Jules' Workshop

Standard

Unit 18

MEASUREMENTS, WAVEFORMS & SYMBOLS

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Electronic Symbols 17

Electronic Test Equipment

Understanding test equipment and the ability to interpret test results is an important attribute for anyone who engages in the service of amateur radio.

There are many variants on test equipment and in this lesson, we will look a few in general terms.

When using any test equipment, safety must take priority.

Electronic test equipment is basically categorized into input-based (analysers, meters) and output-based (generators, power supplies) devices.

Input Test Devices

Multimeters

A multimeter is a handheld test instrument used to measure common electrical values such as voltage, current, and resistance. This is an essential tool for troubleshooting and verifying circuits. Most modern units are digital (DMMs) and can also check continuity, test diodes, and sometimes measure capacitance, frequency, or temperature depending on the model.

When using a multimeter, select the measurement type and range (or rely on auto ranging) and plug the probes into the correct ports. Connect the probes—typically in parallel for voltage and in series for current.

Incorrect settings can blow an internal fuse or damage the equipment.

Multimeters

Digital Analogue

Digital multimeters are self-calibrating in the resistance range. Analogue meters need calibrating by touching the leads together and adjusting the meter dial.

Clamp Ammeter

A clamp ammeter (or clamp meter) measures electrical current by sensing the magnetic field produced by the flowing current. This enables measurements without disconnecting wires or breaking the circuit. Many clamp meters are designed for AC current, while more advanced models can measure DC current.

Many clamp meters also include standard multimeter functions like voltage, resistance, and continuity.

They’re commonly used for quick diagnostics in switchboards, motors, and HVAC systems to confirm load current, detect overloads, and balance phases.

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RF Power Meters

An RF power meter is a test instrument used to measure the power of radio-frequency signals. Most meters consist of a readout plus a power sensor that connects in-line with a coaxial cable.

RF power meters can be either analogue or digital.

Reflectometer bridge (SWR meter)

The SWR meter samples the forward signal from the transmitter and any reflected signal from the antenna. Using these two measurements, the device provides an indication of standing wave ratio present in a feeder.

SWR meters can be either analogue or digital.

SWR meters can be left in circuit as a continuous indication of the antenna system performance.

Frequency Counter

A frequency counter is a device used to sample and measure the number of oscillations or pulses per second (frequency) of a periodic electronic signal. They are used in RF engineering to calibrate oscillators and check signal frequencies.

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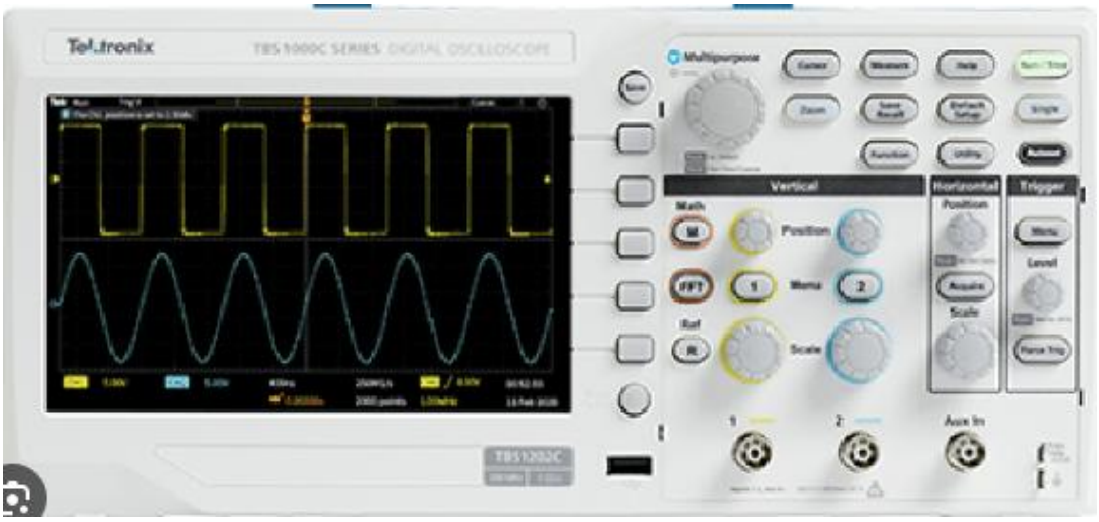
Oscilloscope

An oscilloscope is an electronic test instrument that visually displays how a signal changes over time. The device typically plots voltage on the vertical axis against time on the horizontal axis to reveal waveform shape, amplitude, frequency, noise, and timing relationships.

Digital storage oscilloscopes (DSOs) can capture and store fast transients, offer automatic measurements (e.g., peak-to-peak, RMS, duty cycle), and use triggering controls to stabilize repetitive signals or isolate single events.

Technicians and engineers use oscilloscopes to debug equipment by comparing channels, checking rise/fall times, and spotting glitches that a multimeter might miss.

Use the correct probe attenuation, ensure proper grounding, and follow the scope and probe voltage ratings.

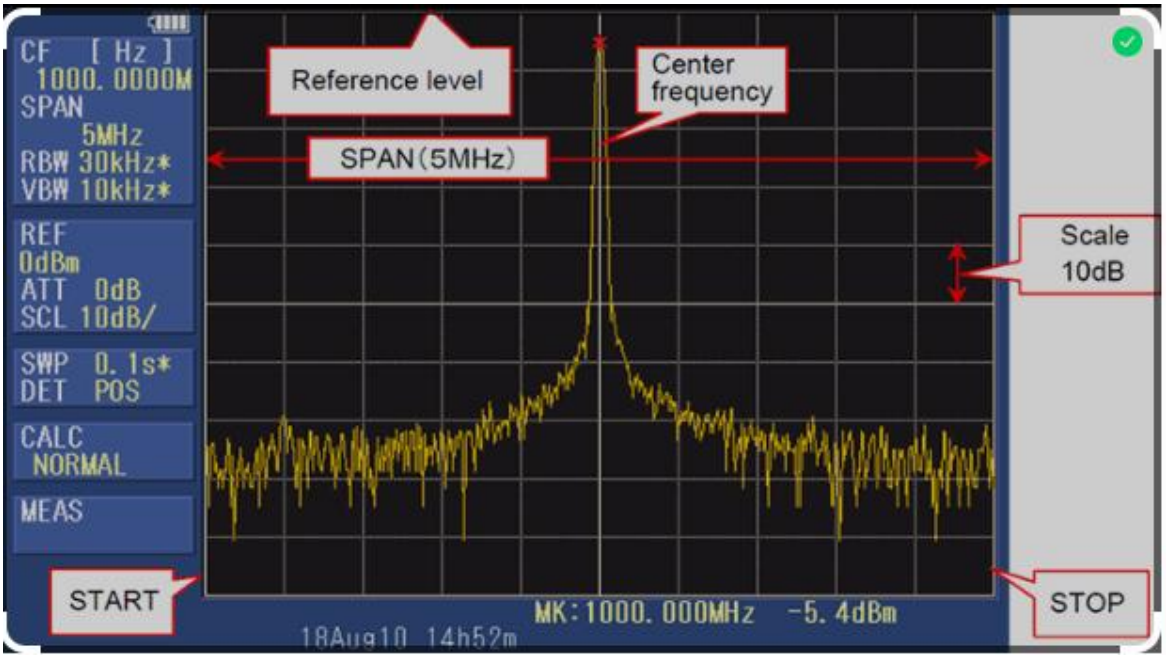


Spectrum Analyser

A spectrum analyser is an instrument that measures and displays a signal's amplitude versus frequency and can display signals across a selected frequency span.

Modern analysers typically support functions like markers, channel power and occupied bandwidth measurements.

Key specifications for a spectrum analyser include frequency range, resolution bandwidth (RBW), video bandwidth (VBW), dynamic range, and phase noise. All these affect the ability to resolve small signals near large ones.



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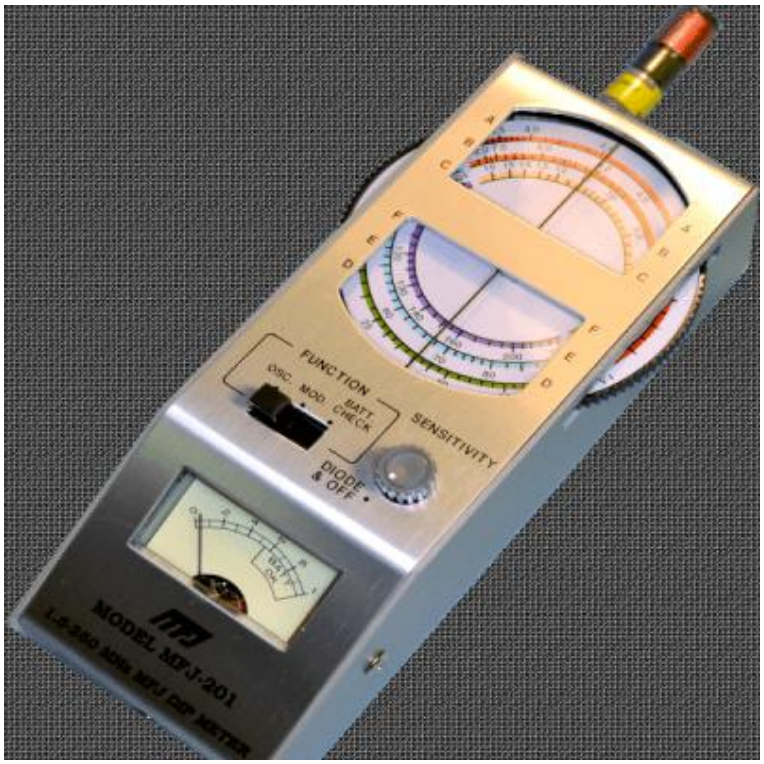
Grid Dip Oscillator

A grid dip oscillator (GDO), or dip meter, is a versatile RF test instrument used to measure the resonant frequency of LC circuits, antennas, and traps without requiring a direct connection.

The GDO works by inductively coupling an exposed, tunable coil to a target circuit; when frequencies match, energy transfer causes a "dip" in the oscillator's meter reading.



Vector Network Analyser (VNA)

These are relatively new to amateur radio users as previously the cost of these devices was very high.

VNAs are used in a wide range of RF and high frequency applications. A VNA injects a known RF signal to the device under test and measures the voltage across its terminals. The VNA can calculate the (complex) impedance. The measurement circuit compares both the amplitude and the phase of the measured signal to that of the source. For gain or loss measurement the VNA connects the same source signal to one port and measures the output signal at the other port of the device under test.

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Output Test Devices

Signal Generators

A generator can output a wave form of the desired shape, frequency and amplitude.

These are used to inject test signals into circuits and measure the output results.

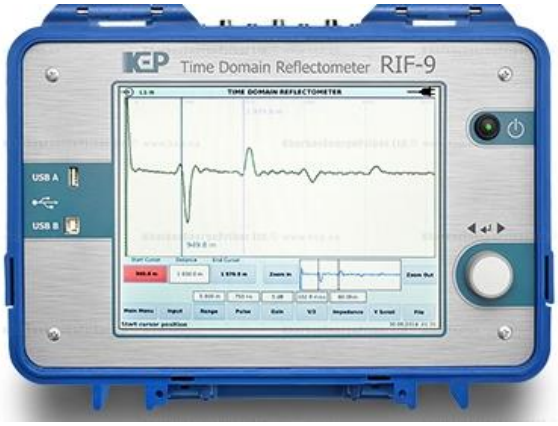
Power Supplies

A laboratory power supply is a precise, regulated device that converts AC mains voltage into adjustable, stable DC voltage. This accurate voltage is used to power devices under test.

Time Domain Reflectometer

A time-domain reflectometer (TDR) is a device used to measure the impedance profile of a component under test. Combining a step generator and an oscilloscope, a fast pulse edge is launched and the results are viewed.

TDR are handy to find a broken cable. If a coax, many meters long, has a break, the TDR signal can calculate the distance the break is from the device.



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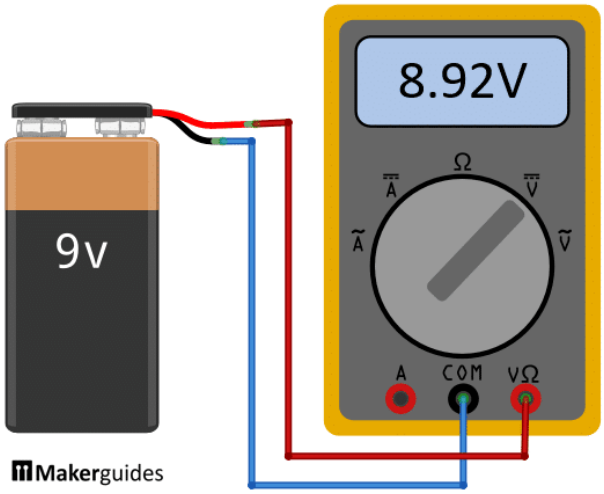
Making Voltage, Current or Resistance Measurements

DC Voltages

A DC voltage measurement is taken across two terminals, and the resulting measurement is the potential difference. The ideal tool for this is the multimeter and set to the appropriate voltage range.

Example: Measuring a car battery should provide a result around 12V.



DC Currents

A DC current needs to be measured in the circuit. The device is measuring the amount of current, in Amperes, flowing though the circuit.

For high levels of current, a very low Ohm resistor, called a shunt resistor, is wired in the circuit and the voltage drop across this resistor is measured. Knowing the resistor size and voltage drop, the meter can display this as current.

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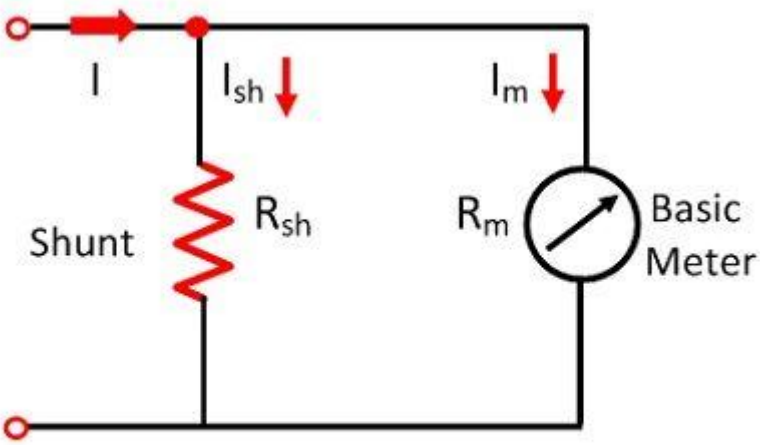


Basic Ammeter Circuit

Circuit Globe

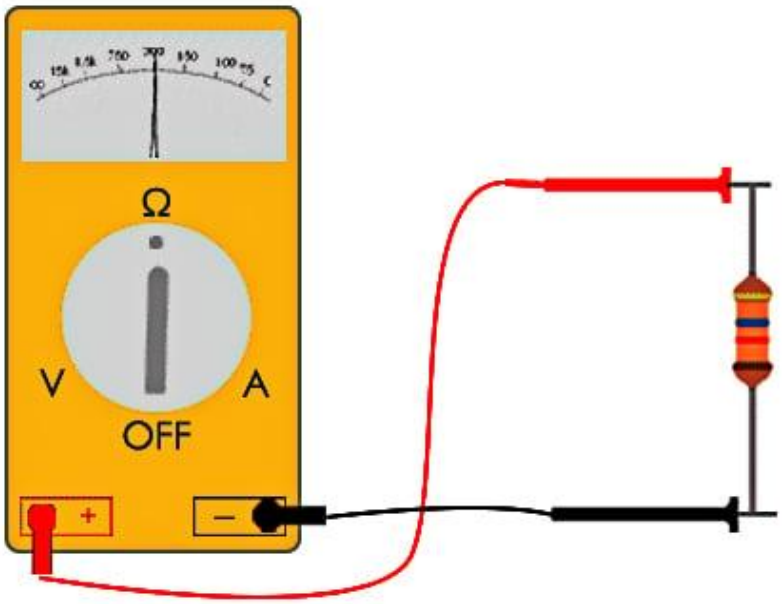
Resistance

A test meter in connected to a device undertest. The meter must have a high input impedance, usually greater than 1 MΩ, to keep the meter load to a minimum. Multimeters have a high input impedance so you can measure low voltages on logic circuits without loading the circuit.

A known voltage, from a battery, is applied to the device and the current flow is measured.

Using Ohms Law, the resistance can be displayed.

The resistance of a device cannot be measured in a circuit. A circuit can have other current paths and will give an incorrect reading.



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AC Voltages

An AC voltage is taken across two terminals, and the resulting measurement is the RMS value of the potential difference. RMS is 0.707 of the peak value.

Example: Measuring the voltage in a power point should provide a result around 230 V.

AC Current

AC current must be measured in circuit. Modern meters measure the current via a clamp meter.

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Making Circuit Measurements

Grounding

A technician should be grounded (Earthed) before taking electrical measurements mainly to prevent electric shock and to protect the equipment being tested.

Grounding reduces static discharge (ESD) where static from your body can damage sensitive electronics. A ground strap/mat safely bleeds off static before you probe circuits.

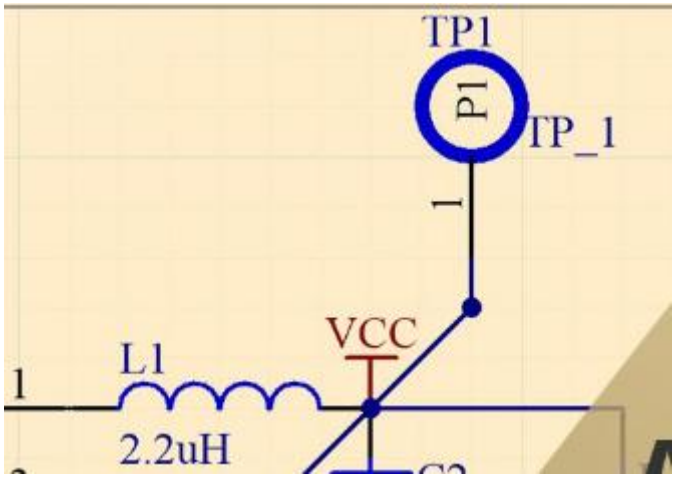
A stable reference (ground/earth or circuit common) reduces “floating” readings and noise, especially in high-impedance measurements.

Test points.

A test point is a designated point on a circuit that is used to make a measurement or inject test signals. Test points are common in circuits under development but once they go into production, the test points are often removed.

Good drawings include test points and what is to be undertaken at that point. Service manuals for some amateur equipment have test points for servicing and tuning the radio.

Next to the TP, or in a separate table, would be text on what should be expected at that test point.
Example: Sine wave at 2 MHz with amplitude of 0.5 V.



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RF Signal

The signal is best observed on an oscilloscope.

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Alternatively, a signal can be injected into the circuit and the output monitored on an oscilloscope.

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Measurement Errors

The errors occurring when testing are known as measurement errors, and these are grouped into three broad categories.

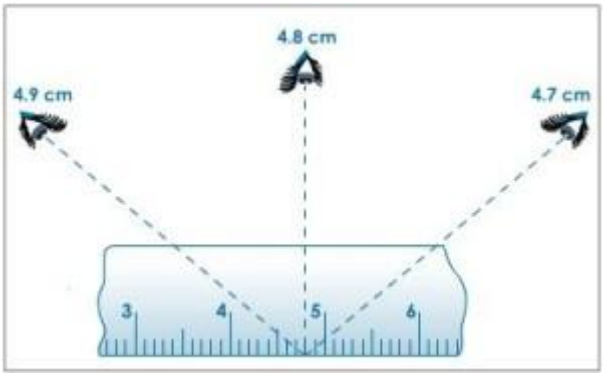
- Operator Errors
- System Errors
- Random Errors

Operator Errors

Operator errors can vary from user to user, depending on their experience.

Some common operator errors can be due to one or all the following examples.

- Selection of the incorrect instrument. If in doubt, ask but this error will be reduced with experience.
- Parallax error. This occurs on needle indicator equipment where the operator views the needle at an angle and not directly above.



- Failure to Calibrate. Starting from an incorrect baseline.

System Errors

- Instrument Error – The measuring device may not be sensitive enough for the task.
- Environmental Error – Environmental effects such as temperature and temperature may impact results.
- Errors in the frequency of the crystal oscillator for frequency measurement.

Random Errors

These errors are unpredictable and not possible to eliminate or minimize. Being consistent with your measurements is a method to minimize any random errors.

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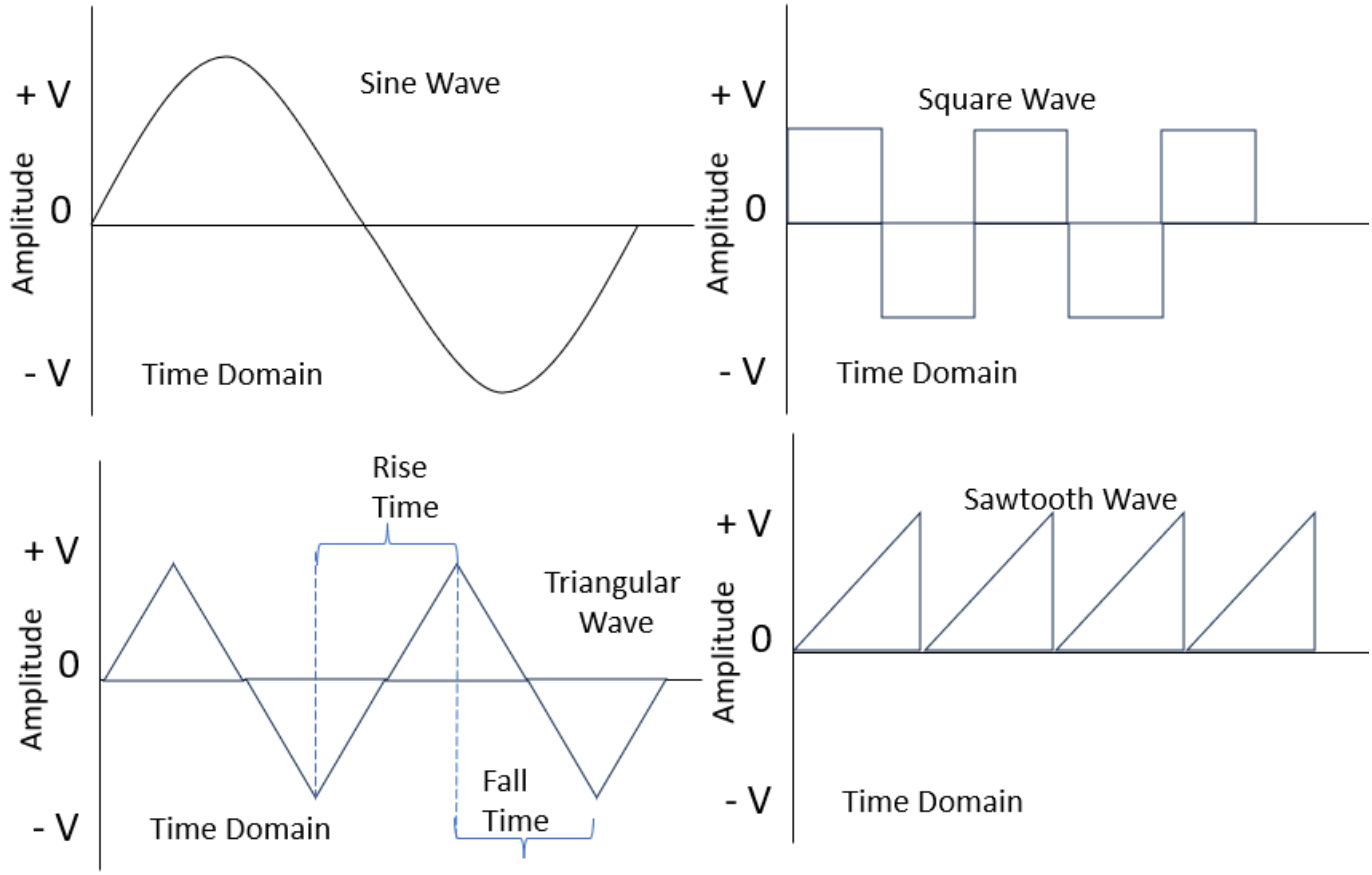
Measuring Waveforms

A signal carries information and a waveform does not. A waveform is a representation of voltage or a current over time. The best device for viewing and measuring waveforms is the oscilloscope. Sample wave forms are shown below.



There are additional considerations when measuring wave forms compared to a simple sine wave.

- **Frequency.** - If a signal is continually repeated, the frequency can be calculated.
- **Period** - The time that it takes for a repeating signal to complete one cycle.
- **Voltage** – Peak or Peak-to-peak voltage can be measured.
- **Amplitude** – Highest voltage at one point.
- **Phase** - Variations in time/position between two comparable signals.
- **Rise/Fall Time** - The rise and fall time of a signal describes the transition of the signal from a low to a high level (or vice versa).

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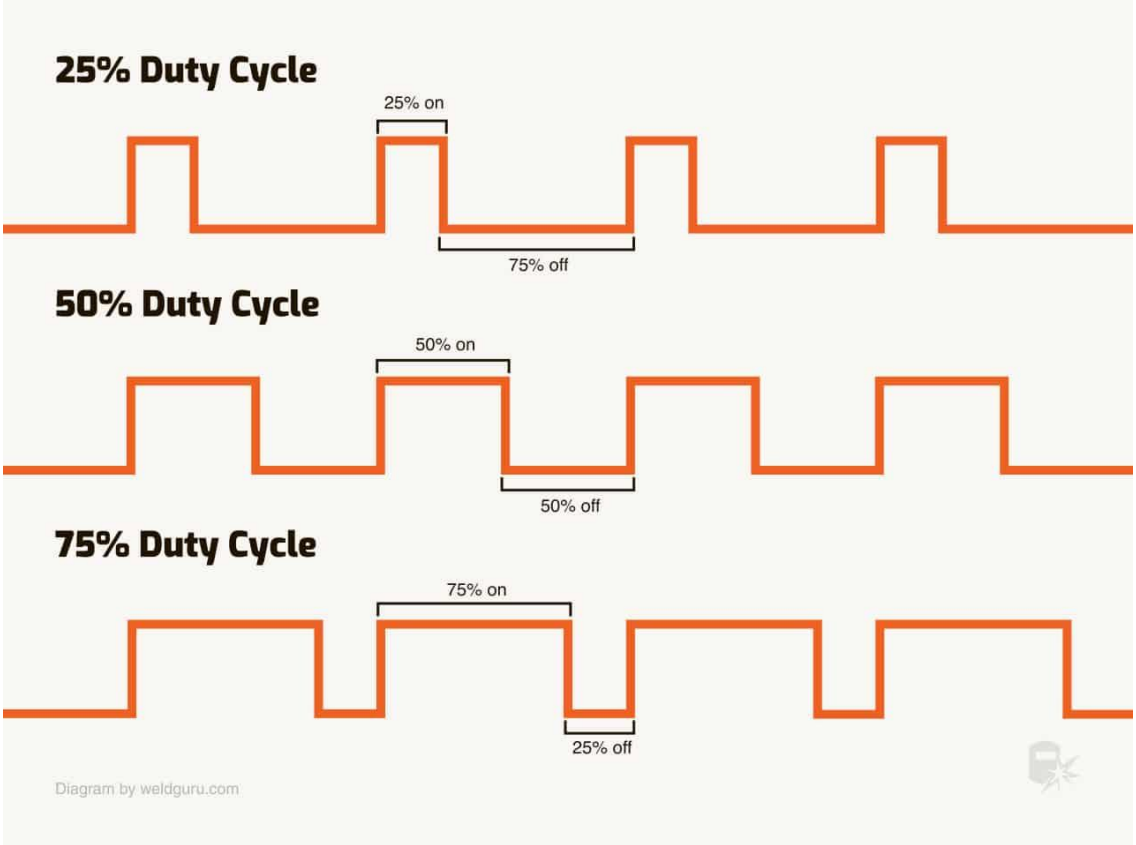
Duty Cycle

Duty cycle is the ratio of time a device or signal is actively "ON" compared to the total time of a full operating cycle, usually expressed as a percentage. Duty cycle is used to manage power in electronic devices (e.g., 60% ON, 40% OFF) or to define safe operating limits for machinery to prevent overheating.



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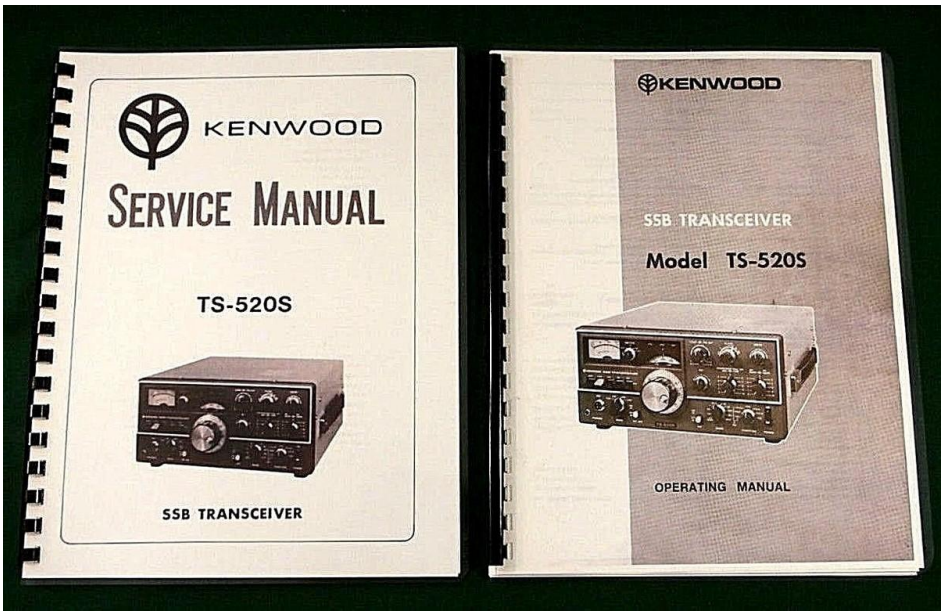
Manuals

Equipment manuals are essential documents for ensuring the safe, efficient, and proper operation of tools and machinery.

The primary manual types include:

- Operator/user manuals for daily use of the equipment.
- Service/repair manuals for technical troubleshooting.
- Maintenance manuals for preventative care. These would be performed routinely.
- Parts catalogues for ordering components.
- Safety manuals for hazard protection.



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Electronic Symbols

Name	Symbol	Comments
Resistor		A resistor is a passive, two-terminal electrical component that limits or regulates the flow of electric current in a circuit.
Variable Resistor		A variable resistor, or potentiometer, is an electro-mechanical component used to adjust resistance within a circuit.
Trimmer Resistor		A trimmer resistor (or trim pot) is a small, adjustable potentiometer used for fine-tuning or calibrating circuit resistance.
Rheostat		A rheostat is a two-terminal variable resistor used to control electrical current flow in a circuit by varying resistance without interrupting power.
Fixed capacitor		A fixed capacitor is a passive electronic component with a non-adjustable, set capacitance value.
Variable Capacitor		A variable capacitor is an electronic component with adjustable capacitance.
Trimmer Capacitor		A trimmer capacitor is a miniature variable capacitor used for precise, one-time or infrequent calibration of electronic circuits.
Polorised Capacitor		A polarized capacitor is an electronic component with distinct positive and negative terminals.
Air Core Inductor		An air core inductor is a passive component of a wire coil wound around a non-magnetic form (plastic, ceramic) or nothing at all (air).
Iron Core Inductor		An iron core inductor is a passive electronic component consisting of a wire coil wound around a ferromagnetic (iron or steel) core to enhance inductance.

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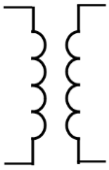
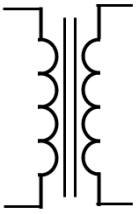
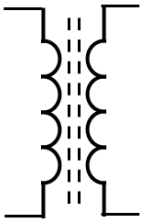
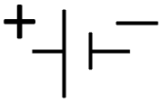
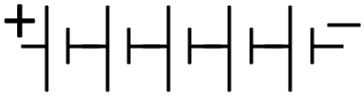
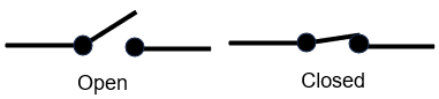
Ferrite Core Inductor		A ferrite core inductor is a passive electronic component using a ferromagnetic ceramic core to achieve high inductance, high magnetic permeability, and low electrical conductivity.
Powered Core Inductor		Powered core inductors are passive electronic components used for energy storage and filtering in power supply circuits.
Variable Inductor		A variable inductor is a passive electronic component with adjustable inductance.
Air Core Transformer		An air-core transformer, used for high frequencies, has air, or a non-magnetic material, instead of a solid iron core to hold the windings.
Iron Core Transformer		An iron core transformer uses a soft iron core to efficiently transfer magnetic energy between coils, boosting magnetic flux linkage for improved efficiency.
Ferrite Core Transformer		A ferrite core transformer is a high-frequency transformer utilizing a ferromagnetic ceramic core.
Electrical Cell		An electric cell converts stored chemical energy into electrical energy around 1.2v. Positive and negative symbols are not usually shown.
Battery		A battery is a collection of electric cells. Positive and negative symbols are not usually shown.
Lamp		Turns electrical energy into light.
Switch		
Fuse		A fuse is a safety device designed to protect circuits from overcurrent.

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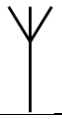
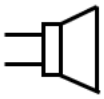
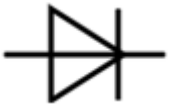
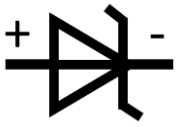
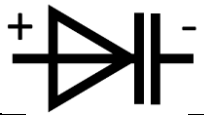
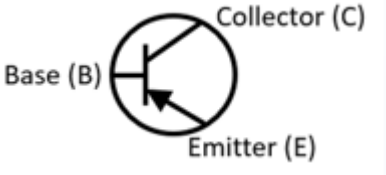
Earth		Electrical earth (or grounding) connects non-current-carrying metal parts of equipment to the physical ground.
Chassis Earth		Chassis earth is the electrical connection of an equipment's metal frame or casing to a common reference point, often earth ground, to ensure safety and stability.
Antenna		A transducer that converts RF signals to electrical signals.
Speaker		Converts electrical signals into sound.
Microphone		Converts sound into electrical signals.
Crystal		Electronic crystals are used in electronics to generate precise, stable frequencies for oscillators.
Diode		A diode is a two-terminal semiconductor device that acts as a one-way switch for electricity.
Zener Diode		More correctly termed reverse breakdown diodes. This effect, called Zener breakdown, occurs at a defined voltage, enabling the diode to be used as a voltage reference.
Varactor or Varicap Diode		Diode acting as a voltage-controlled capacitor.
Light Emitting Diode (LED)		Special diodes that emit light when activated.
NPN Transistor		An NPN transistor is a current controlling three-terminal Bipolar Junction Transistor (BJT) that functions as an electronic switch or amplifier.
PNP Transistor		An PNP transistor is a current controlling three-terminal Bipolar Junction Transistor (BJT) that functions as an electronic switch or amplifier.

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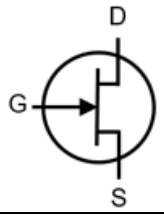
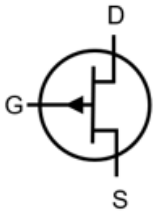
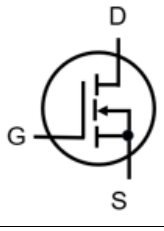
N Channel FET		An N-channel FET (Field-Effect Transistor) is a voltage-controlled semiconductor device.
P Channel FET		A P-channel FET (Field-Effect Transistor) is a voltage-controlled semiconductor that acts as a switch or amplifier.
N Channel MOSFET		An N-channel MOSFET (NMOS) is a three-terminal voltage-controlled semiconductor device that acts as a fast-switching or amplifying transistor
P Channel MOSFET		A P-Channel MOSFET is a voltage-controlled transistor that conducts current when a negative voltage is applied to the gate relative to the source, typically used for high-side switching.

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