EQUIPMENT DOCUMENTATION

PRINCIPLES OF MEASUREMENT
MEASUREMENT OF VOLTAGE AND RESISTANCE
Both voltage and resistance are measured across a circuit element. That is, the measuring instrument is connected in parallel with the circuit element whose voltage drop or resistance is to be measured.

As an example, consider the following circuit:

To measure the voltage drop across resistor \( R_1 \), the measuring instrument is connected in the following way:

When measuring resistance, the circuit must be disconnected from all voltage sources (power supply, battery, etc.). Also, if the circuit element whose resistance is to be measured is connected to other circuit elements, then the meter reading may or may not equal the resistance of the desired circuit element, depending on how the other circuit elements are connected.

To measure the resistance of \( R_1 \), the measuring instrument is connected in the following way:
Note that the switch from the power supply must be opened (the power supply must be turned **OFF**) when measuring resistance.

If the resistance meter is connected at points A and B, as shown below, the measured resistance is NOT $R_3$, but instead is the equivalent resistance of the parallel combination of $R_2$ and $R_3$.

![Circuit Diagram](image1)

To obtain a value for the resistance of just $R_3$, $R_3$ would have to be physically disconnected from the other resistors:

![Circuit Diagram](image2)

**MEASUREMENT OF CURRENT**

Current is measured with an ammeter. To measure current, the current must flow through the ammeter, so the ammeter is connected in series in the portion of the circuit where current is to be measured.

To measure the current flowing through $R_1$, in the example circuit used previously, the ammeter is connected in the following way:

![Circuit Diagram](image3)

*Note that the circuit must be ‘broken’ or ‘opened’ so that the ammeter can be inserted into the branch of the circuit containing $R_1$.***
BK PRECISION 4011A 5 MHz FUNCTION GENERATOR

Figure 1. Model 4011A Controls and Indicators.

CONTROLS AND INDICATORS

FRONT PANEL (Refer to Fig. 1)

1. **POWER Switch.** Turns power on and off.
2. **RANGE Switch.** Selects output frequency range. Seven ranges from 5 Hz to 5 MHz. Switch indicates maximum frequency of range and is adjusted with COARSE FREQUENCY control to 0.1 times the maximum. For example, if the 50 kHz range is selected, the output frequency can be adjusted from 50 kHz to 500 kHz.
3. **FUNCTION Switch.** Selects sine, square, or triangle waveform at OUTPUT jack.
4. **OUTPUT LEVEL Control.** Controls the amplitude of the signal at the OUTPUT jack. Output level can be decreased by approximately 20 dB with this control.
5. **DC OFFSET Control.** Enabled by the DC OFFSET Switch (12). Clockwise rotation from center changes the DC offset in a positive direction while counterclockwise rotation from center changes the DC offset in a negative direction.
6. **OUTPUT Jack.** Waveform selected by FUNCTION switch as well as the superimposed DC OFFSET voltage is available at this jack.

7. **TTL/CMOS Jack.** TTL or CMOS square wave, depending on the position of the CMOS LEVEL switch (13) is output at this jack. This output is independent of the OUTPUT LEVEL and DC OFFSET controls.
8. **CMOS LEVEL Control.** Rotating this control clockwise increases the amplitude of the CMOS square wave at the TTL/CMOS jack.
9. **VCG Jack.** Voltage Controlled Generator input. Permits external control of generator output frequency by a DC voltage input at this jack. A positive voltage will decrease frequency.
10. **DUTY CYCLE Control.** Enabled by the DUTY CYCLE Switch (14). Rotation from center position adjusts the duty cycle of the main OUTPUT signal.
11. **20dB Switch.** When engaged, the signal at the OUTPUT jack is attenuated by 20 dB.
12. **DC OFFSET Switch.** When engaged, enables operation of the DC OFFSET control (5).

13. **CMOS LEVEL Switch.** When engaged, changes the TTL signal to CMOS signal at the TTL/CMOS jack.
14. **DUTY CYCLE Switch.** When engaged, enables operation of DUTY CYCLE control (10).
15. **FINE FREQUENCY Control.** Vernier adjustment of the output frequency for ease of setting frequency.
16. **COARSE FREQUENCY Control.** Coarse adjustment of the output frequency from 0.1 to 1 times the selected range.

17. **COUNTER DISPLAY.** Displays frequency of internally generated waveform.
18. **GATE LED.** Indicates when the frequency counter display is updated. When the 50K through 5M ranges are selected, the LED will flash 10 times per second (every 0.1 seconds). When the 50 through 5K ranges are selected, the LED will flash once every second and when the 5 range is selected, the LED will flash every 10 seconds. As the LED turns off, the display is updated.
19. **Hz and kHz LED.** Indicates whether the counter is reading in Hz or kHz.
20. **Inverter Switch**
The B+K Precision Model 4011A Function Generator is a versatile instrument capable of producing a variety of output waveforms over a broad range of frequencies. To gain a working familiarity with the unit, it is recommended that it be connected initially to an oscilloscope, so that the effects of the various controls on the output waveforms can be observed. Use this manual as required for reference until becoming accustomed to the operating procedures.

FREQUENCY AND WAVEFORM SELECTION

1. Initially, verify that the DUTY CYCLE (14), CMOS LEVEL (13), DC OFFSET (12), -20dB (11) switches are in the OUT position (released). This will produce a symmetrical waveform unaffected by the other controls.

2. Plug the unit into an appropriate power source and turn it on by engaging the POWER switch (1).

3. Select the desired waveform (SINE, SQUARE, or TRIANGLE) by engaging one of the FUNCTION switches (3). Phase relationships of the waveforms are shown in Fig. 2.

4. Select the frequency of the waveform by engaging one of the RANGE switches (2). The output frequency is displayed, along with the appropriate measurement units, kHz or Hz (19), on the LED display.

5. Rotate the COARSE (16) frequency control to quickly set the output frequency to the approximate desired value. The FINE (15) frequency control can then be used to easily set the output to the specific desired value. The frequency selected is available at the OUTPUT jack (6). In addition, a digital signal, either TTL or CMOS is available at the TTL/CMOS jack (7) (refer to the "TTL/CMOS OUTPUT" section of this manual).

6. Adjust the amplitude of the output as desired using the OUTPUT LEVEL control (4). Rotation of this control varies the amplitude from maximum to 20dB below maximum. An additional attenuation of -20dB is available by pushing in the -20dB switch (11). The attenuation factors can be combined for a total of -40dB. The maximum signal level is 10V p-p (into 50Ω).

7. A superimposed DC component can be added to the output signal by engaging the DC OFFSET switch (12) to enable operation of the DC OFFSET control (5). Rotation of this control adds a positive or negative DC component to the output signal. The DC component introduced is independent of the OUTPUT LEVEL control and can be varied by ±10 volts open circuited or ±5 volts into 50Ω. The DC Offset does not affect the TTL/CMOS output jack. The effect of DC OFFSET is shown in Fig. 3.

CONSIDERATIONS

1. Counterclockwise rotation of the COARSE frequency control decreases the output frequency to approximately one-tenth of the maximum for the range selected (10:1). For example, if the 50K range is selected and the COARSE frequency control is set to full counterclockwise, the output frequency is approximately 5kHz.

2. It is advisable to set the FINE frequency control to the approximate center of its rotation before setting the COARSE frequency control. This assures that the FINE control will not reach its limit while trying to finalize the frequency setting.

3. The FINE frequency control provides approximately ±5% frequency deviation from the COARSE control setting. This provides a vernier adjustment to easily set the frequency to a precise value.

4. When the 5Hz range is selected, the gate time is 10 seconds and the display is updated once every 10 seconds. The result of a frequency change will not be displayed until 10 seconds later. Adjust the frequency in progressively smaller steps, waiting for the display to update until the desired frequency is obtained.

5. When outputting square waves or when using the TTL output, terminate the cable into 50Ω to minimize ringing. Also, keep cables as short as possible.

6. Remember that the output signal swing of the generator is limited to ±10 volts open circuited or ±5 volts into 50Ω, and applies to the combined peak-to-peak signal and DC offset. Clipping occurs slightly above these levels. Fig. 3 illustrates the various operating conditions encountered when using the DC offset. If the desired output signal is large or if a large DC offset is required, an oscilloscope should be used to make sure that the desired signal is obtained without undesirable clipping.
FREDERIKSEN AC/DC POWER SUPPLY

DC voltage (0-24 V) and current (0-10 A) are controlled with the knobs on the front panel. From 0-12 V, the maximum current is 10 A. From 12-24 V, the maximum current linearly decreases from 10 A to 6 A, dependent on voltage setting. Note that the current control functions as a current limiter. When using the supply to study the behaviour of a circuit, it is important to ensure that the current is being determined by the circuit itself, and not by the setting of the current control.

60 Hz AC output (0-24 V) is also controlled with a knob on the front panel.

The AC side and the DC side each have two digital displays showing voltage and current.

AMPROBE 37XR-A DIGITAL MULTIMETER

Measuring DC Voltage

1. Set the Function Switch to V.
2. If RANGE is displayed, press the RANGE button to enable autoranging.
3. Connect the Test Leads: Red to VΩ ‒, Black to COM
4. Connect the Test Probes to the circuit test points.
5. Read the display, and, if necessary, correct any overload (OL) conditions.

See Figure 1
Measuring AC Voltage (True rms)  
See Figure -2- & -3-
See Additional Features to find out the advantages of true rms.

1. Set the Function Switch to $\bar{V}$.
2. If RANGE is displayed, press the RANGE button to enable autoranging.
3. If dBm is displayed, press the yellow button to turn off dBm (enable $\bar{V}$)
4. Connect the Test Leads: Red to $V \Omega \rightarrow$, Black to COM
5. Connect the Test Probes to the circuit test points.
6. Read the display, and, if necessary, correct any overload (OL) conditions.
Preparing for Current Measurements

- Turn off circuit power before connecting the test probes.
- Allow the meter to cool between measurements if current measurements approach or exceeds 10 amps.
- A warning tone sounds if you connect a test lead to a current input before you select a current function.
- Open circuit voltage at the measurement point must not exceed 1000 V.
- Always measure current in series with the load. Never measure current across a voltage source.
Measuring DC Current

1. Set the Function Switch to a current function, μA, mA, or 10A.
2. If the 10A function is not selected and RANGE is displayed, press the RANGE button to enable autoranging.
3. Connect the Test Leads: Red to μA mA or 10A, Black to COM
4. Turn off power to the circuit being measured.
5. Open the test circuit (——X——) to establish measurement points.
6. Connect the Test Probes in series with the load.
7. Turn on power to the circuit being measured.
8. Read the display, and, if necessary, correct any overload (OL or -OL) conditions.
Measuring AC Current (True rms)  See Figure -3- & -5-
See Additional Features to find out the advantages of true rms.
1. Set the Function Switch to a current function and range, μA, mA, or 10A.
2. If DC is displayed, press the yellow button to turn on AC.
3. If the μA or mA function is not selected and RANGE is displayed, press the RANGE button to enable autoranging.
4. Connect the Test Leads: Red to μA mA or 10A, Black to COM
5. Turn off power to the circuit being measured.
6. Open the test circuit (→X←) to establish measurement points.
7. Connect the Test Probes in series with the load.
8. Turn on power to the circuit being measured.
9. Read the display, and, if necessary, correct any overload (OL) conditions.
Measuring Resistance

1. Set the Function Switch to $\Omega$.
2. If $\text{m} \Omega$ is displayed, press the yellow button to display $\Omega$.
3. If RANGE is displayed, press the RANGE button to enable autoranging.
4. Connect the Test Leads: Red to V $\Omega \rightarrow$, Black to COM
5. Turn off power to the circuit being measured. Never measure resistance across a voltage source or on a powered circuit.
6. Discharge any capacitors that may influence the reading.
7. Connect the Test Probes across the resistance.
8. Read the display. If $D\ell$ appears on the highest range, the resistance is too large to be measured.
Measuring Capacitance

1. Set the Function Switch to the \( \equiv \) function.
2. If RANGE is displayed, press the RANGE button to enable autoranging.
3. Connect the Test Leads: Red to COM, Black to mA
4. Turn off power to the circuit being measured.
5. Discharge the capacitor using a 100 kΩ resistor.
6. Free at least one end of the capacitor from the circuit.
7. Connect the Test Probes across the capacitor. When measuring an electrolytic capacitor match the test lead polarity to the polarity of the capacitor.
8. Read the display.

See Figure -9-
Measuring Inductance

1. Set the Function Switch to mH or H.
2. If RANGE is displayed, press the RANGE button to enable autoranging.
3. Connect the Test Leads: Red to H mA, Black to COM
4. Turn off power to the circuit being measured.
5. Free at least one end of the inductor from the circuit.
6. Connect the Test Probes across the inductor.
7. Read the display.

This lead goes to the mA terminal
Measuring Frequency

1. Set the Function Switch to Hz.
2. If % is displayed, press the yellow button to display Hz.
3. If RANGE is displayed, press the RANGE button to enable autoranging.
4. Connect the Test Leads: Red to Hz, Black to COM
5. Connect the Test Probes to the signal source.
6. Read the display.
**Electrical Specifications**

**DC VOLTS**
- Ranges: 1000mV, 10V, 100V, 1000V (Auto/Manual ranging)
- Resolution: 100 μV
- Accuracy: ±0.1 % rdg + 5 dgts
- Input impedance: 10 MΩ
- Overload protection: 1000 V dc or 750 V ac rms

**AC VOLTS TRUE RMS** (45 Hz - 2 kHz)
- Ranges: 1000mV, 10V, 100V, 750V (Auto/Manual ranging)
- Resolution: 100 μV
- Minimum reading on 1000mV range: 14 mV
- Accuracy:
  - ±(1.2 % rdg + 10 dgts) 45 Hz to 500 Hz
  - ±(2.0 % rdg + 10 dgts) 500 Hz to 2 kHz
  - ±(2.0 % rdg + 10 dgts) 45 Hz to 1 kHz
- On 750 V range

**DC CURRENT**
- Ranges: 100μA, 1000μA, 10mA, 100mA, 400mA, 10A (Auto/Manual ranging)
- Resolution: 0.01 μA
- Accuracy:
  - ±(0.5 % rdg + 10 dgts) on 100μA range
  - ±(0.5 % rdg + 5 dgts) on 1000μA to 400mA ranges
  - ±(1.5 % rdg + 10 dgts) on 10A range

**AC CURRENT TRUE RMS** (45 Hz to 1 kHz)
- Ranges: 100μA, 1000μA, 10mA, 100mA, 400mA, 10A (Auto/Manual ranging)
- Resolution: 0.01 μA
- Accuracy:
  - ±(1.5 % rdg + 10 dgts) on 100μA to 100mA ranges
  - ±(2.0 % rdg + 10 dgts) on 400mA range
  - ±(2.5 % rdg + 20 dgts) on 10A range

**RESISTANCE**
- Ranges: 1000Ω, 10kΩ, 100kΩ, 1000kΩ, 1MΩ, 40MΩ (Auto/Manual ranging)
- Resolution: 100 mΩ
- Accuracy: ±(0.5 % rdg + 8 dgts) on 1000Ω to 100kΩ ranges
- ±(1.0 % rdg + 10 dgts) on 10MΩ range
- ±(2.0 % rdg + 10 dgts) on 40MΩ range
- Open circuit volts: -0.45 V dc typical
- Overload protection: 1000 V dc or 750 V ac rms

**CAPACITANCE**
- Ranges: 40nF, 400nF, 4μF, 40μF, 400μF (3999 counts) (Auto/Manual ranging)
- Resolution: 0.01 nF
- Accuracy: ±(3.0 % rdg + 10 dgts) on 40nF, 400μF ranges
- ±(3.0 % rdg + 5 dgts) on 400nF to 40μF ranges
- Test voltage: < 1 V
- Test Frequency: 1.3 Hz on 40nF to 40μF ranges; 0.7 Hz on 400μF range
- Input protection: 0.5A/1000V fast blow ceramic fuse 6.3×32 mm on μA/mA input

**INDUCTANCE**
- Ranges: 4mH, 40mH, 400mH, 4H, 40H (3999 counts) (Auto/Manual ranging)
- Resolution: 1 μH
- Accuracy: ±(5.0 % rdg + 30 dgts)*
*For values of Q ≤ 7
- Test frequency: 1 kHz on 4mH, 40mH ranges, 200 Hz on 400mH to 40H ranges.
- Input protection: 0.5A/1000V fast blow ceramic fuse 6.3×32 mm on μA/mA input
The oscilloscope is one of the most important instruments in the fields of electrical measurement and electronics. Rather than simply giving a numerical measurement value, an oscilloscope plots the voltage of the input signal versus time. A dual-trace oscilloscope, such as the TBS1052B-EDU, allows plotting one input voltage versus another input voltage. This produces a "phase ellipse" which can be used to measure the phase difference between the two signals.

Since the oscilloscope allows measurement of the voltage of the input signal it can be thought of as a voltmeter, and like a voltmeter the oscilloscope is connected across (in parallel with) the part of the circuit across which the voltage is to be measured. Note that each input channel of the oscilloscope has a pair of red and black terminals. These correspond to the positive and negative terminals of a voltmeter, respectively. We say that the voltage at the point of the circuit connected to the red terminal is being measured with respect to the point of the circuit connected to the black terminal.

*Note that the black scope input terminal must be connected to the GROUND (negative) terminal of the power source. For the function generator the black terminal of the output is ground.*
For example, consider the following circuit:

Suppose you are asked to measure the voltage across circuit element 2, or equivalently, the voltage at B with respect to C ($V_{BC}$). The oscilloscope would be connected with the red input terminal to B and the black input terminal to C:

As has been mentioned, voltage is measured with the oscilloscope by measuring the vertical displacement of the beam from the 0 voltage position. The 0 voltage position can be found either by putting the scope input switch to the GND position, or by taking the lead connected to the red input terminal of the scope and disconnecting it from the circuit.

*Note that the 0 voltage trace (a horizontal line) can be moved to correspond to any horizontal position on the screen by using the vertical position control for the appropriate channel. i.e. There is NO special significance to the x-axis on the grid unless YOU give it a special significance by adjusting the controls so that it corresponds to the 0 voltage location.*