the ratio of the pulse width to the period and is usually expressed as a percentage:

Actual pulses differ from the idealized model shown in Figure 1 (a). They may have sag, overshoot, or *und*ershoot, as illustrated in Figure 1 (b). In addition, if cables are mismatched in the system, ringing may be observed. Ringing is the appearance of a short oscillatory transient that appears at the top and bottom of a pulse, as illustrated in Figure 1(c).



(a) (b) (c)

Figure 1

All measurements involve some error due to the limitations of the measurement instrument. In this experiment, you will be concerned with rise time measurements. The rise time of the oscilloscope’s vertical amplifier (or digitizer’s amplifier on a DSO) can distort the measured rise time of a signal. The oscilloscope’s rise time is determined by the range of frequencies that can be passed through the vertical amplifier (or digitizing amplifier). This range of frequencies is called the bandwidth, an important specification generally found on the front panel of the scope. Both analog and digital oscilloscopes have internal amplifiers that affect rise time.

If the oscilloscope’s internal amplifiers are too slow, rise time distortion may occur, leading to erroneous results. The oscilloscope rise time should be at least four times faster than the signal’s rise time if the observed rise time is to have less than 3% error. If the oscilloscope rise time is only twice as fast as the measured rise time, the measurement error rises to over 12%! To find the rise time of an oscilloscope when the bandwidth is known, the following approximate relationship is useful:

where t(r)scope is the rise time of the oscilloscope in microseconds and BW is the bandwidth in megahertz. For example, an oscilloscope with a 60 MHz bandwidth has a rise time of approximately 0.006 p,s or 6 ns, Measurements of pulses with rise times faster than about 24 ns on this oscilloscope will have measurable error. A correction to the measured value can be applied to obtain the actual rise time of a pulse. The correction formula is

where t(r)true is the actual rise time of the pulse, t(r) displayed is the observed rise time, and t(r)scope is the rise time of the oscilloscope. This formula can be applied to correct observed rise times by 10% or less.

In addition to the rise time of the amplifier or digitizer, digital scopes have another specification that can affect the usable bandwidth. This specification is the maximum sampling rate. The required sampling rate for a given function depends on a number of variables, but an approximate formula for rise time measurements is

From this formula, a 1 GHz sampling rate (1 GSa/s) will have a maximum usable bandwidth of 217 MHz. If the digitizer amplifier’s bandwidth is less than this, then it should be used to determine the equivalent rise time of the scope.

Measurement of pulses normally should be done with the input signal coupled to the scope using dc coupling. This directly couples the signal to the oscilloscope and avoids causing pulse sag which can cause measurement error. Probe compensation should be checked before making pulse measurements. It is particularly important in rise time measurements to check probe compensation. This check is described in this experiment. For analog oscilloscopes, it is also important to check that variable knobs are in their calibrated position.

**PROCEDURE**

1. From the manufacturer’s specifications, find the bandwidth of the oscilloscope you are using. Normally the bandwidth is specified with a 10X probe connected to the input. You should make oscilloscope measurements with the 10X probe connected to avoid bandwidth reduction. Use the specific bandwidth to compute the rise time of the oscilloscope as explained in the Summary of Theory. This will give you an idea of the limitations of the oscilloscope you are using to make accurate rise time measurements. Enter the bandwidth and rise time of the scope in Table 1.
2. Look on your oscilloscope for a probe compensation output. This output provides an internally generated square wave, usually at a frequency of 1.0 kHz. It is a good idea to check this signal when starting with an instrument to be sure that the probe is properly compensated. To compensate the probe, set the VOLTS/DIV control to view the square wave over several divisions of the display. An adjustment screw on the probe is used to obtain a good square wave with a flat top. An improperly compensated oscilloscope will produce inaccurate measurements. If directed by your instructor, adjust the probe compensation.
3. Set the signal generator for a square wave at a frequency of 100 kHz and an amplitude of 4.0 V. A square wave cannot be measured accurately with your meter—you will need to measure the voltage with an oscilloscope. Check the zero volt level on the oscilloscope and adjust the generator to go from zero volts to 4.0 V. Most signal generators have a separate control to adjust the dc level of the signal.
4. Measure the parameters listed in Table 2 for the square wave from the signal generator. Be sure the oscilloscope’s SEC/DIV is in its calibrated position. If your oscilloscope has percent markers etched on the front gradicule, you may want to uncalibrate the VOLTS/DIV when making rise and fall time measurements. Use the vertical POSITION control and VOLTS/DIV vernier to position the waveform between the 0% and 100% markers on the osciloscope display. Then measure the time between the 10% and 90% markers. [[1]](#footnote-1)

5. To obtain practice measuring rise time, place a 1000pF capacitor across the generator output. Measure the new rise and fall times. Record yours result in Table 3.

1. If you have a separate pulse output from your signal generator, measure the pulse characteristics listed in Table 4. To obtain good results with fast signals, the generator should be terminated in its characteristic impedance (typically 50Ω). You will need to use the fastest sweep time available on your oscilloscope. Record your results in Table 4.

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| **Report for**  **Experiment A-9(2)** | **Name**  **Date**  **Class** |

**ABSTRACT:**

**DATA:**

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| **Table 1**  **Oscilloscope.**   |  |  | | --- | --- | | BW |  | | t(r) |  | | **Table 2**  **Signal Generator.**  (square wave output)   |  |  | | --- | --- | | Rise time, t(r) |  | | Fall time, t(r) |  | | Period, T |  | | Pulse width, t(r) |  | | Percent duty cycle |  | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3**  **Signal Generator.**  (with 1000 pF capacitor across output)   |  |  | | --- | --- | | Rise time, t(r) |  | | Fall time, t(f) |  | | **Table 4**  **Signal generator.**  (pulse output)   |  |  | | --- | --- | | Rise time, t(r) |  | | Fall time. t(f) |  | | Period, T |  | | Pulse width, tw |  | | Percent duty cycle |  | |

**RESULTS AND CONCLUSION:**

**EVALUATION AND REVIEW QUESTIONS**

1. Were any of the measurements limited by the bandwidth of the oscilloscope? If so, which ones?

2. If you need to measure a pulse with a predicted rise time of 10 ns, what bandwidth should the oscilloscope have to measure the time within 3%?

3. The SEC/DIV control on many oscilloscopes has a X 10 magnifier. When the magnifier is ON, the time scale must be divided by 10. Explain.

1. An oscilloscope presentation has the SEC/DIV control set to 2.0 ms/div and the X10 magnifier is OFF. Determine the rise time of the pulse shown in 2.

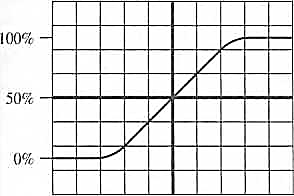


Figure 2

1. Repeat Question 4 for the X10 magnifier ON.

1. 1If your oscilloscope has cursor measurements, the rise time can directly when the cursors are positioned on the 10% and 90% levels. [↑](#footnote-ref-1)