# DE ANZA COLEGE – PHYSICS 4B LAB – FALL 2024

Lab 6 – Using the Oscilloscope and Function Generator

## TITLE

Using the Oscilloscope and Function Generator

## OBJECTIVE

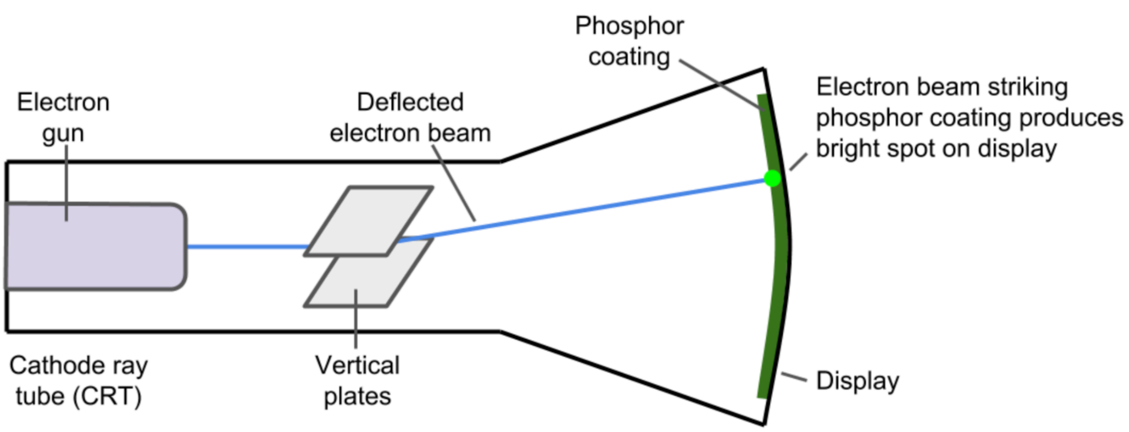
To learn to use the oscilloscope for measuring DC voltage from a battery and AC voltage generated by a function generator.

## THEORY

### History of the Oscilloscope

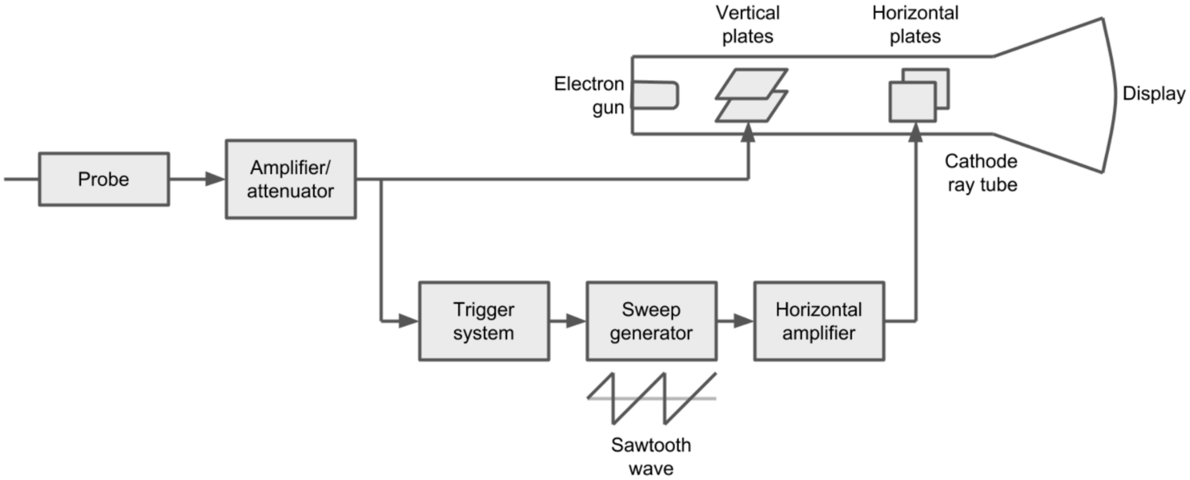
The primary function of the oscilloscope is to measure the time evolution of an electric signal. In the late 1800s, scientists discovered that subatomic particles (now known as electrons) would travel in straight lines from the cathode end of a Crookes tube. As a result, scientists dubbed these particles "cathode rays." In the subsequent years, other scientists discovered that these rays could be bent by applying an electric field or a magnetic field.

In 1897, German physicist and inventor Karl Ferdinand Braun built the first oscilloscope cathode ray tube (CRT) by applying a voltage to vertical plates over and under the electron beam. The electron beam would strike a phosphor plate on the opposite end and paint a bright dot. As the voltage varied across the plates, the dot would dance up and down, as shown below[1].




[1] Taken from How Oscilloscopes Work

Jonathan Zenneck, physicist and electrical engineer from the Kingdom of Württemberg (now part of Germany), added a set of horizontal plates to the CRT in 1899, which allowed the electron beam to sweep back and forth across the screen. With the ability to control vertical and horizontal motion, we can now construct a graph of an electrical signal on a screen in real-time.




**Probe:** The piece that connects to your circuit under test. Most probes have two tips, as oscilloscopes measure the electric potential difference (voltage) between two points.

**Amplifier/Attenuator:** Often, an electrical signal needs to be amplified (increased in amplitude) or attenuated (decreased in amplitude) to be effectively displayed to the user or to not damage the internal circuitry of the oscilloscope.

**Trigger System:** A trigger is a user-defined condition (such as a voltage threshold) that determines when the oscilloscope should begin drawing a waveform. This can be extremely helpful in finding sporadic pulses in a circuit or synchronizing the display to a repeating pattern, like a sine wave, so that it appears steady on the screen.

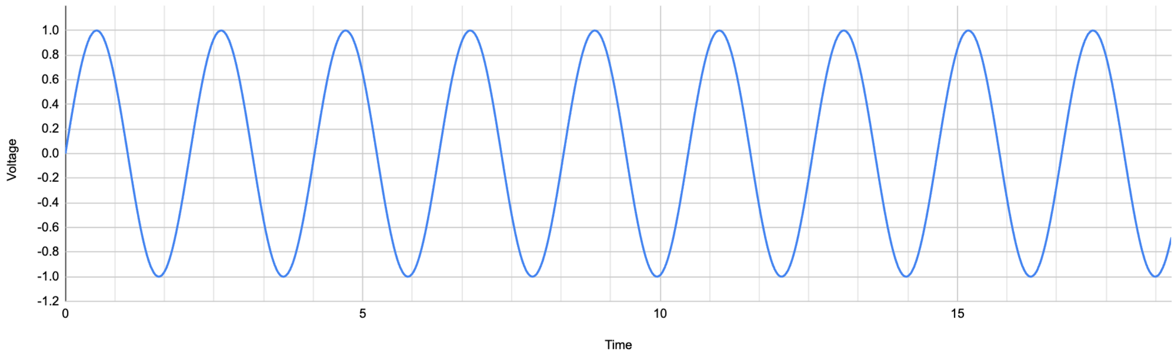
**Sweep Generator:** To control the horizontal plates in the CRT, the sweep generator creates a repeating sawtooth voltage pattern. This causes the beam to sweep from one side to the other in the CRT. The frequency and triggering of the sweep generator is set by the user.

**Horizontal Amplifier:** Much like the amplifier found after the probe, the horizontal amplifier increases the amplitude of the sawtooth wave from the sweep generator so that it can control the horizontal plates in the CRT.

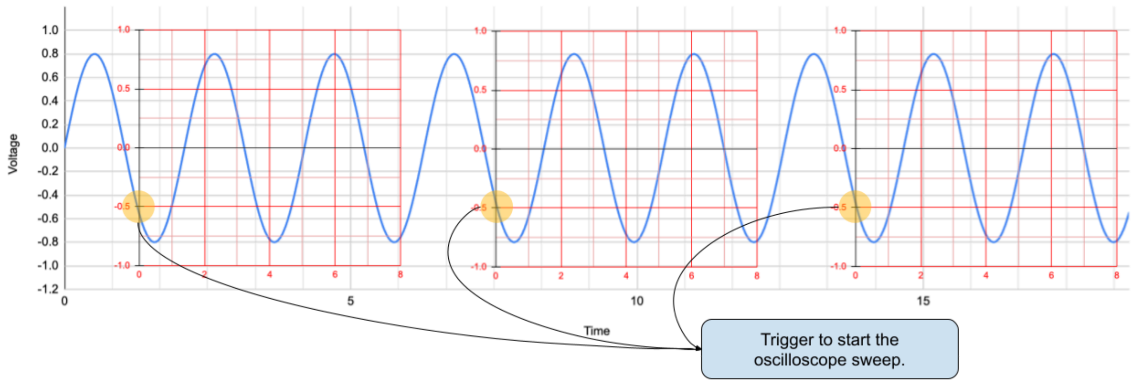
**CRT:** An electron gun fires a steady stream of electrons onto a phosphor-coated screen, which produces a bright dot. Two sets of plates control the deflection of the beam. The vertical plates are directly controlled by the voltage seen on the probe, and the horizontal plates are controlled by the sweep generator. As the deflection of the beam changes rapidly, a solid line appears on the screen. This line on the display represents the voltage (as seen on the probe) as it varies over time.

## Understanding the mechanics of plotting the signal

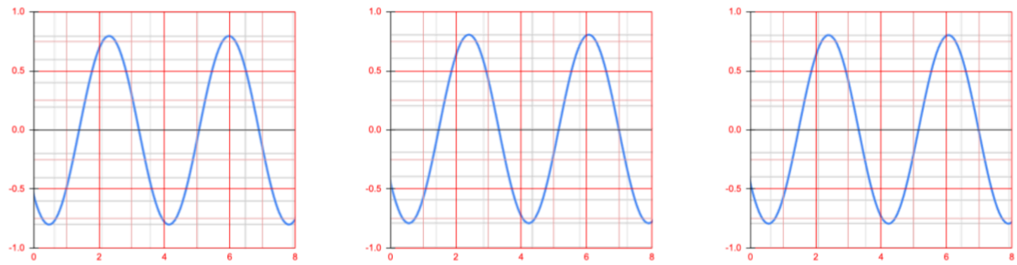
Let's assume we have the following signal that our signal generator is giving us:



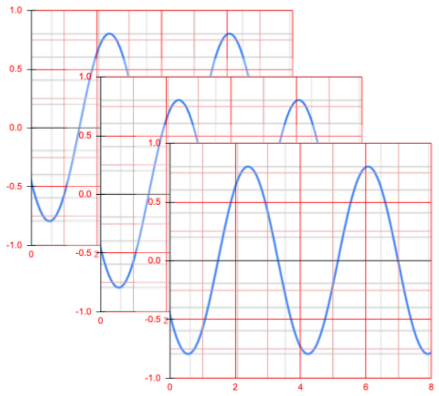

The oscilloscope is set up such that it has a certain trigger point for the signal and waits for the trigger signal to do the successive sweep as shown below.




As a result of this we capture the following snapshots:



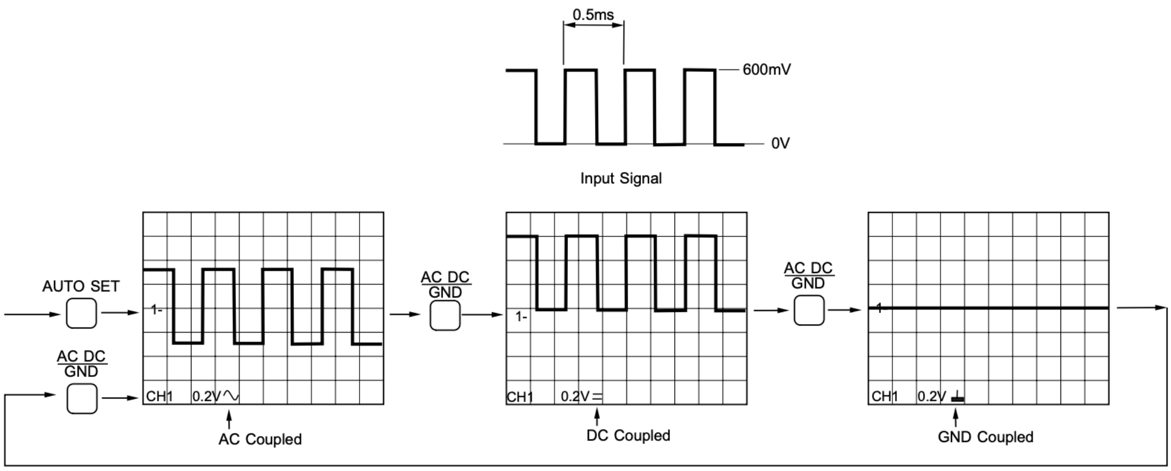
Now think of these as "frames" in a TV/Video signal. These frames are successively superimposed over each other. As their starting point is the same and the signal is a repetitive signal, we get the same pattern in each sweep. Therefore we can see a steady image on the screen.



You can imagine that playing these frames successively will result in a steady image as opposed to one that is moving across the screen. Now you can make measurements of frequency and amplitude.

### Vertical Coupling

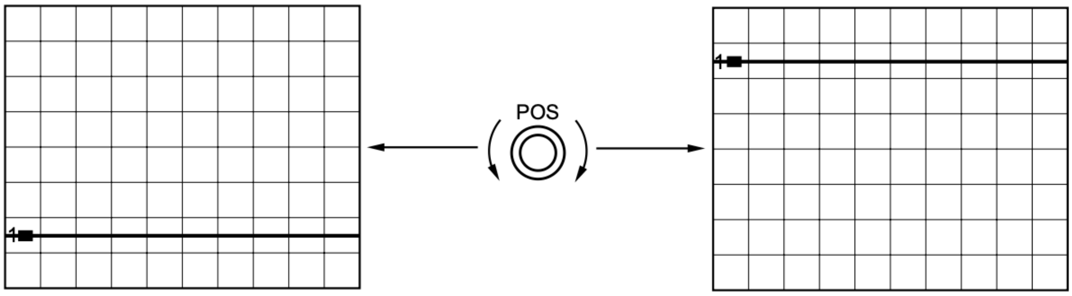
The oscilloscope can adjust the vertical bias of the signal to make measurements easier. For the square wave of the characteristic shown, pressing  the AC DC Gnd keys successively will bring out the following views on the screen below. Note that the CH1 0.2V means that each horizontal line represents a 0.2V change in voltage. Given our source voltage fluctuates between 0 and 600mV, it should take exactly three spaces in the vertical direction.



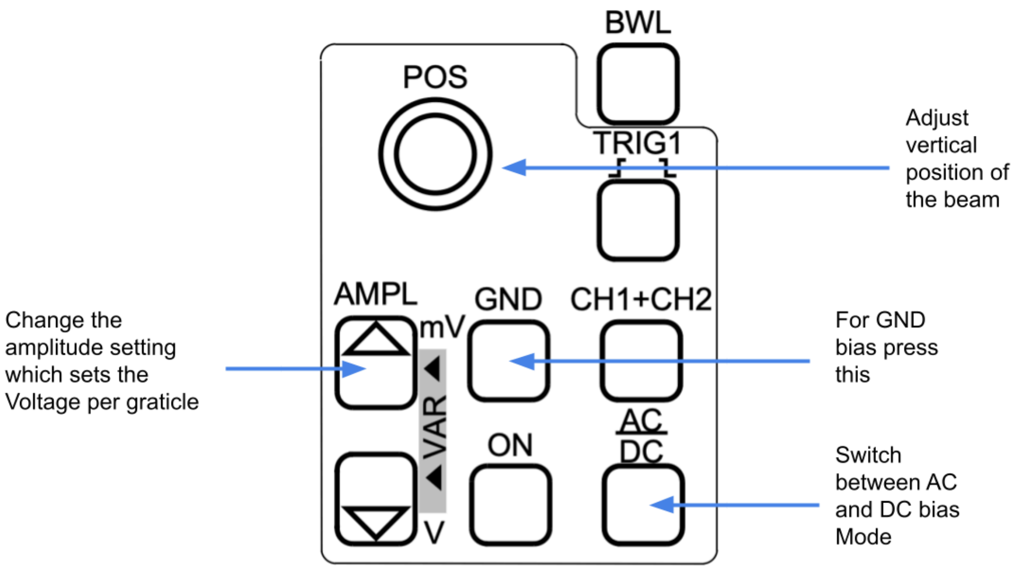
## Measuring DC Voltage

Therefore, to measure DC voltage

1. We first need to make sure that the GND coupled position matches one of the graticles[2] on the oscilloscope (let's say at 2/8 vertically) and the voltage base is 1V/graticle. Use the **POS** knob of the Channel you are using and adjust.



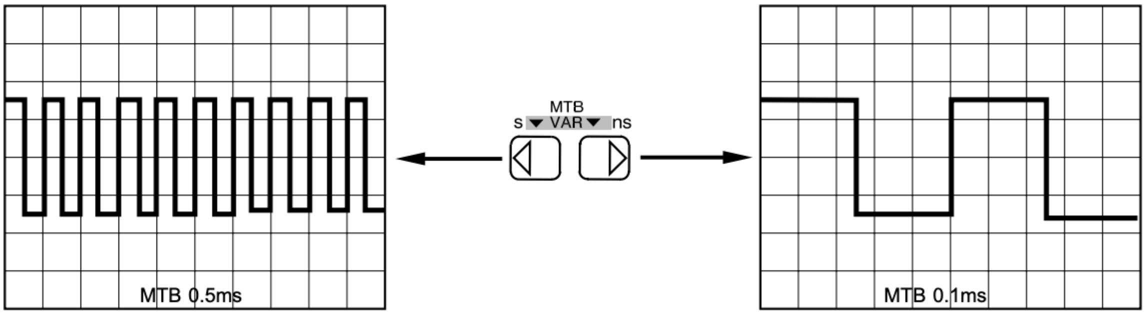

2. Now move to DC coupled mode. Measure the position compared to the GND coupled position in terms of the graticle. Let's say we get graticle 5/8. That means we have a voltage of 3V as we are 3 graticles away from the GND and each graticle is 1V apart.




[2] Thesea re fixed lines drawn on the scope screen. The time base and voltage base settings read off these graticles.

### Measuring AC Voltage

To measure AC Voltage, we would need to change the time base such that we get a nice curve on the screen. The key here is to set the time base. We accomplish this by




Pressing the MTB button. We will see that the scale for the graticles is shown below on the screen and changes as we press this.

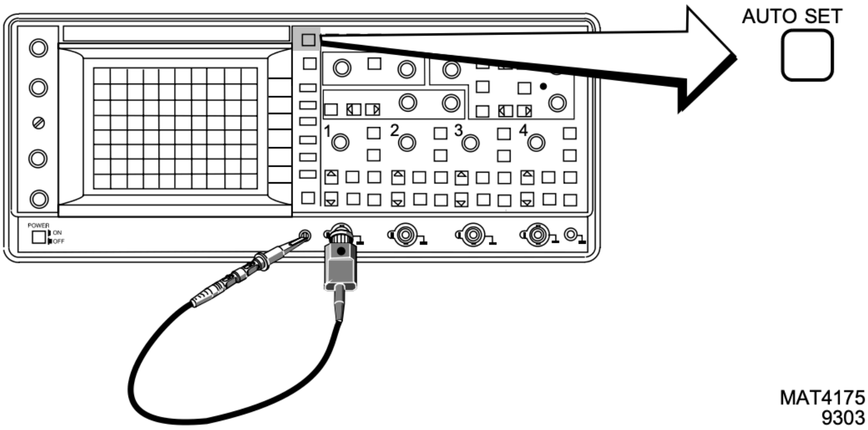
For fine adjustment, we pressed **both** buttons to go into the fine selection mode. In this case, the increases/decreases in the scale will be more fine granulated. In the original setting they will be 0.5ms → 0.2ms → 0.1ms. However if you want even finer adjustments, hold both buttons and you shall be able to set the time base to 0.085ms for example, meaning each graticle is 0.085ms. That will allow you to calculate the frequency of the wave more accurately.

## EQUIPMENT

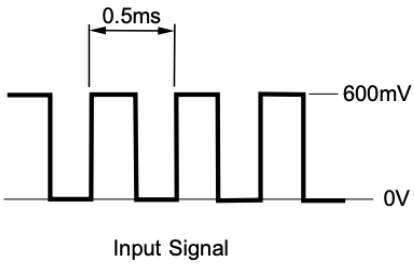
1. BNC Cables
2. Analog Oscilloscope
3. Function Signal Generator
4. Digital Hand Held Multimeter

## PROCEDURE

1. Setup the oscilloscope and calibrate



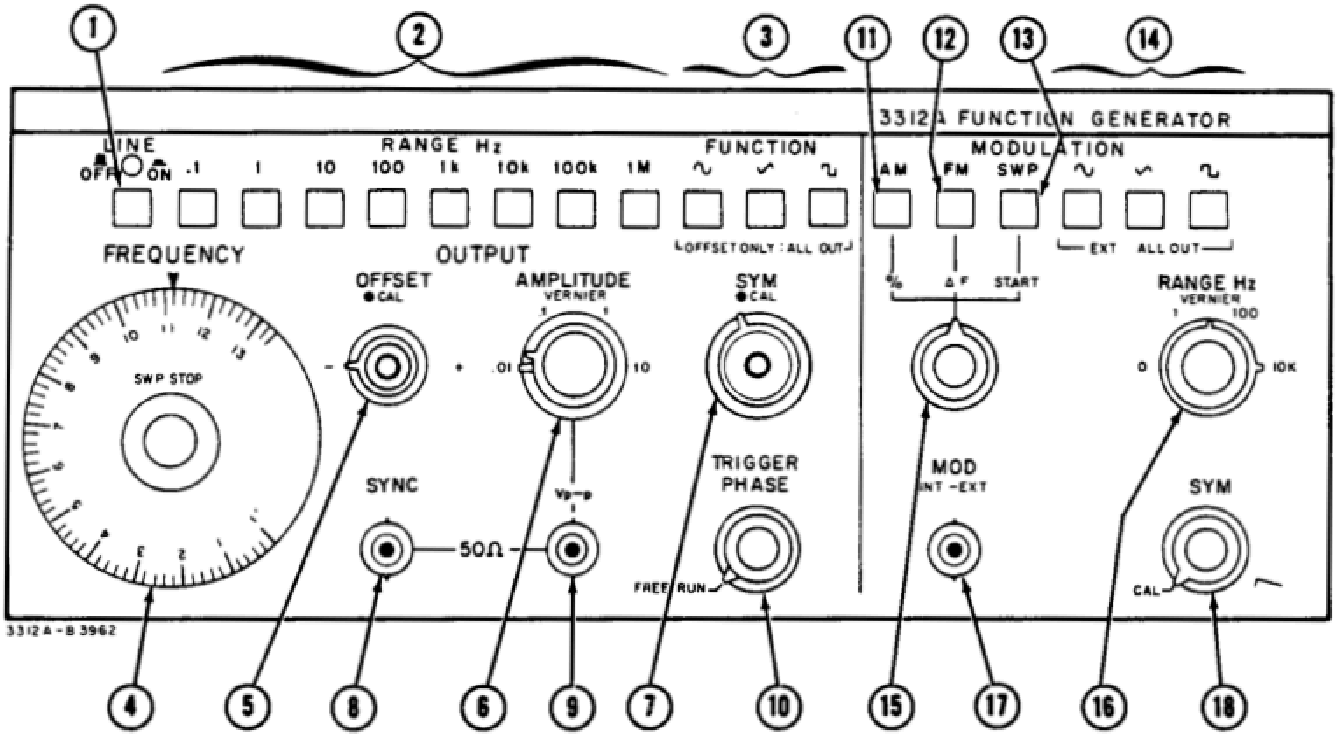

The oscilloscope generates a signal which looks like this:




With this signal, the oscilloscope can calibrate all channels automatically. Before the start of your experiment you should do this.

2. Measure the period of the calibration signal and the amplitude and compare it with the values above. Compare the variance in the periodicity and amplitude
3. Using the DC method described in Theory, measure the voltage of two dry cell batteries and compare to the DMM measurement value. Report the % difference in the readings.
4. Now measure the signal from the function generator. Output a signal of a sine wave with an amplitude of approximately 10V and frequency of 1kHZ. Measure the values with the oscilloscope. Compare the % difference to the setting versus the measurement.

## APPENDIX - FUNCTION GENERATOR




(1) LINE: S18 switch applies or removes ac power. The green LED is lit when ON.

(2) RANGE Hz: S1 through S8, pushbuttons select frequency range. RANGE selection times the reading on the FREQUENCY dial determines the output frequency of the main generator.

(3) FUNCTION: Interlocked buttons select one of three functions. When they are all out, the dc level may be set accurately (S9, S10, S11).

(4) FREQUENCY: Sets the desired frequency within the range of any of the RANGE pushbuttons.

(5) OFFSET: R616 sets the dc operating point of any function. CAL position removes the dc offset. $E_{ac} + E_{dc}$ must be less than 10 V or clipping of the waveform will occur.

(6) AMPLITUDE: S22, R613(a), (b), adjust the peak-to-peak amplitude of the waveform. It is attenuated in steps of 1:1, 10:1, 100:1, 1000:1; the VERNIER adjusts from zero to maximum output volts for the particular range selected.

(7) SYM: R608 varies the symmetry of output waveforms and the SYNC output. CAL is symmetrical.

(8) SYNC: A square wave $180^\circ$ out of phase with the main generator. Useful for synchronizing external instruments or driving a counter.

(9) OUTPUT: Terminal for all main generator functions. 20 V p-p into open circuit or 10 V p-p into 50 ohms, in the 1:1 attenuator position.

(10) TRIGGER PHASE: R615 sets the starting phase of the output signal in the burst mode. FREE RUN disables the burst.

(11) AM: Selects amplitude modulation. Functional for internal or external modulation.

(12) FM: S13 selects frequency modulation. Functional for internal or external modulation.

(13) SWP: S14 selects sweep mode. This function overrides AM and FM.

(14) ∿ ⋀ ⊓⊔ : S15, S16, S17 select the modulating function. External modulation is possible when all buttons are out, and the modulating signal is applied to the MOD INT-EXT jack.

(15) % Δ F START: R612 selects the percent of AM, the deviation in FM, or the start frequency of the SWP.

(16) RANGE Hz: R602, S21 select one of the three ranges of modulating frequencies with continuous control within each range via the VERNIER. The 0 position is used to set the start sweep frequency.

(17) MOD INT-EXT: Input for external AM or FM. Waveforms of the modulation generator are also available at this output when internal modulation is used.

(18) SYM: R601 varies the symmetry of the modulation output waveform. CAL selects a 90:10 ramp for SWP and symmetrical for all other functions.