SECTION-B

ELECTRONIC INSTRUMENTS

- Different from the Q associated with resonators and filters

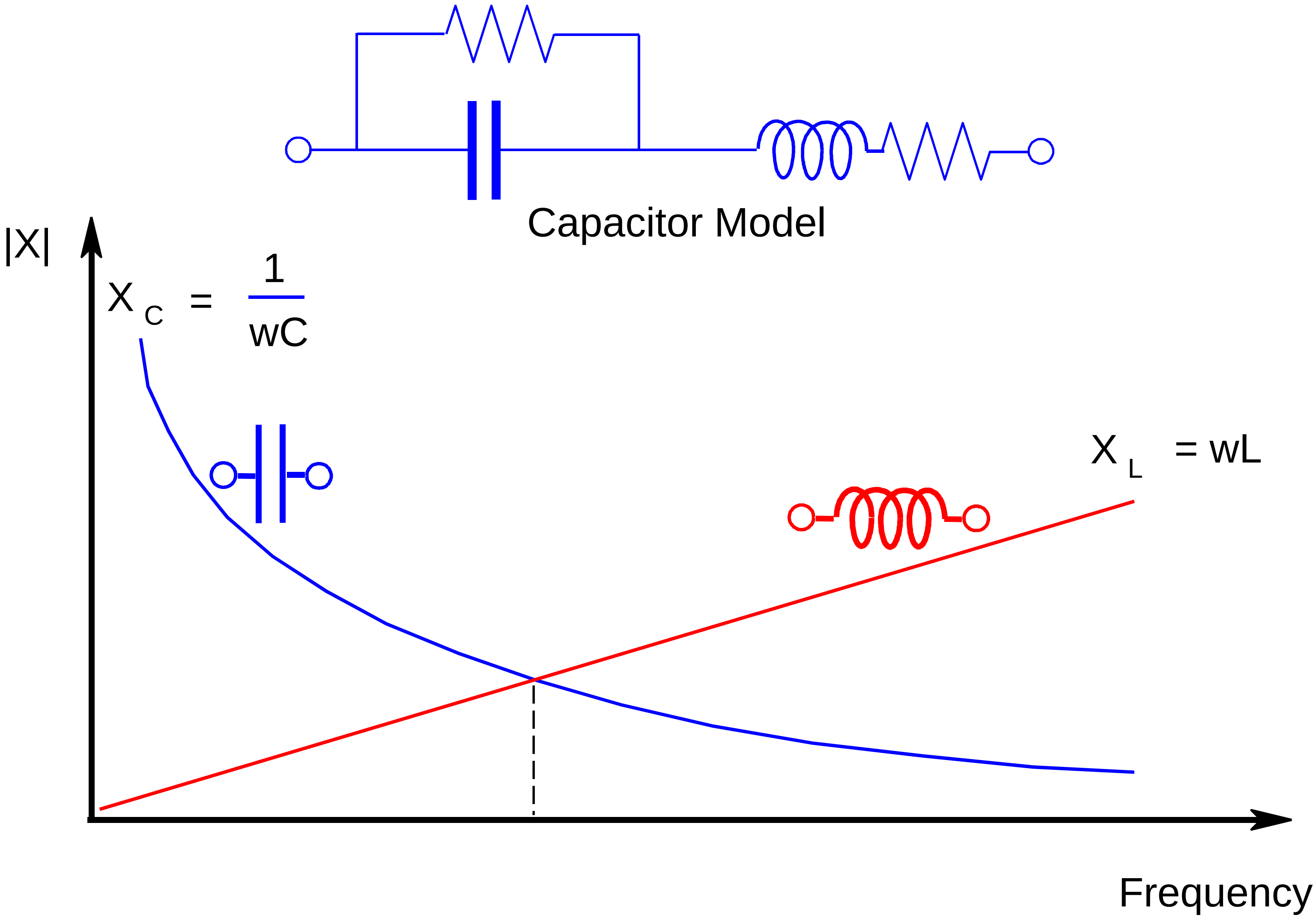
- $$Q = \frac{\text{Energy stored}}{\text{Energy lost}} = \frac{X_s}{R_s}$$

- The better the component, then

  $R \Rightarrow 0 \qquad Q \Rightarrow \infty$

- $D = \frac{1}{Q}$, mainly used for capacitors

H

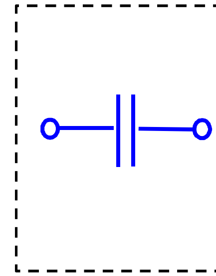


H

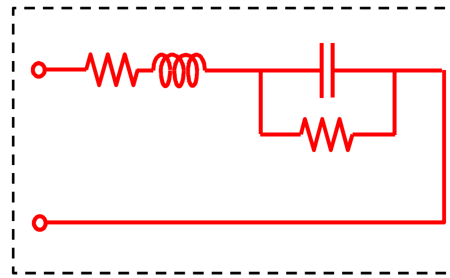
Component Dependency Factors

- Test signal frequency
- Test signal level
- DC bias, voltage and current
- Environment (temperature, humidity, etc.)
- Component's current state
- Aging

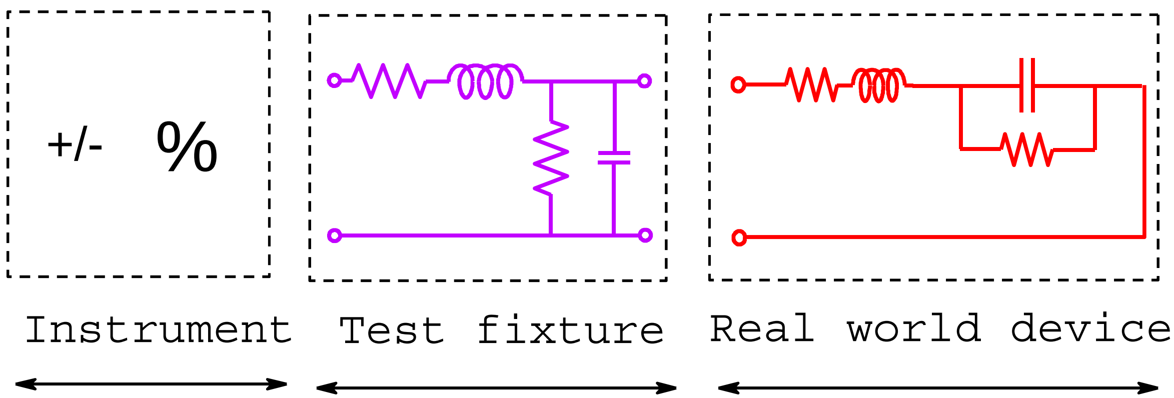
- TRUE



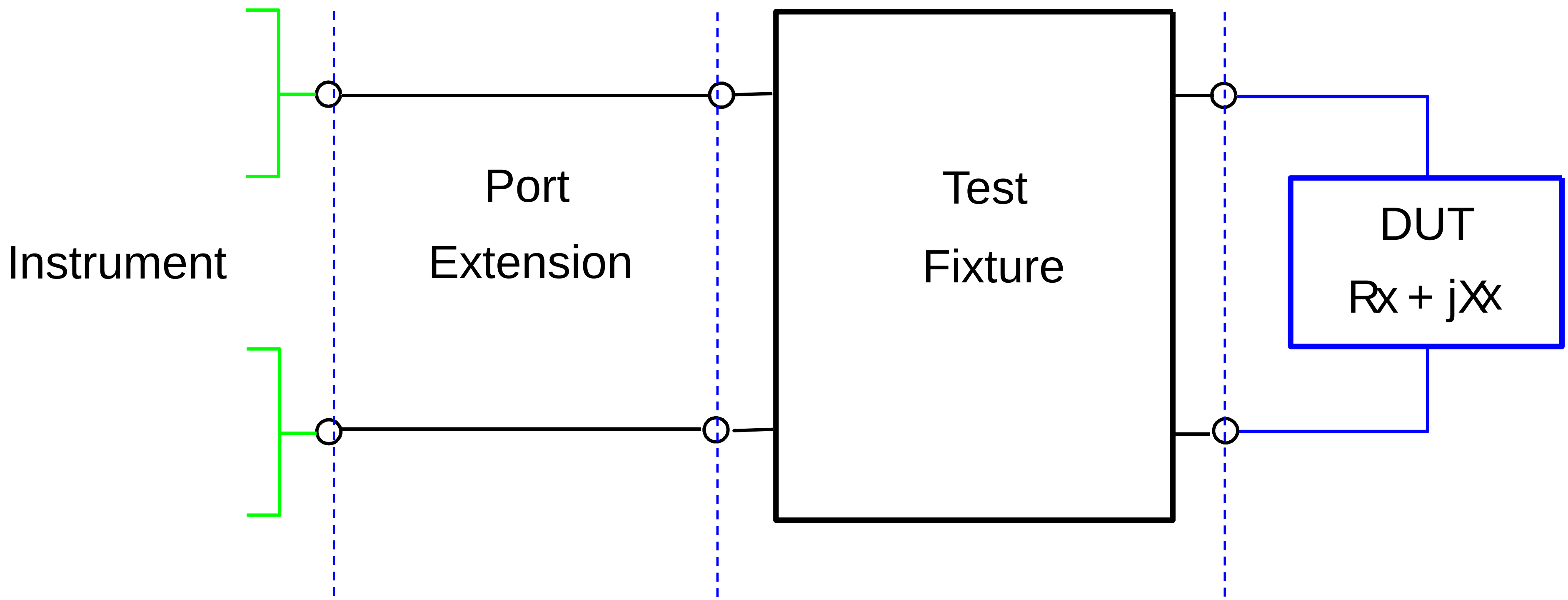
- EFFECTIVE



- INDICATED



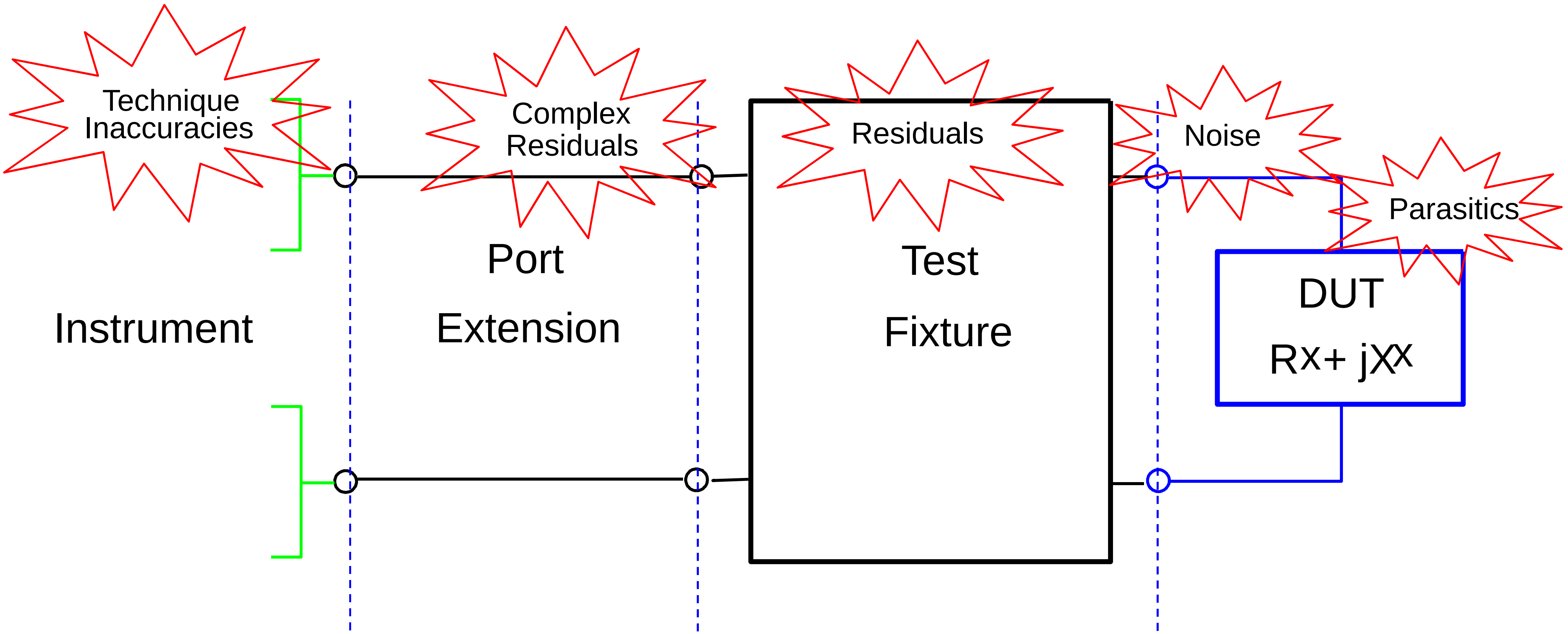
H



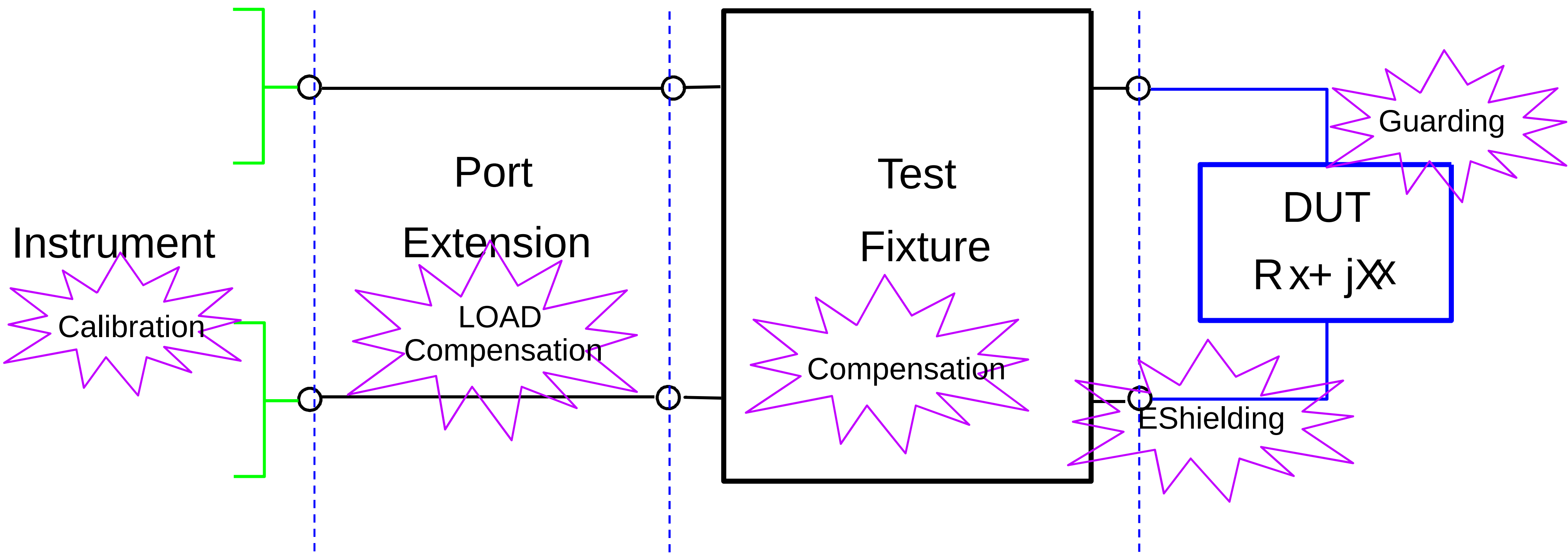
H

Sources of Measurement Errors

- Measurement technique inaccuracies
- Port Extension complex residuals
- Fixture residuals
- RFI and other noise
- DUT stray and lead parasitics

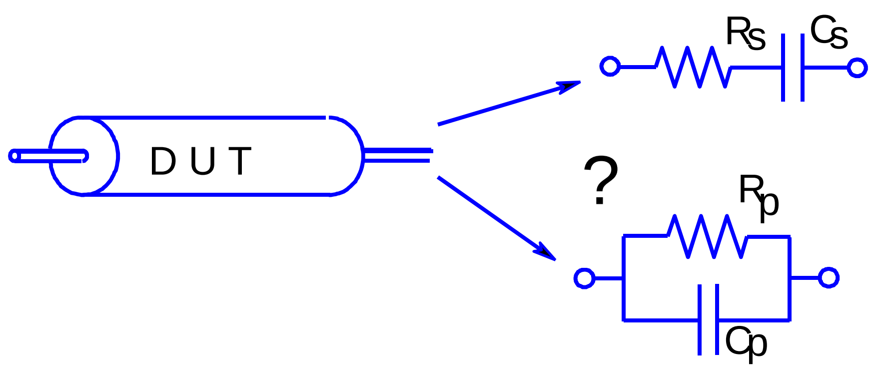

Technique
Inaccuracies
Complex
Residuals
Residuals
Noise
Parasitics
Instrument
Port
Extension
Test
Fixture
DUT
Rx+ jXx

H


Instrument
Calibration
Port
Extension
LOAD
Compensation
Test
Fixture
Compensation
Guarding
DUT
Rx+ jXx
EShielding

H

	I-V Method	Reflection Coefficient Method
Measured	I, V	$\Gamma_{x,y}$
Direct Calculations	$Z = \dfrac{V}{I}$	$Z = Z_o \dfrac{1 + \Gamma}{1 - \Gamma}$
Model based Approximations		Ls , Lp, Cs, Cp, Rs or ESR, Rp, D, Q



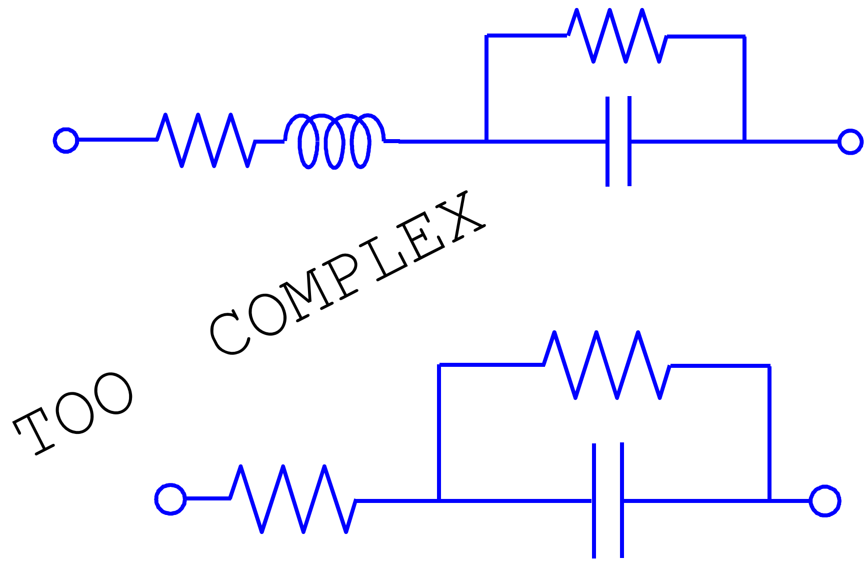
H

Requires Simplified Models

Complete Capacitor Model

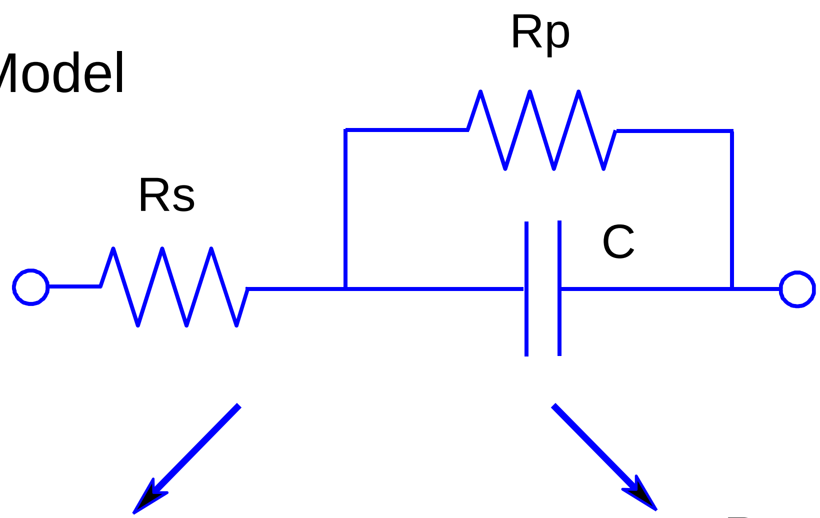
Rs,Ls,Rp,Cp ?

No L Capacitor Model

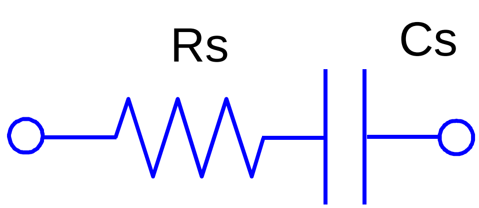


Rs vs Rp , who wins ?

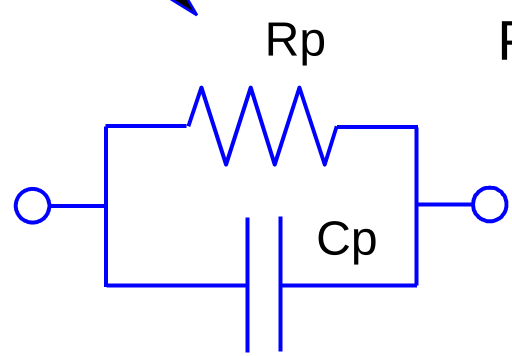
No L Capacitor Model



Series model



Parallel model



Large C

Small L

Small C

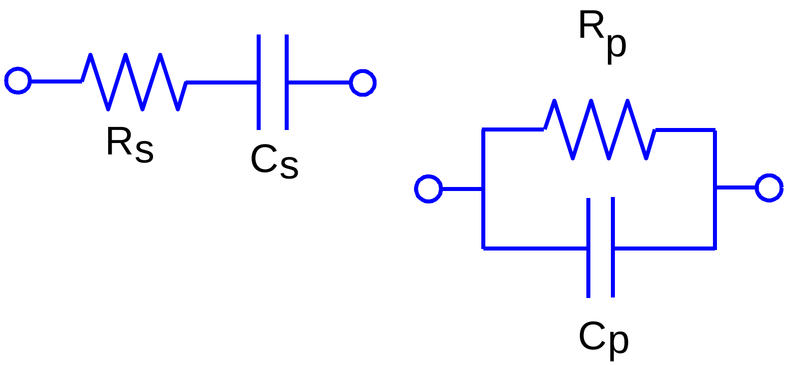
Large L

SMD

H

- Both are correct

$$C_s = C_p\,(1 + D^2)$$



- One is a better approximation

- For high Q or low D components,

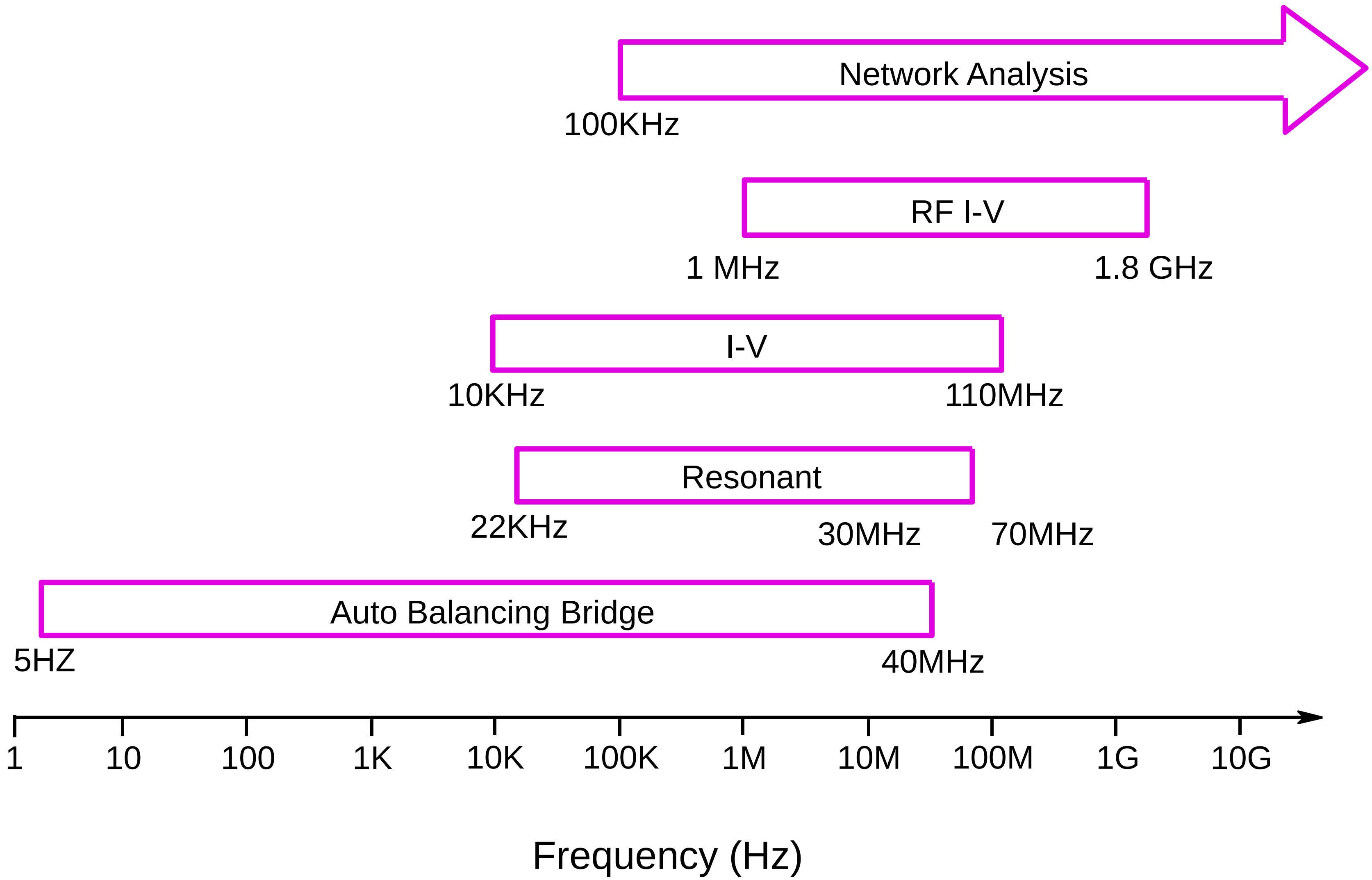
$$C_s \approx C_p$$

- Auto Balancing Bridge
- Resonant (Q-adapter / Q-Meter)
- I-V (Probe)
- RF I-V
- Network Analysis (Reflection Coefficient)
- TDR (Time Domain Reflectometry)

- Technique Selection Criteria
- Theory of Operation
- Advantages and Disadvantages of each technique
- Expanded connection information and theory for auto balancing bridge (r4 terminal pair) instruments
- Error Compensation to minimize measurement error

- Frequency
- DUT Impedance
- Required measurement accuracy
- Electrical test conditions
- Measurement parameters
- Physical characteristics of the DUT

H

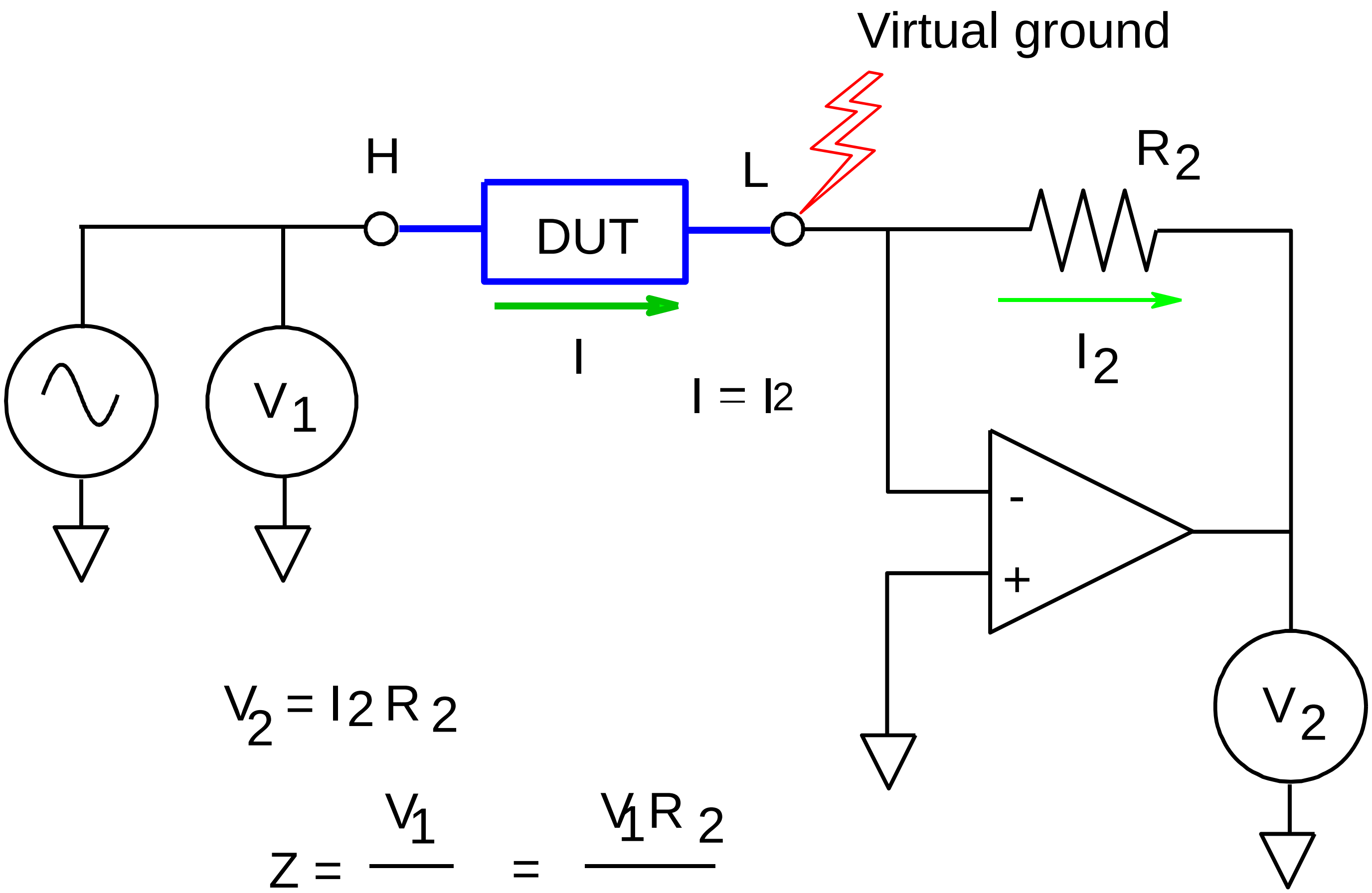


Network Analysis
100KHz
RF I-V
1 MHz
1.8 GHz
I-V
10KHz
110MHz
Resonant
22KHz
30MHz
70MHz
Auto Balancing Bridge
5HZ
40MHz
1
10
100
1K
10K
100K
1M
10M
100M
1G
10G
Frequency (Hz)

H

- All are good
- Each has advantages and disadvantages
- Multiple techniques may be required

H



$$V_2 = I_2 R_2$$

$$Z = \frac{V_1}{I_2} = \frac{V_1 R_2}{V_2}$$

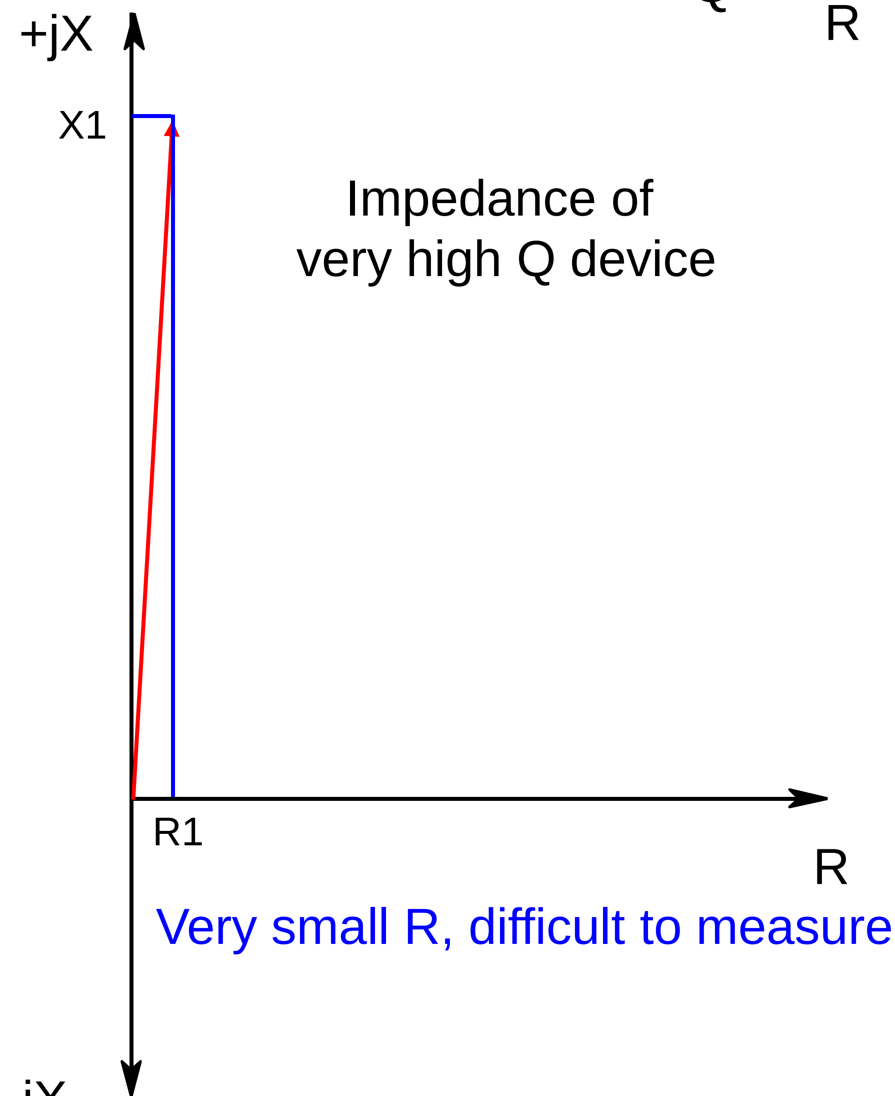
H

Auto Balancing Bridge

Advantages and Disadvantages

- Most accurate, basic accuracy 0.05%
- Widest measurement range
- C,L,D,Q,R,X,G,B,Z,Y,O,...
- Widest range of electrical test conditions
- Simple-to-use
- Low frequency, f < 40MHz

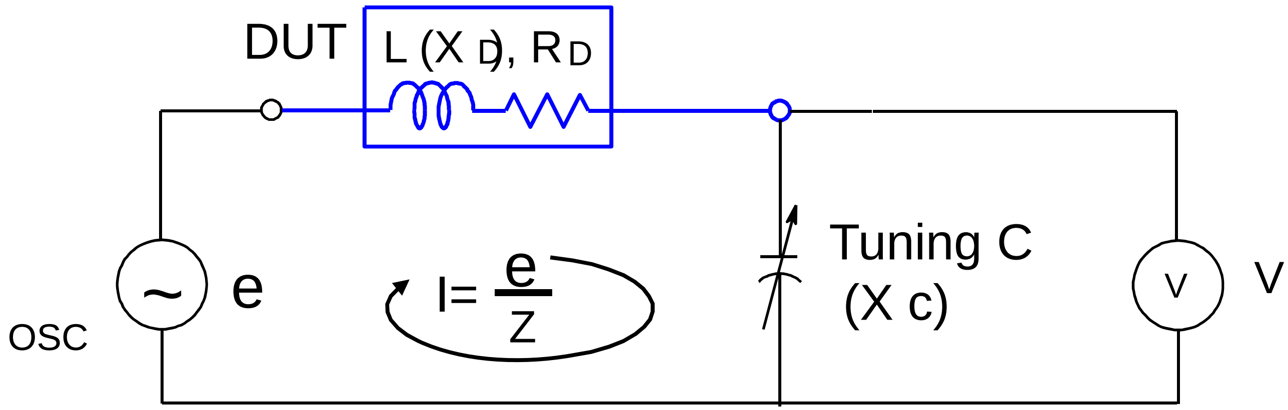
$$Q = \frac{X_l}{R}$$



+jX
X1
Impedance of very high Q device
R1
R
Very small R, difficult to measure
-jX

H

- Tune C so the circuit resonates
- At resonance $X_D = -X_C$, only R_D remains



$$X_C = \frac{V}{I} = \frac{R_D V}{e} \quad \text{(at resonance)}$$

$$Q = \frac{|X_D|}{R_D} = \frac{|X_C|}{R_D} = \frac{|V|}{e}$$

Resonant Method

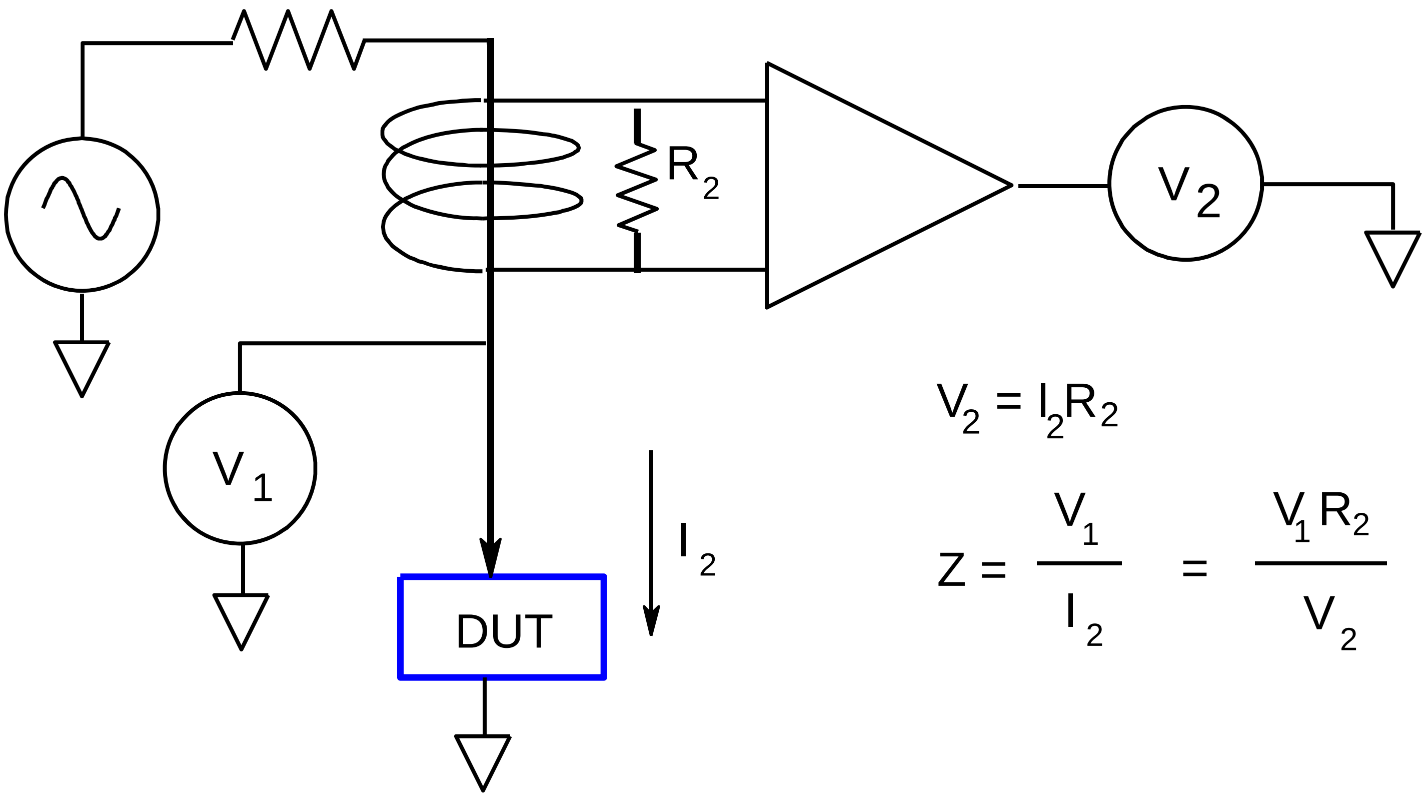
Advantages and Disadvantages

Very good for high Q - low D measurements

Requires reference coil for capacitors

Limited L,C values accuracy

Vector	Scalar
75kHz - 30MHz	22kHz - 70MHz
automatic and fast	manual and slow
easy to use	requires experienced user
limited compensation	No compensation



$$V_2 = I_2 R_2$$

$$Z = \frac{V_1}{I_2} = \frac{V_1 R_2}{V_2}$$

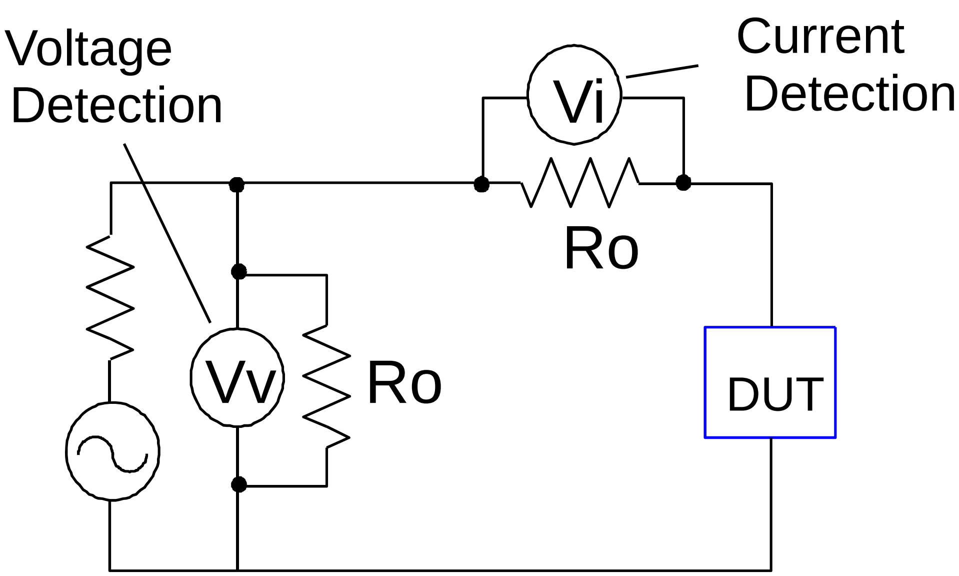
H

I-V (Probe)

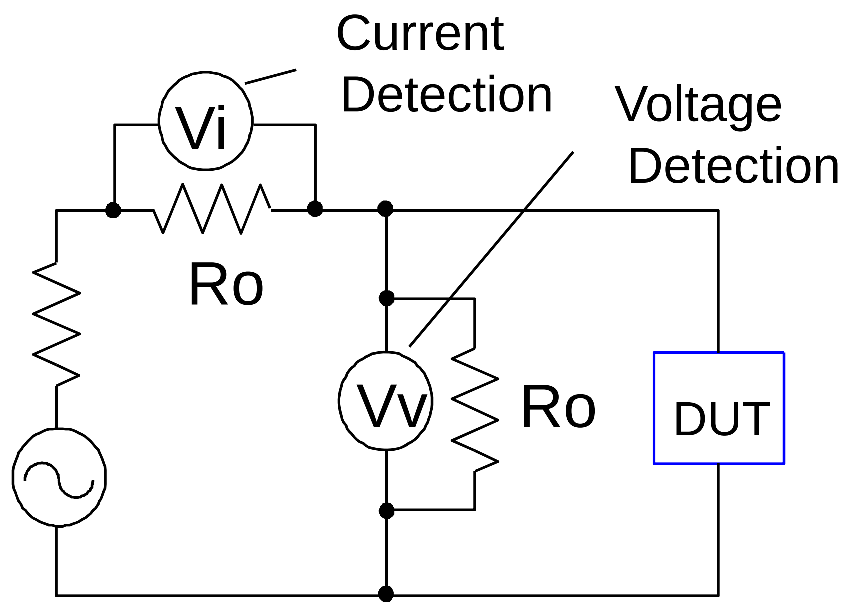
Advantages and Disadvantages

- Medium frequency, 10kHz < f < 110MHz
- Moderate accuracy and measurement range
- Grounded and in-circuit measurements
- Simple-to-use

High Impedance Test Head



Low Impedance Test Head

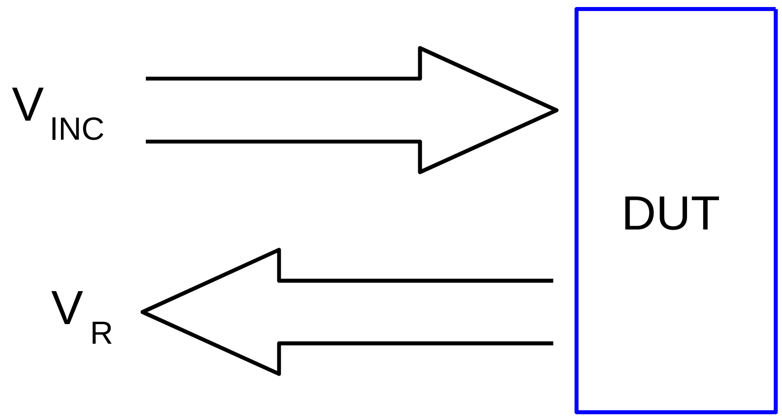


H

RF I-V

Advantages and Disadvantages

- High frequency, 1MHz < f < 1.8GHz
- Most accurate method at > 100 MHz
- Grounded device measurement

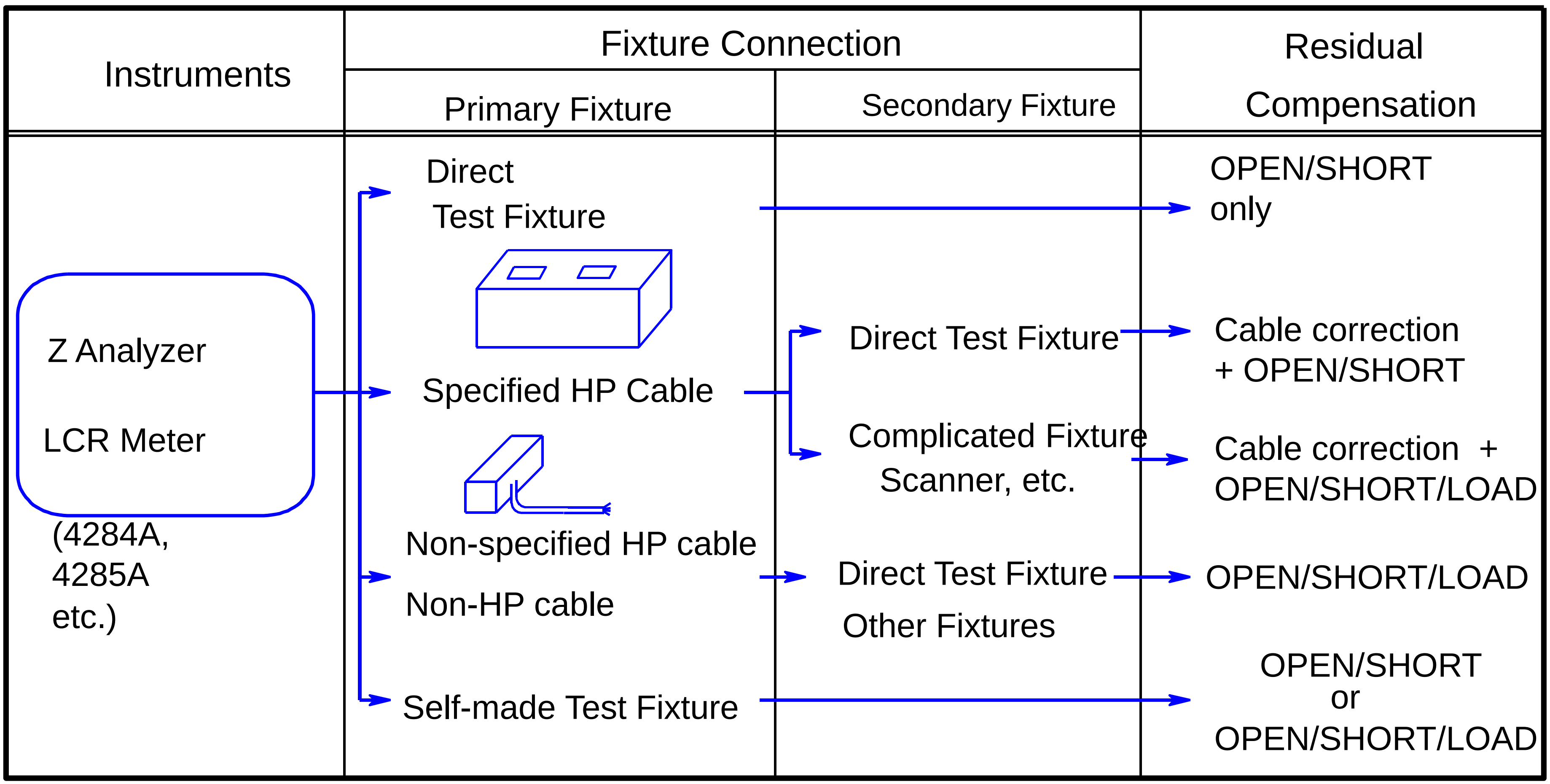


$$\Gamma = \frac{V_R}{V_{INC}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

H

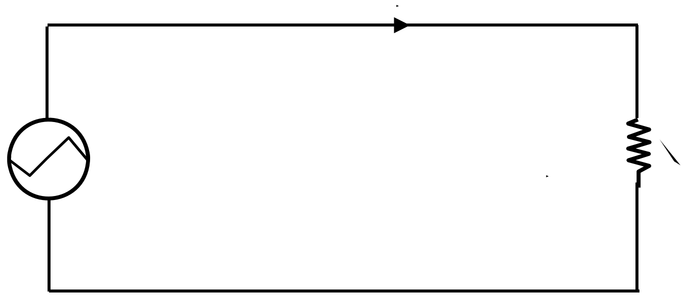
Which compensation technique should you select?

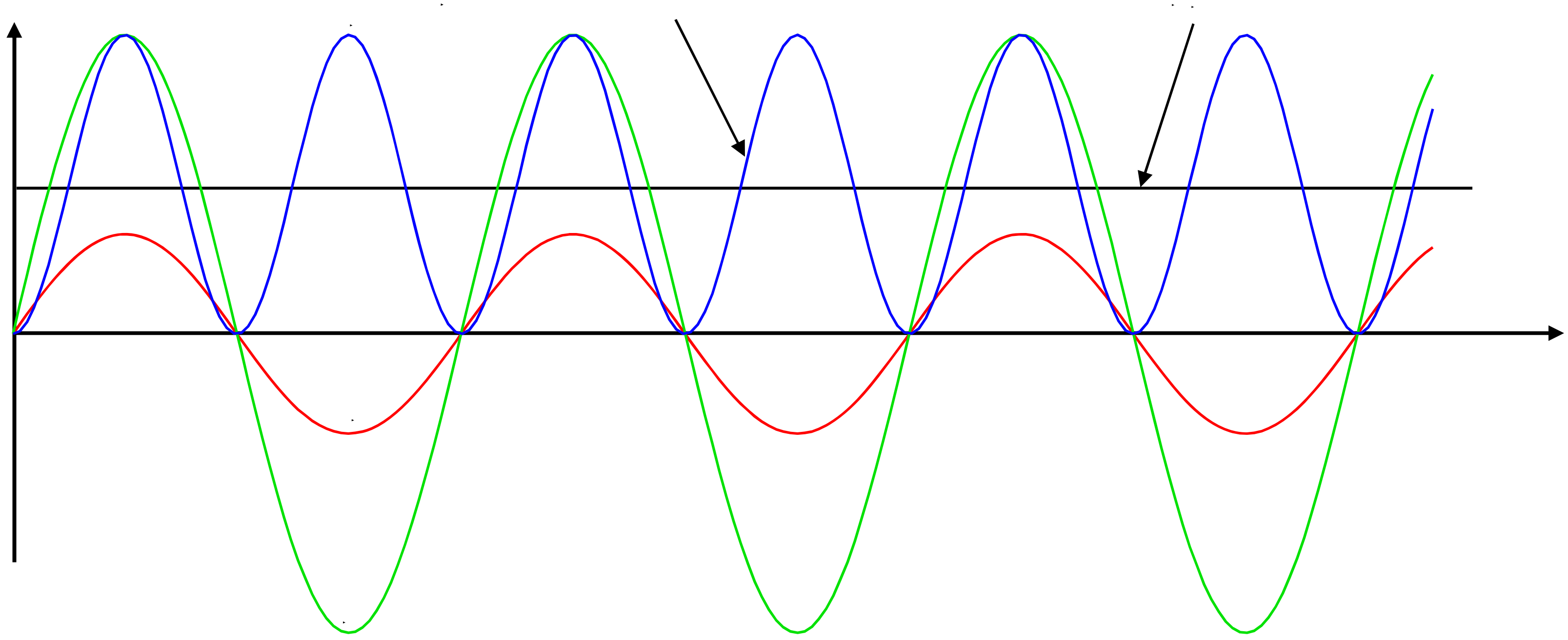
- Selection Guideline -



H

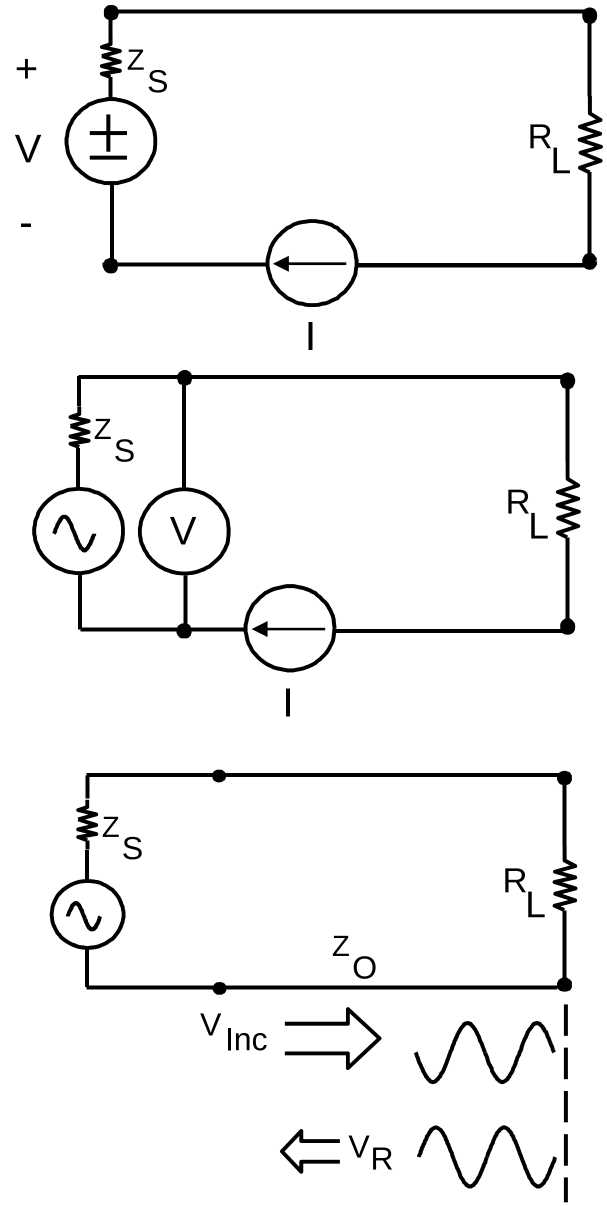
H



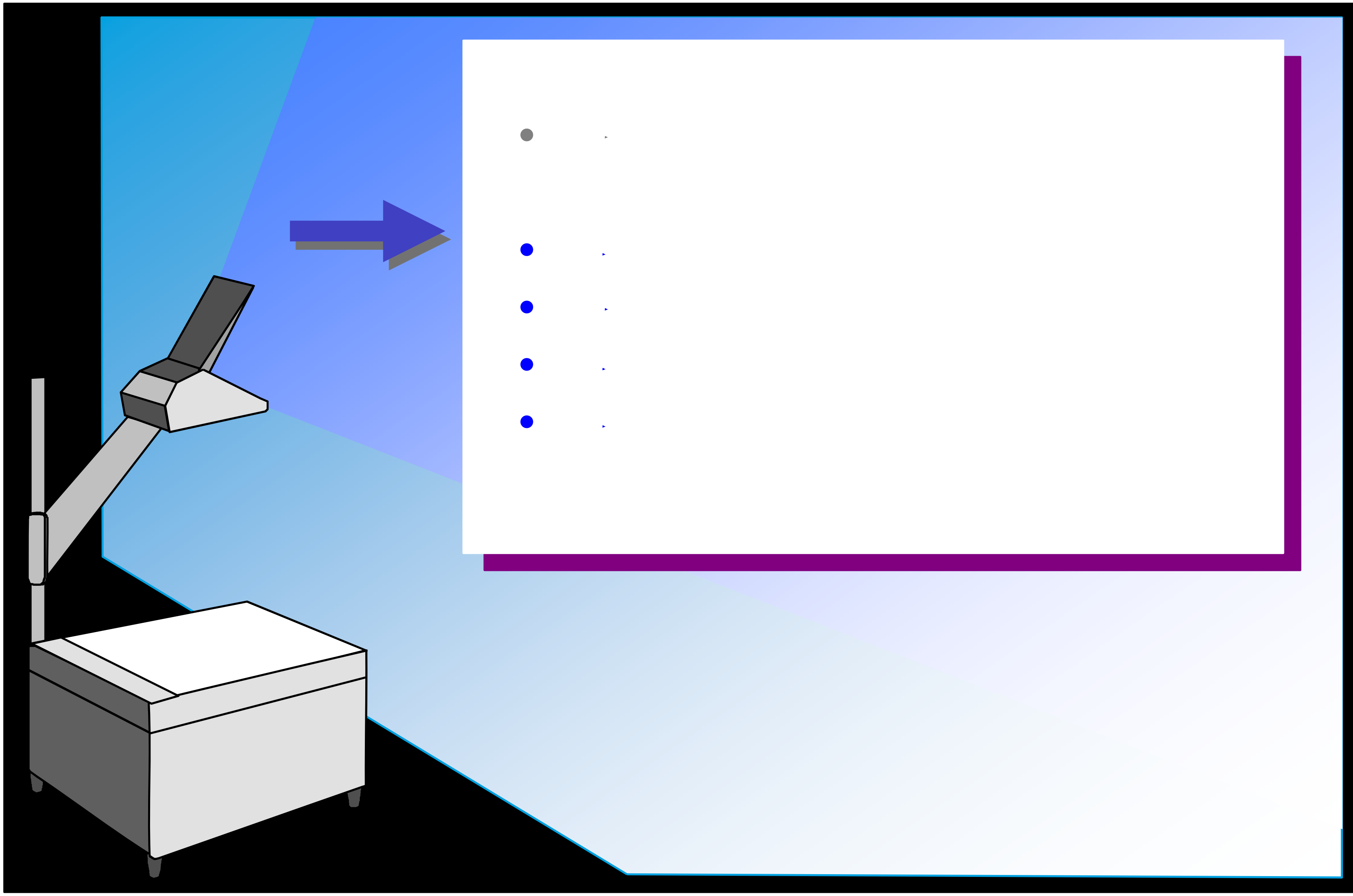


H

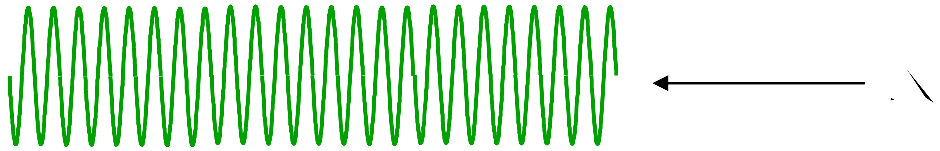
- DC
- Low Frequency
- High Frequency

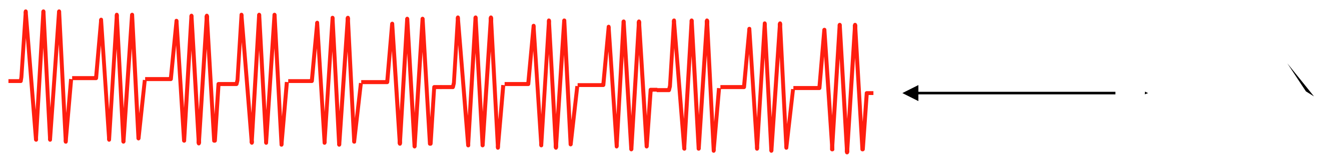


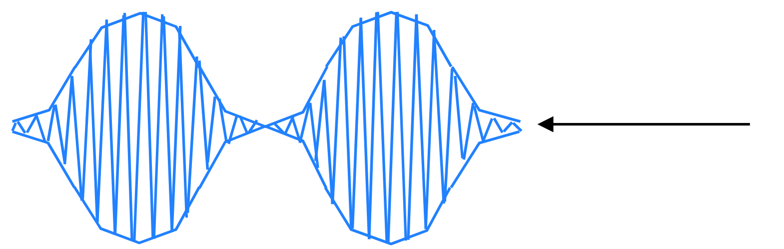
H



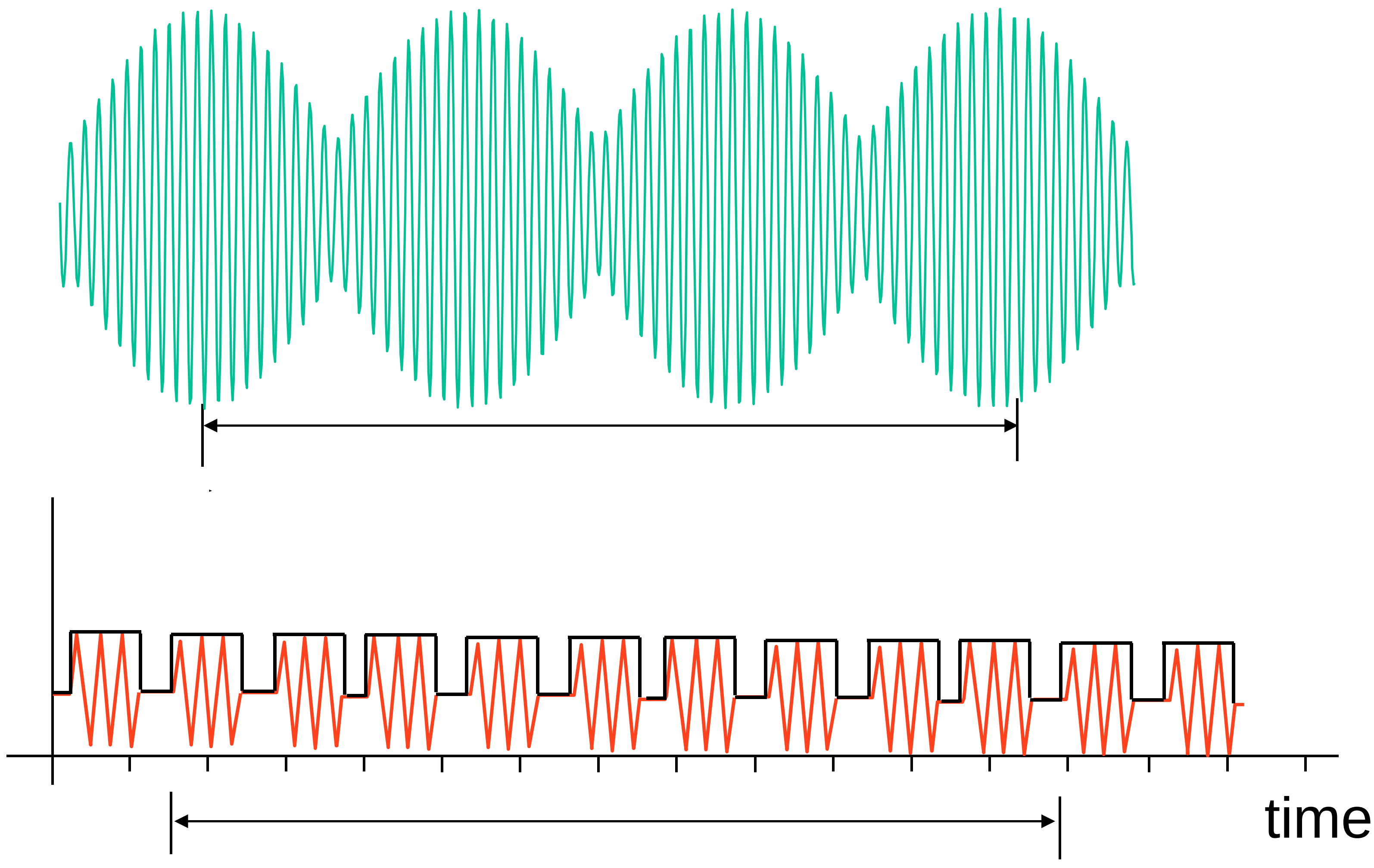
H







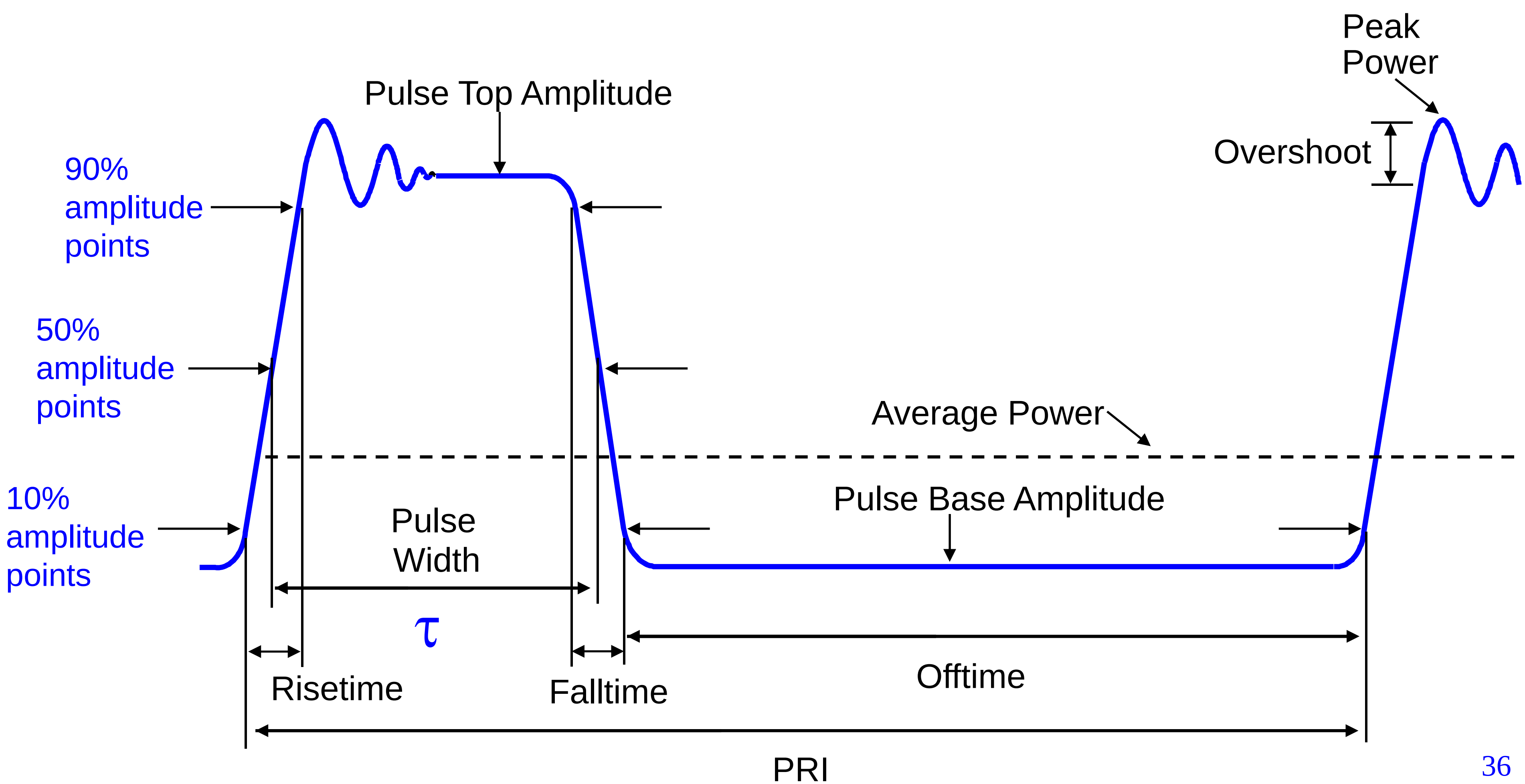
H



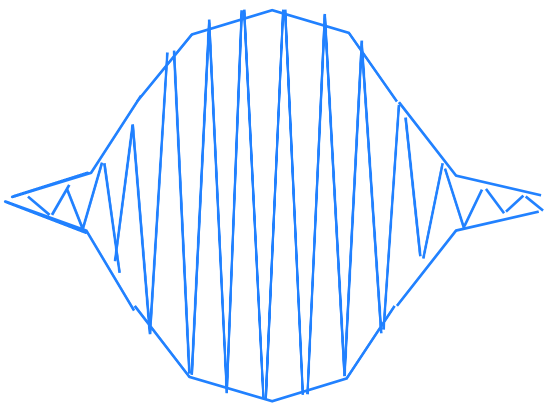
H

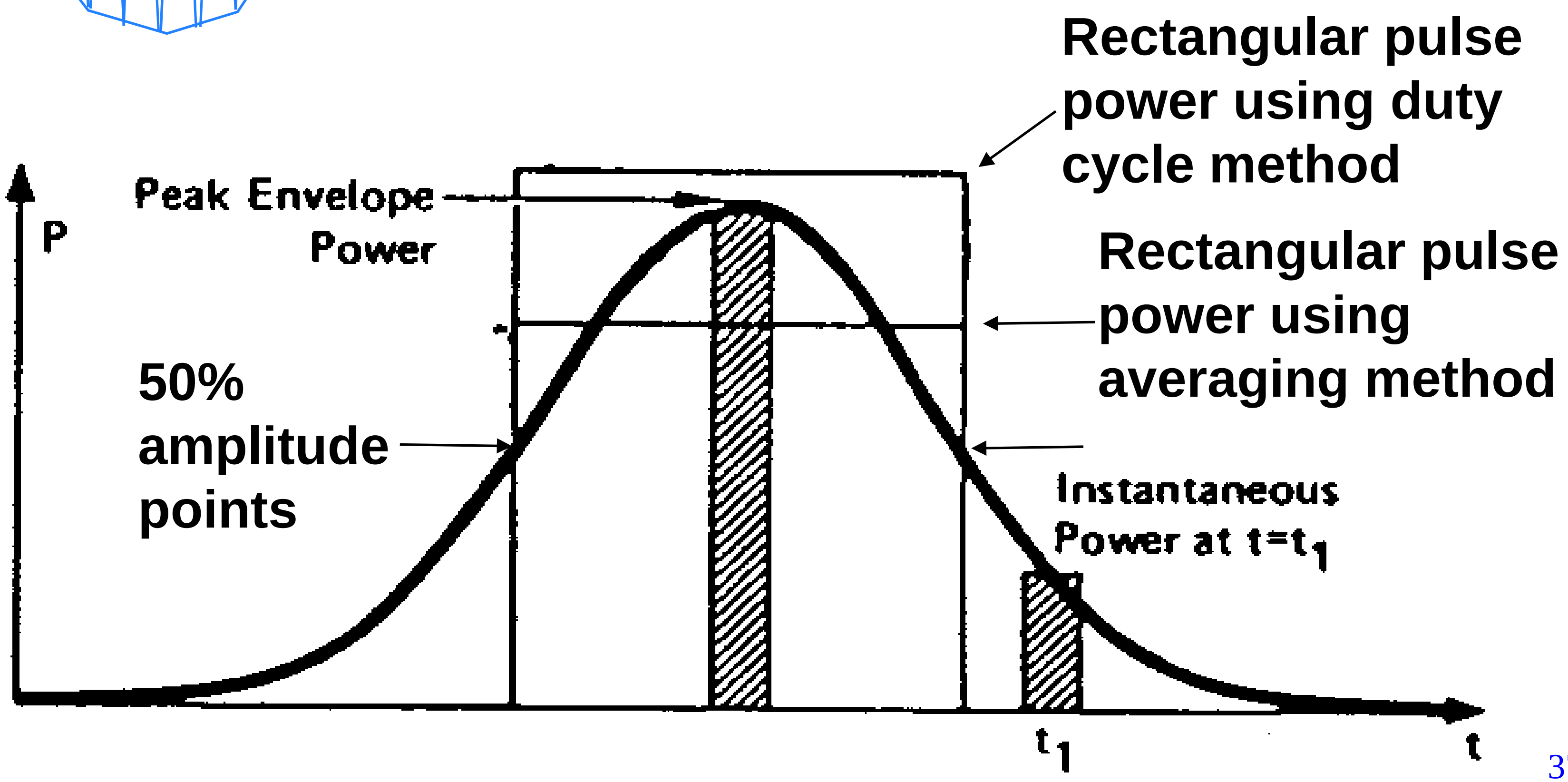
Pulse Power

- .



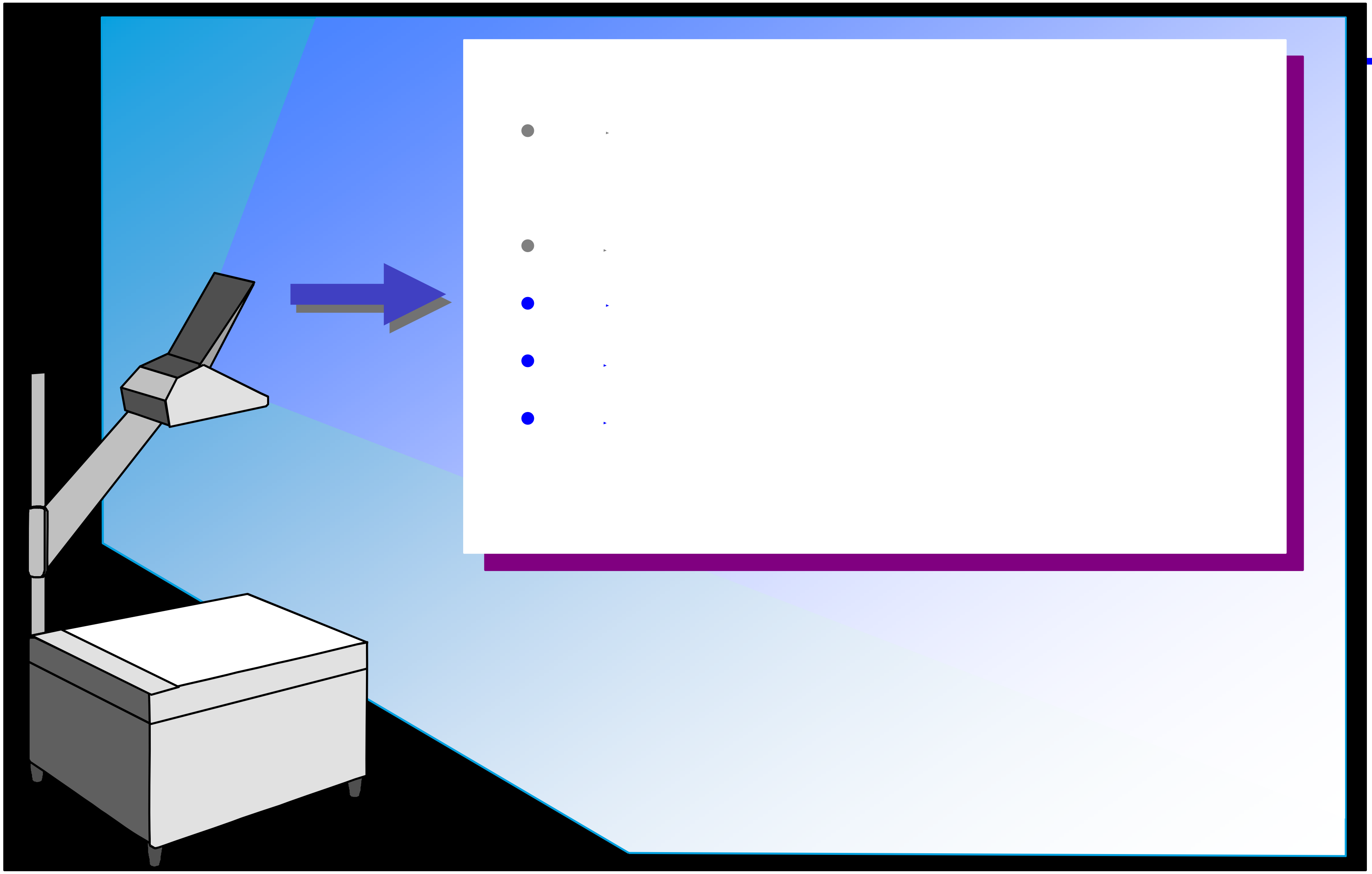
H




Rectangular pulse power using duty cycle method
Peak Envelope Power
P
Rectangular pulse power using averaging method
50% amplitude points
Instantaneous Power at t=t1
t1
t

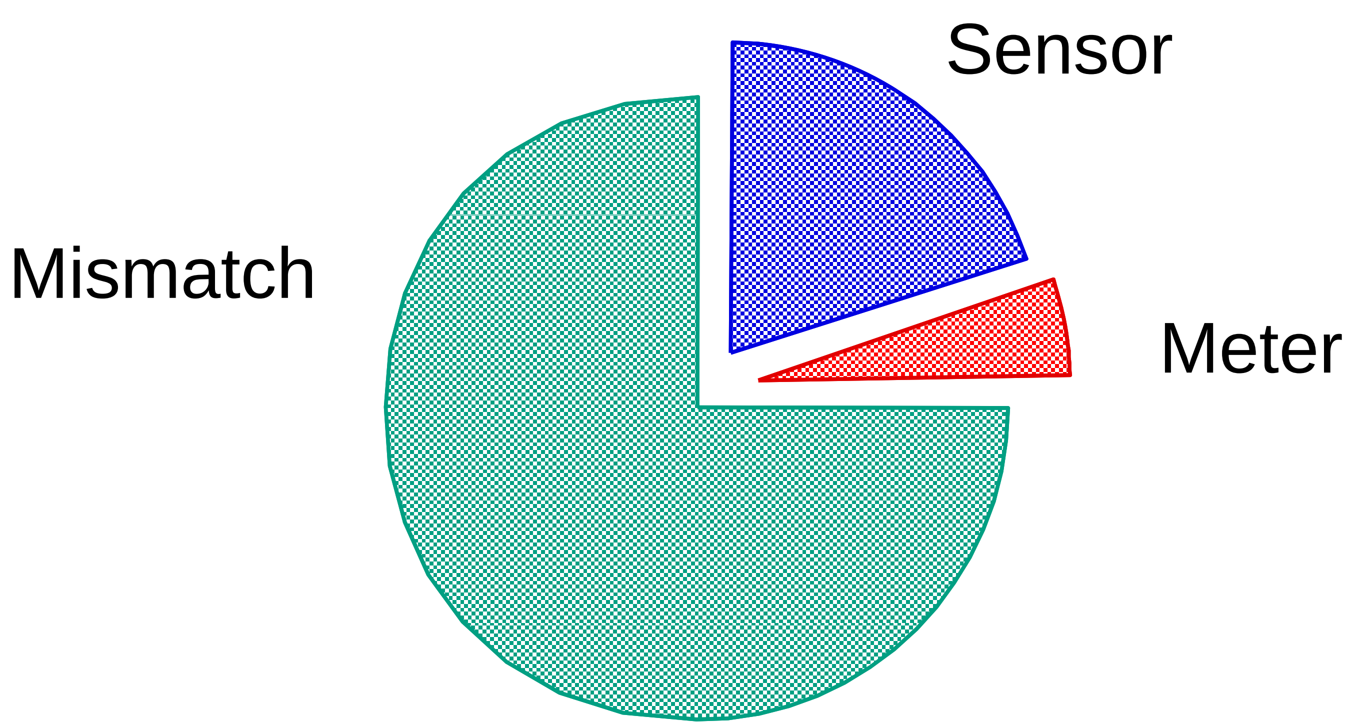
H

H

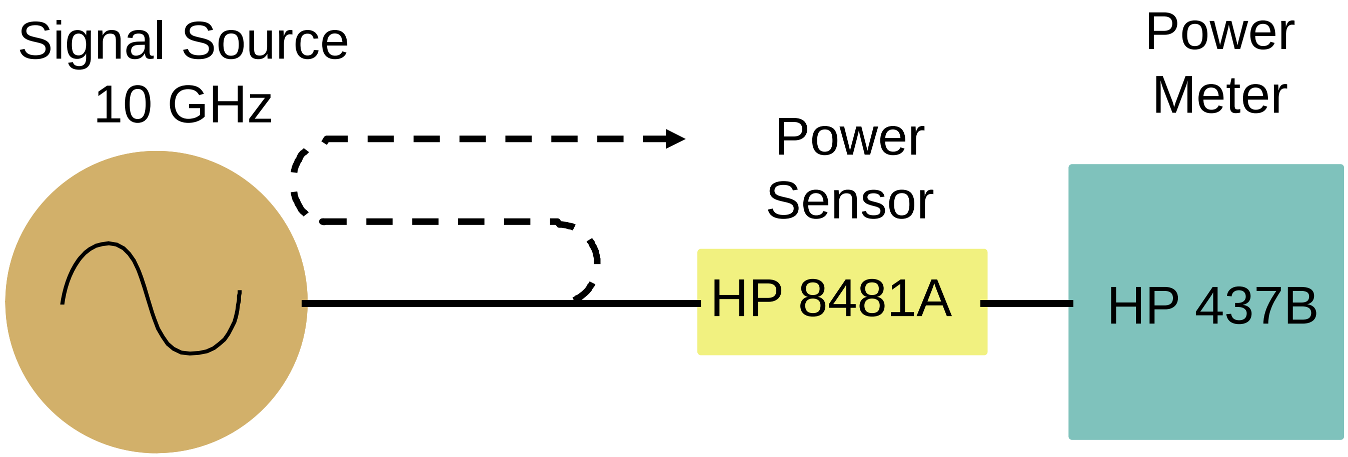


H

-
-
-



H



SWR = 2.0

$\rho_{SOURCE} = 0.33$

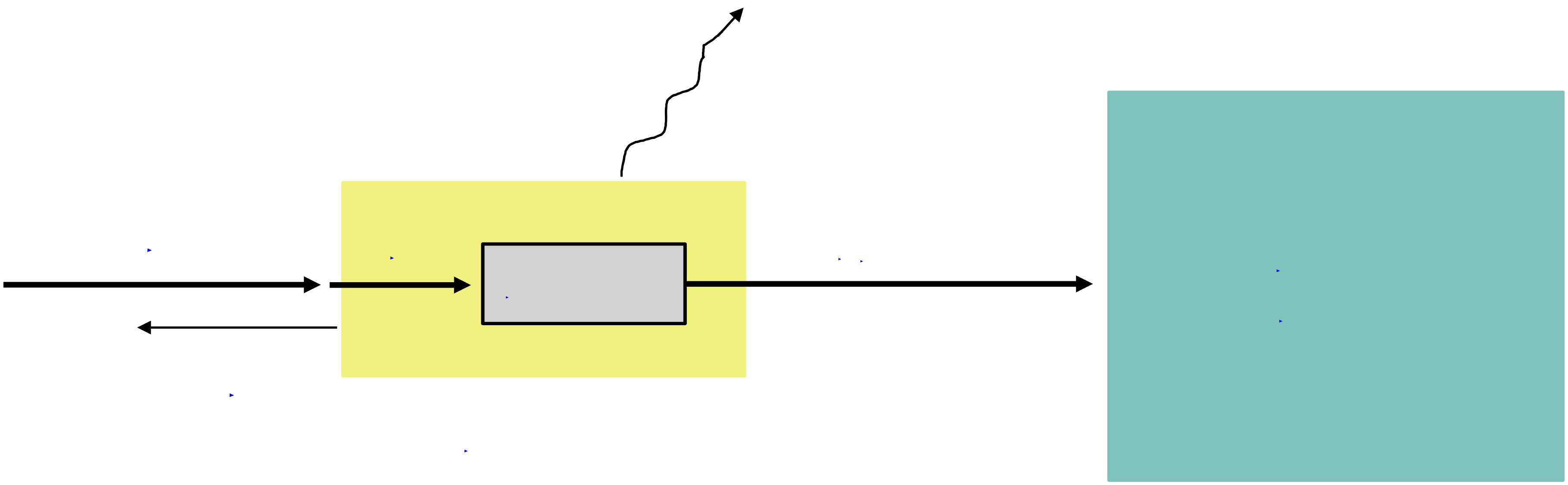
$SWR = 1.18$

$\rho_{SENSOR} = 0.083$

$$\text{Mismatch Uncertainty} = \pm 2 \bullet \rho_{SOURCE} \bullet \rho_{SENSOR} \bullet 100\%$$

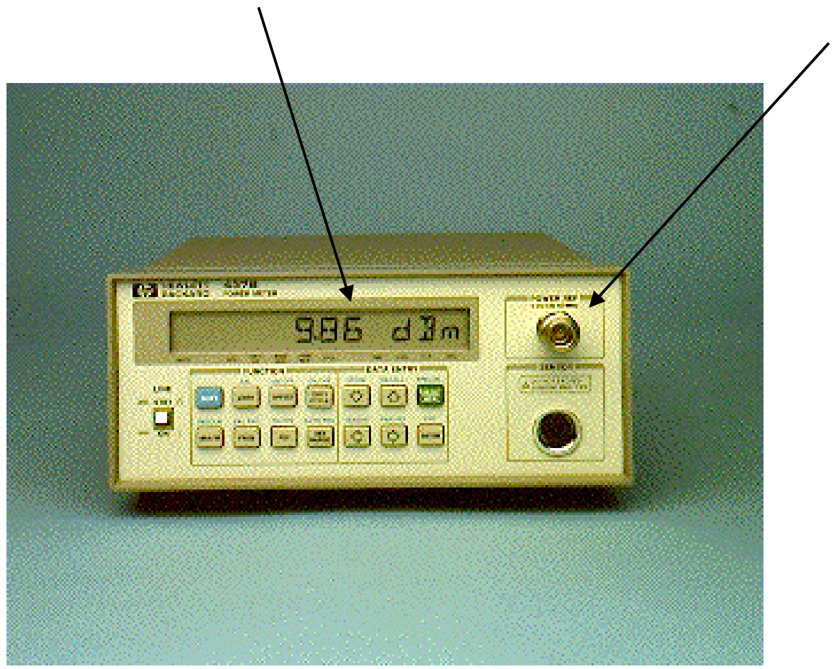
$$\text{Mismatch Uncertainty} = \pm 2 \bullet 0.33 \bullet 0.083 \bullet 100\% = \pm 5.5\%$$

H



η

H


9.86 dBm

±

±

±

±

H

-

±

H

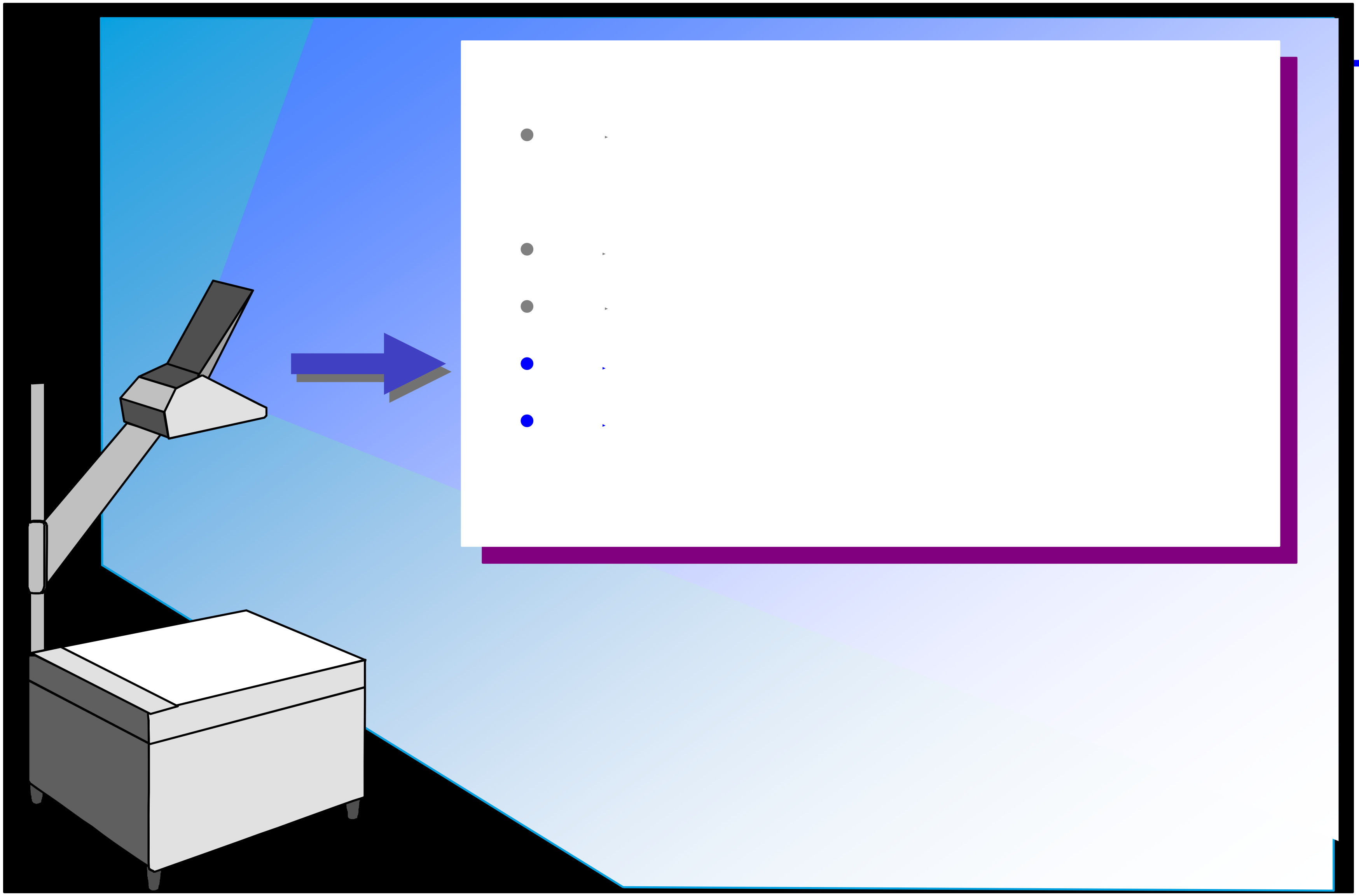
$$= \sqrt{(5.5\%)^2 + (1.9\%)^2 + (1.2\%)^2 + (0.5\%)^2}$$

$$= \pm\ 6.0\%$$

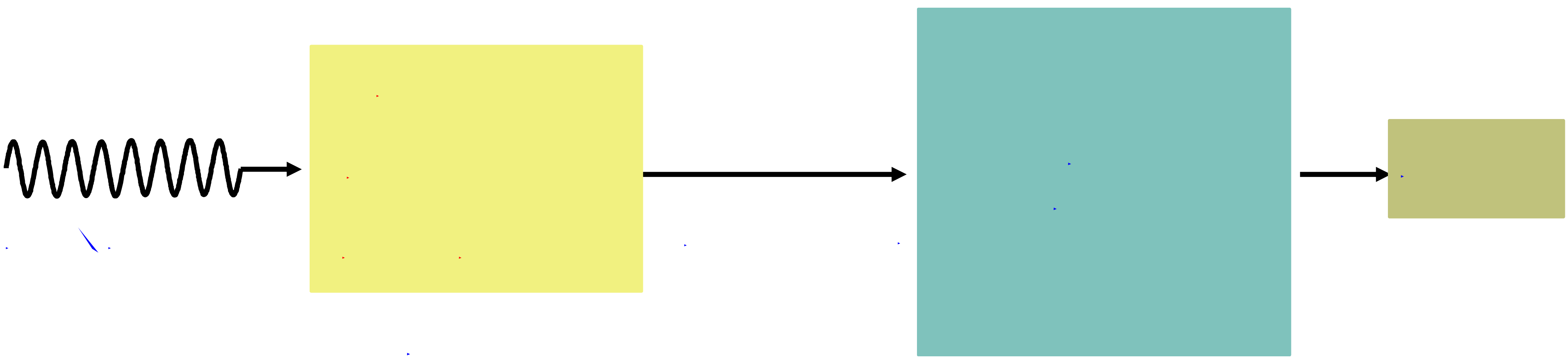
$$+\ 6.0\% = 10 \log (1 + 0.060) = +0.25 \text{ dB}$$

$$-\ 6.0\% = 10 \log (1 - 0.060) = -0.27 \text{ dB}$$

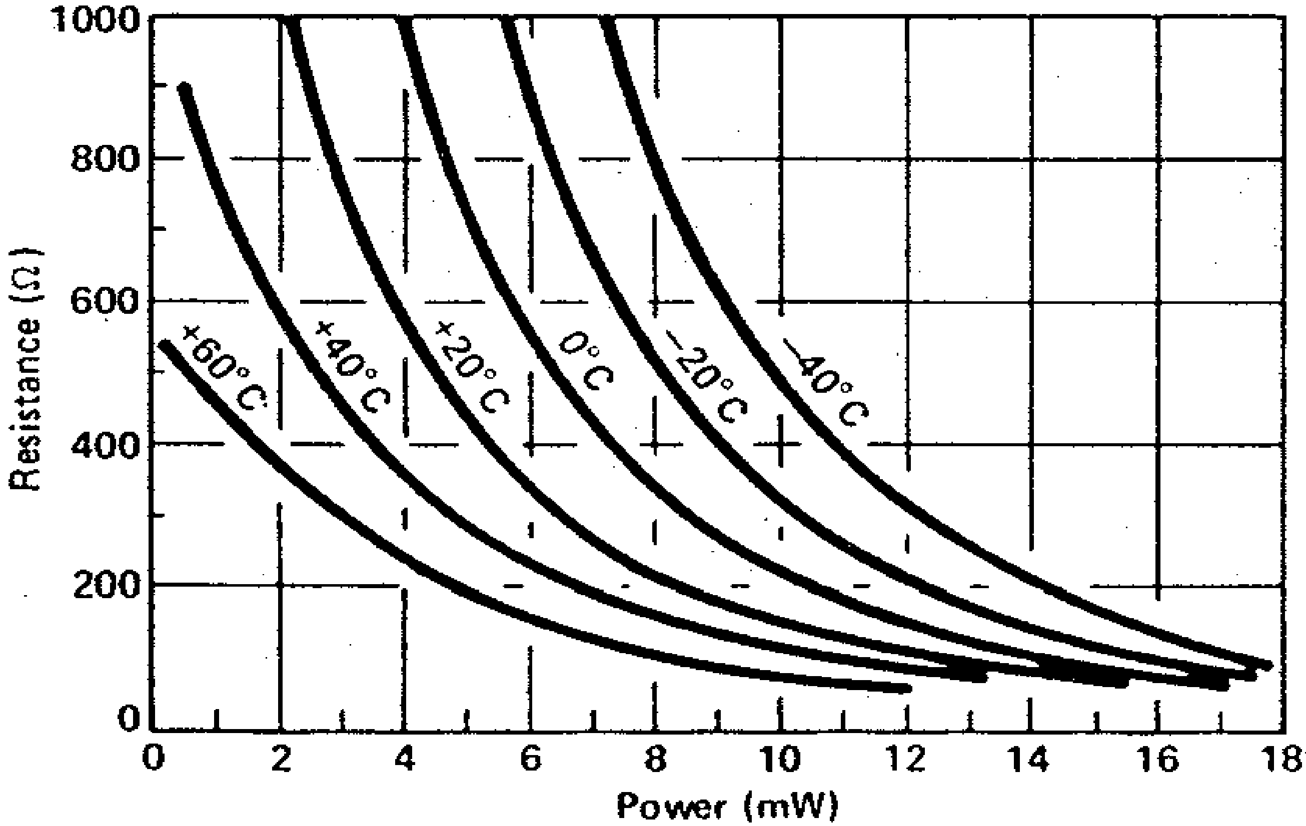
H



H

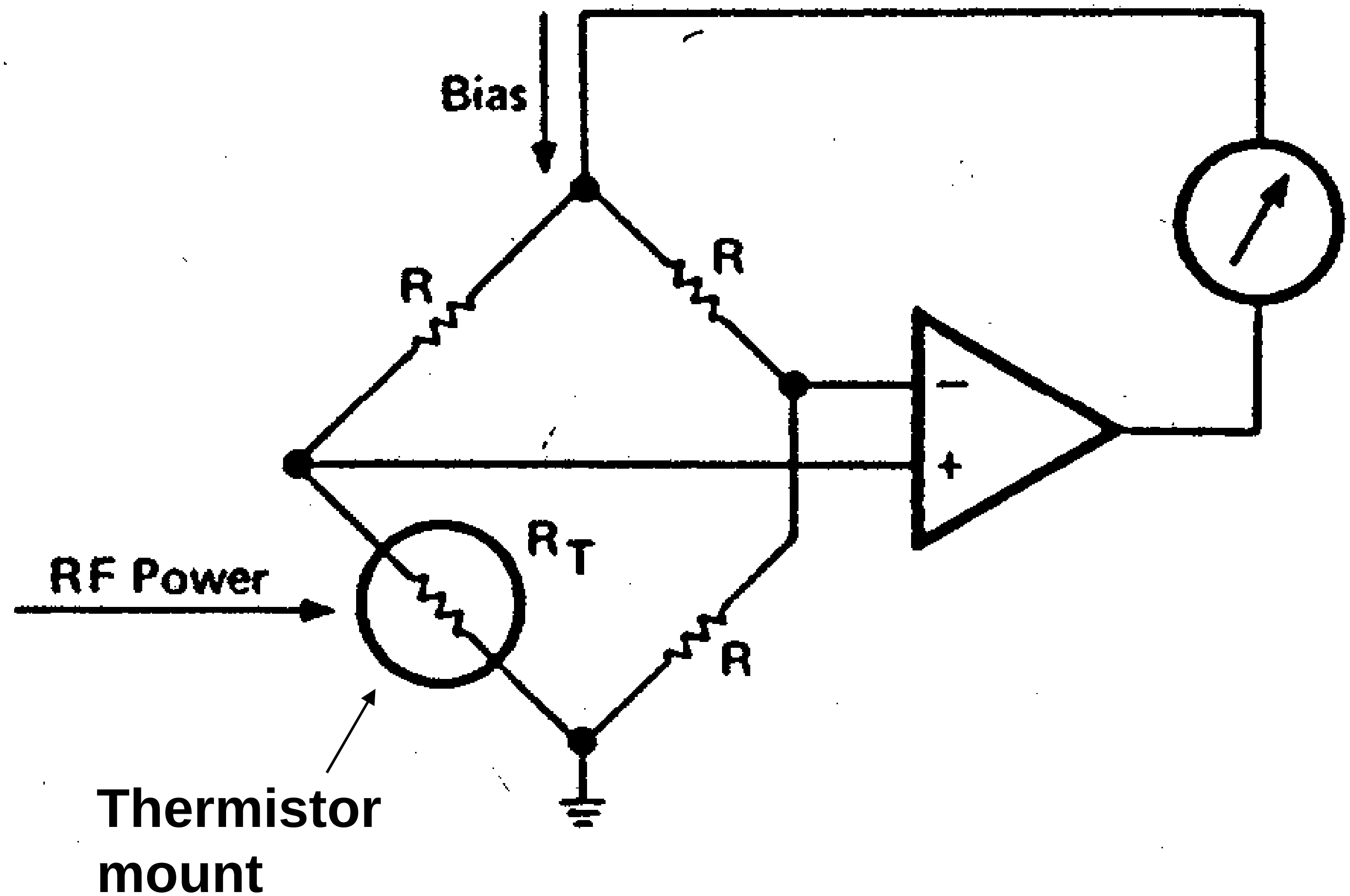


H

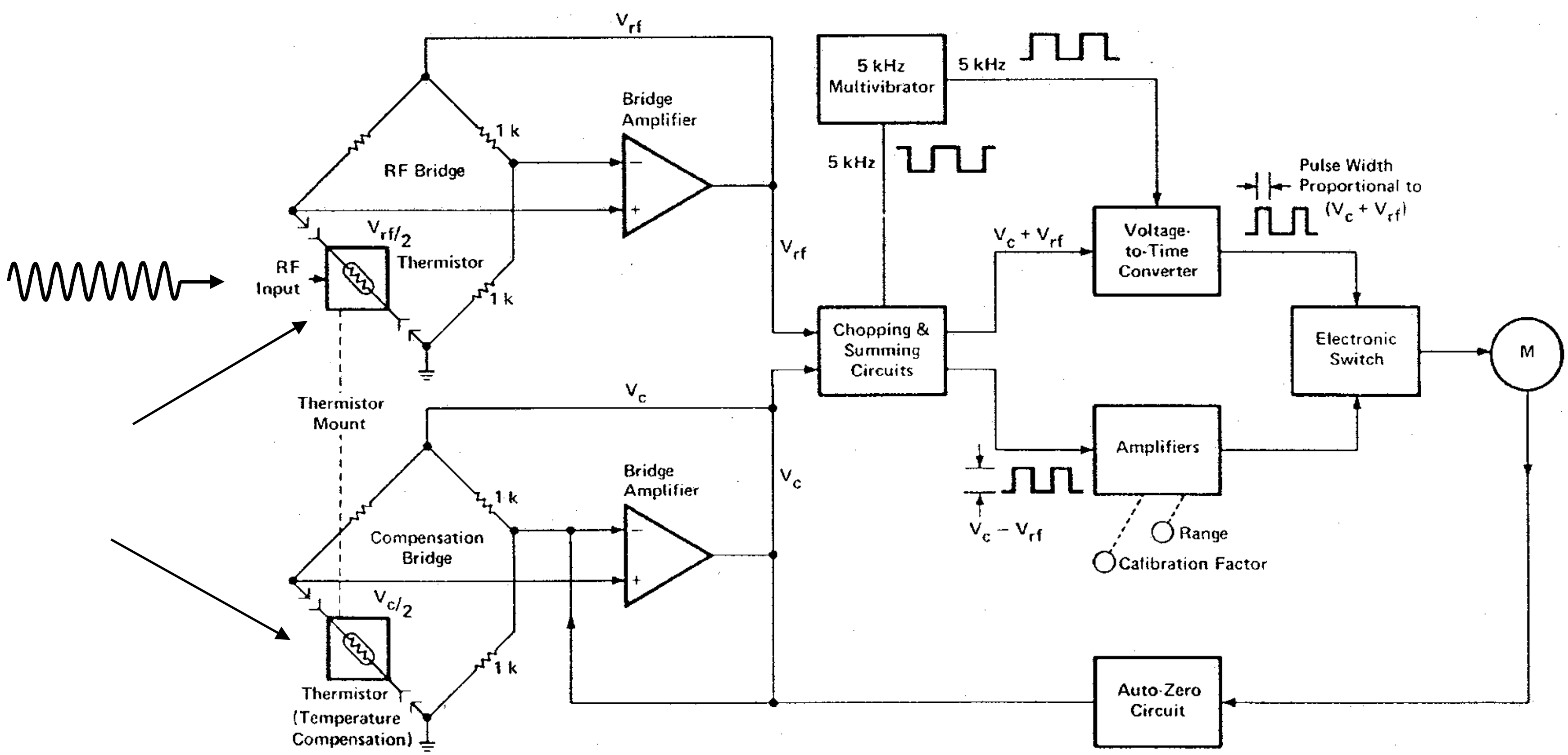

1000
800
600
400
200
0
Resistance (Ω)
+60°C
+40°C
+20°C
0°C
−20°C
−40°C
0
2
4
6
8
10
12
14
16
18
Power (mW)

H

•

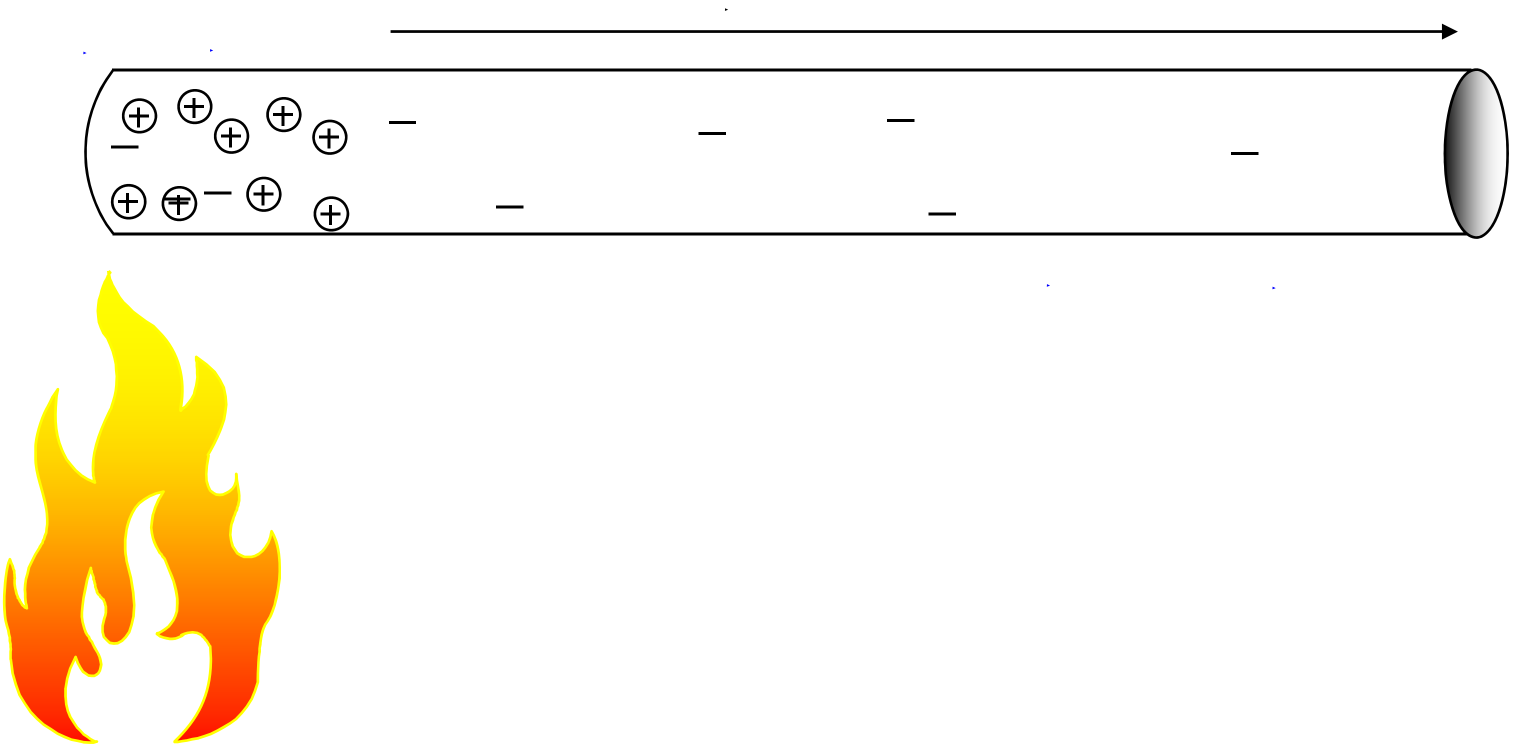


H

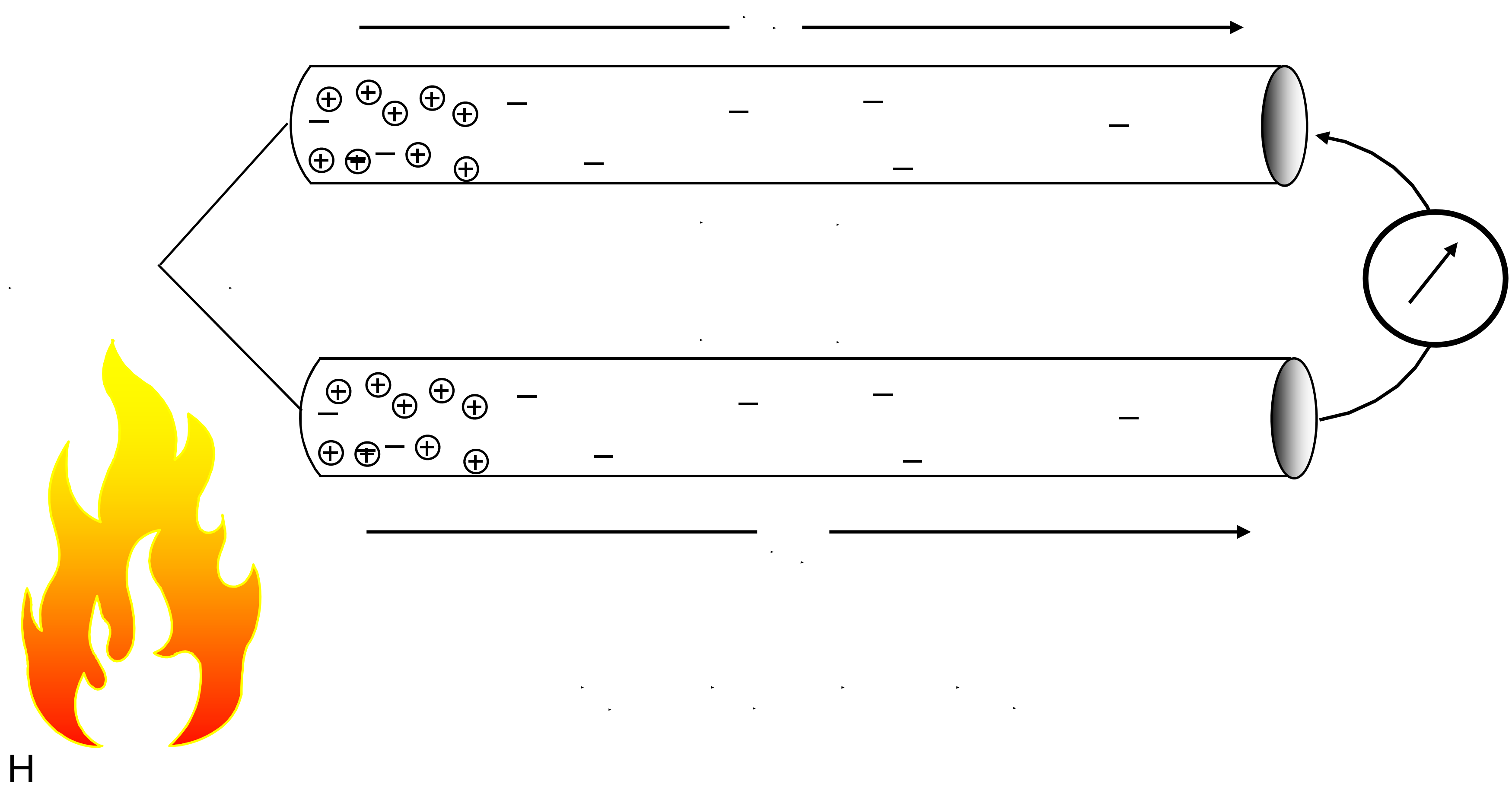


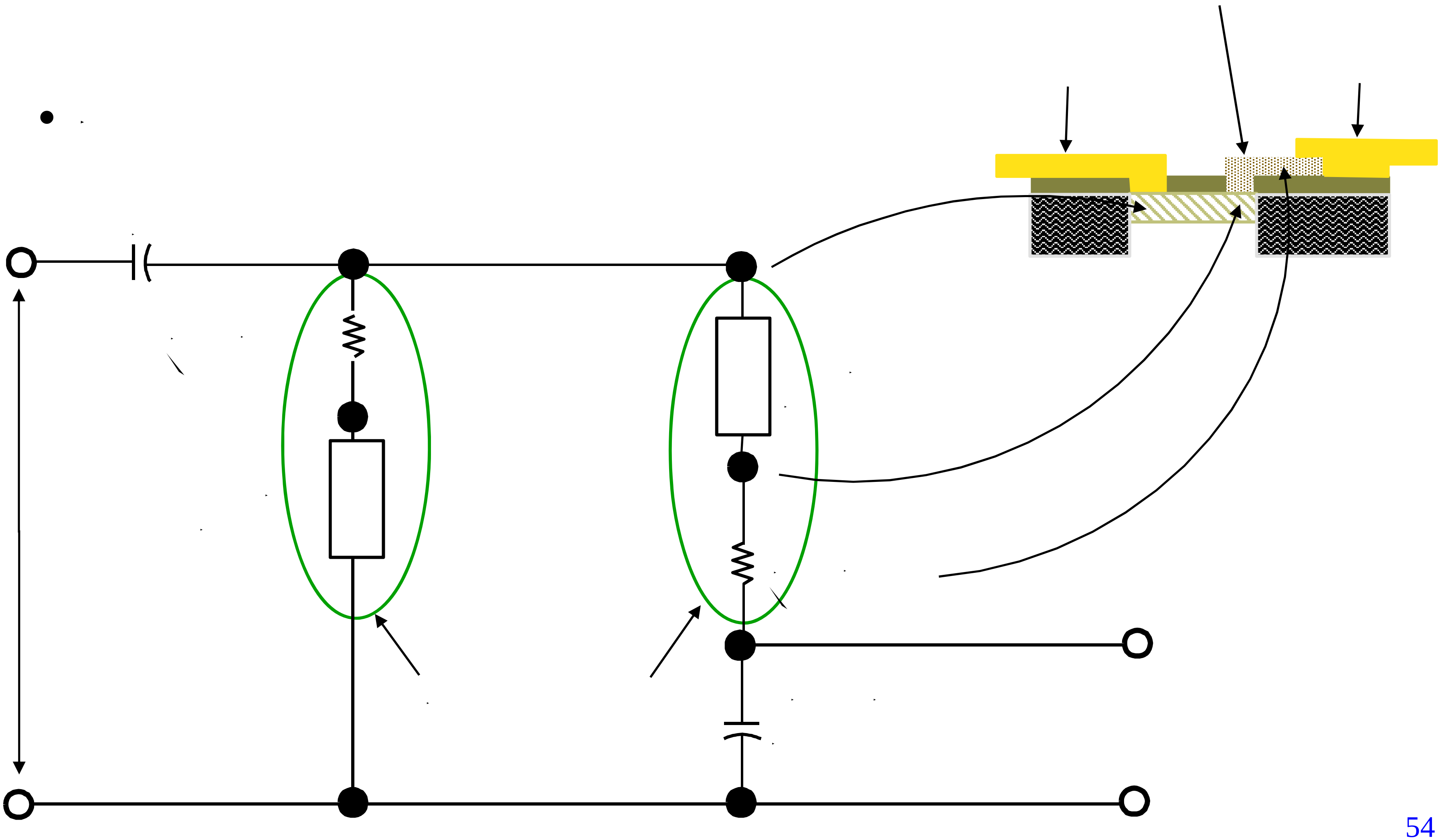
V_{rf}
5 kHz Multivibrator
5 kHz
Bridge Amplifier
1 k
RF Bridge
5 kHz
Pulse Width Proportional to $(V_c + V_{rf})$
$V_{rf}/2$
Thermistor
RF Input
V_{rf}
$V_c + V_{rf}$
Voltage-to-Time Converter
1 k
Chopping & Summing Circuits
Electronic Switch
M
Thermistor Mount
V_c
Amplifiers
Bridge Amplifier
V_c
1 k
Compensation Bridge
$V_c - V_{rf}$
Range
Calibration Factor
$V_c/2$
1 k
Auto-Zero Circuit
Thermistor (Temperature Compensation)

H

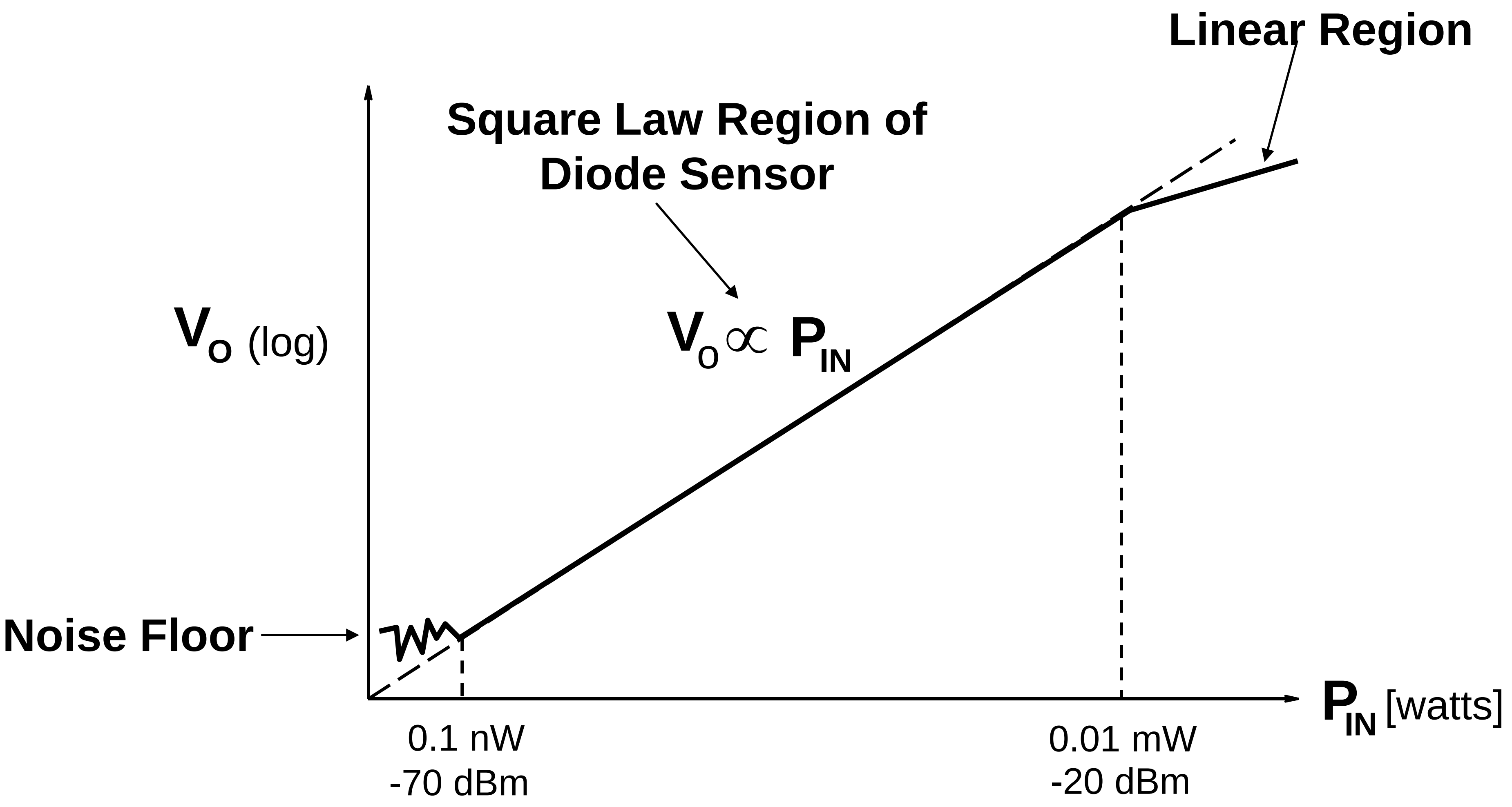


H


H

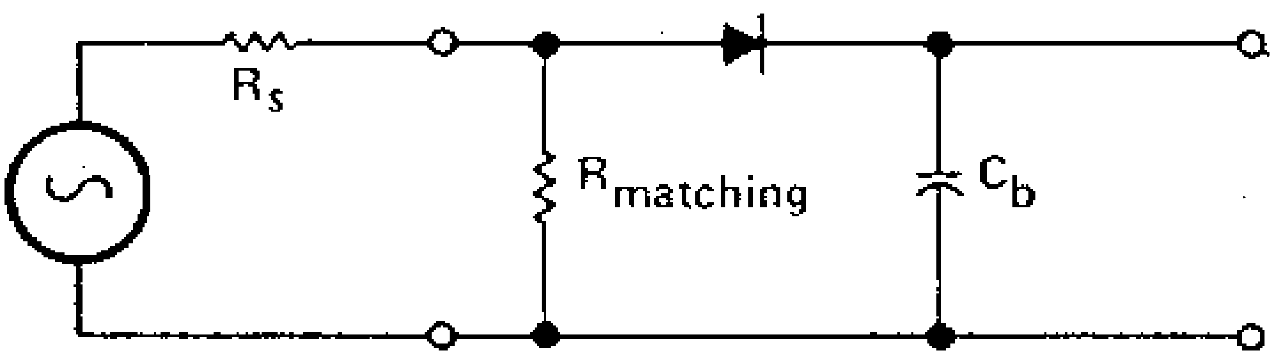


H

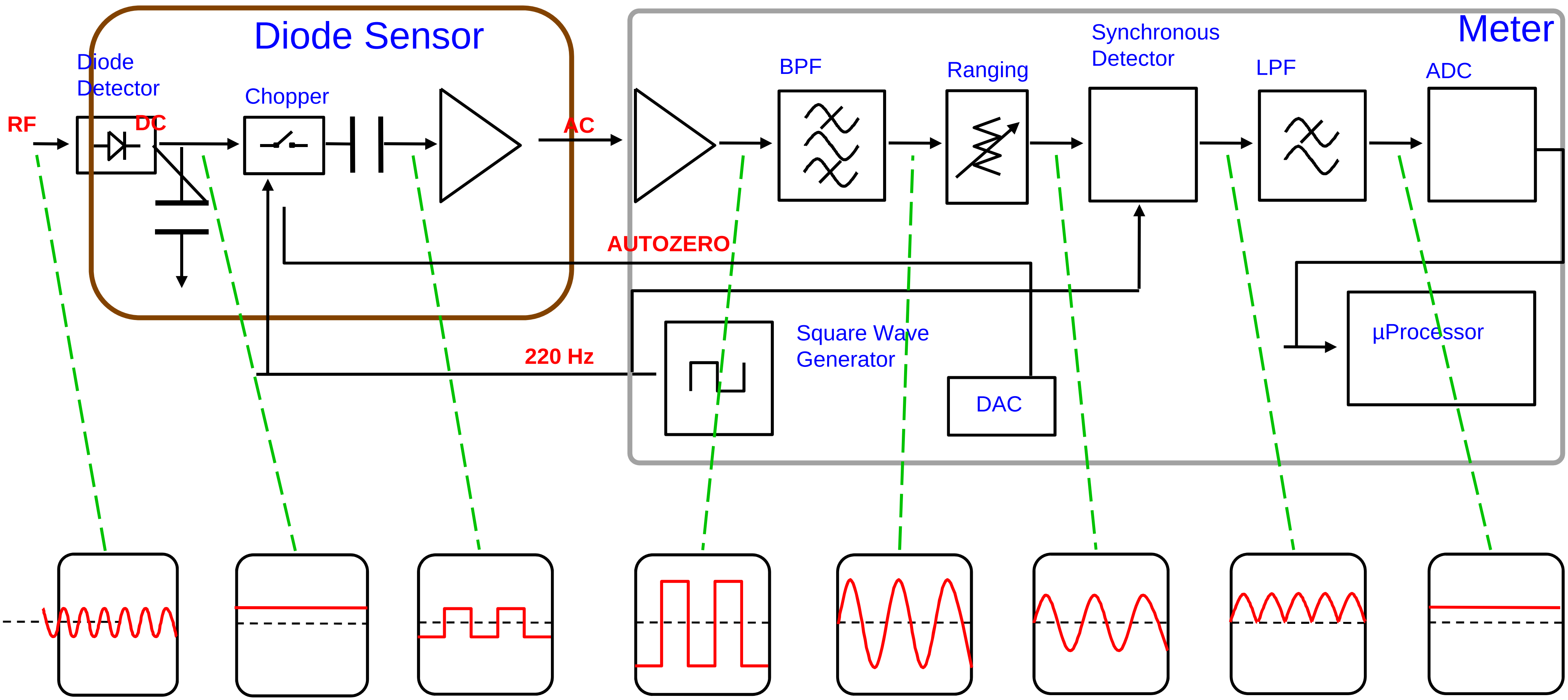


Linear Region
Square Law Region of
Diode Sensor
$V_O \propto P_{IN}$
V_O (log)
Noise Floor
P_{IN} [watts]
0.1 nW
-70 dBm
0.01 mW
-20 dBm

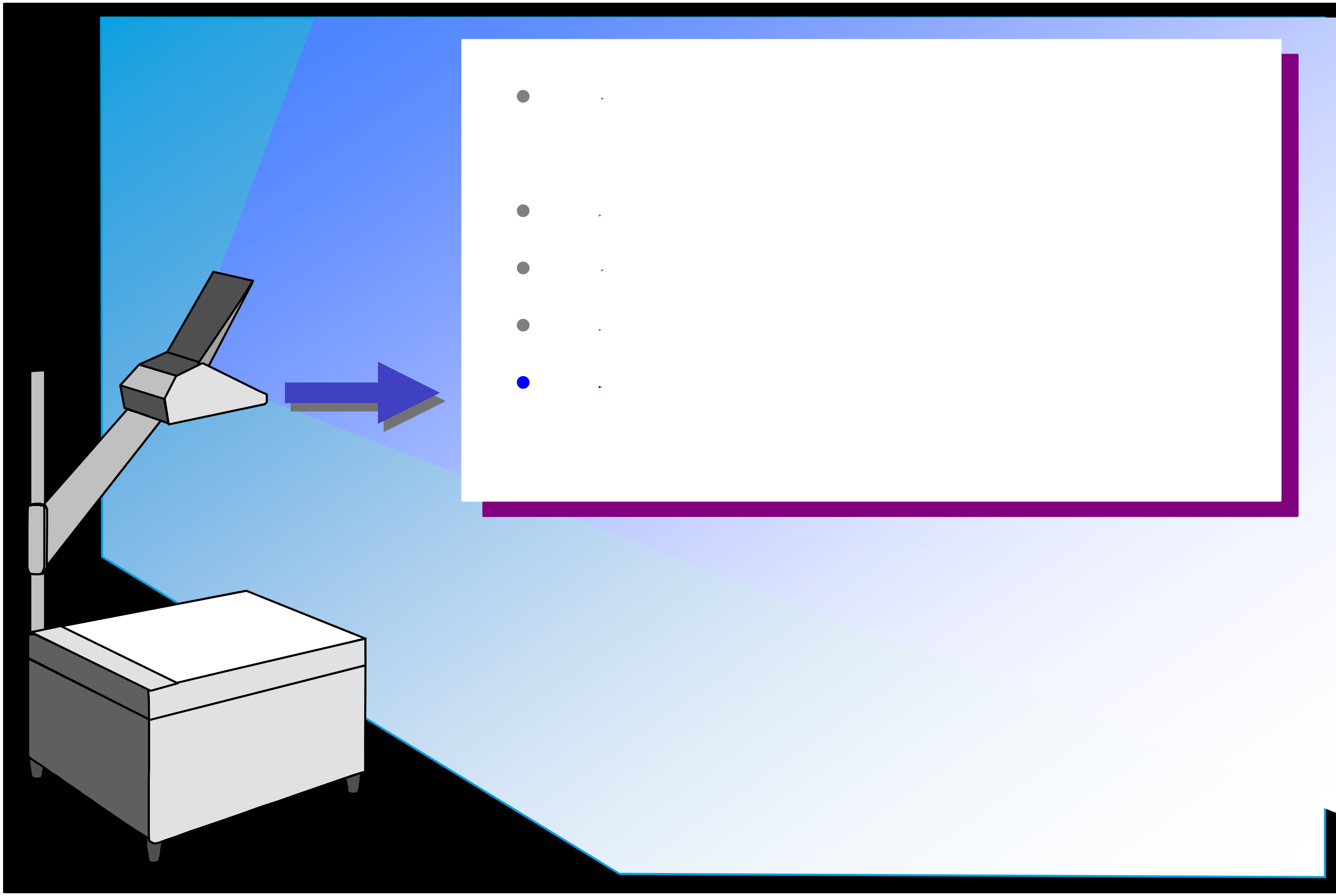
H



H

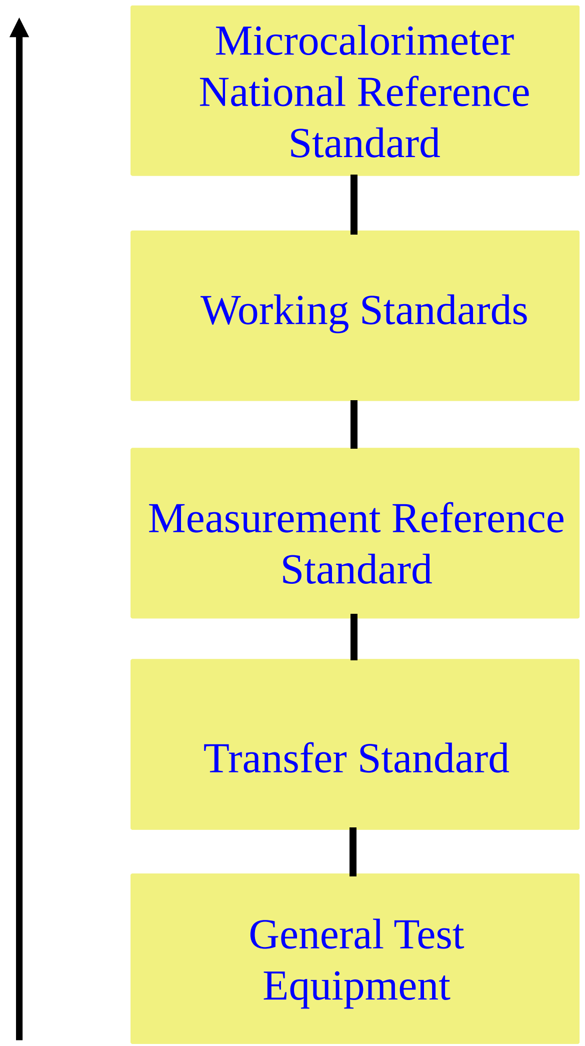

Diode Sensor
Meter
Diode
Detector
RF
DC
Chopper
AC
BPF
Ranging
Synchronous
Detector
LPF
ADC
AUTOZERO
Square Wave
Generator
220 Hz
DAC
µProcessor

H

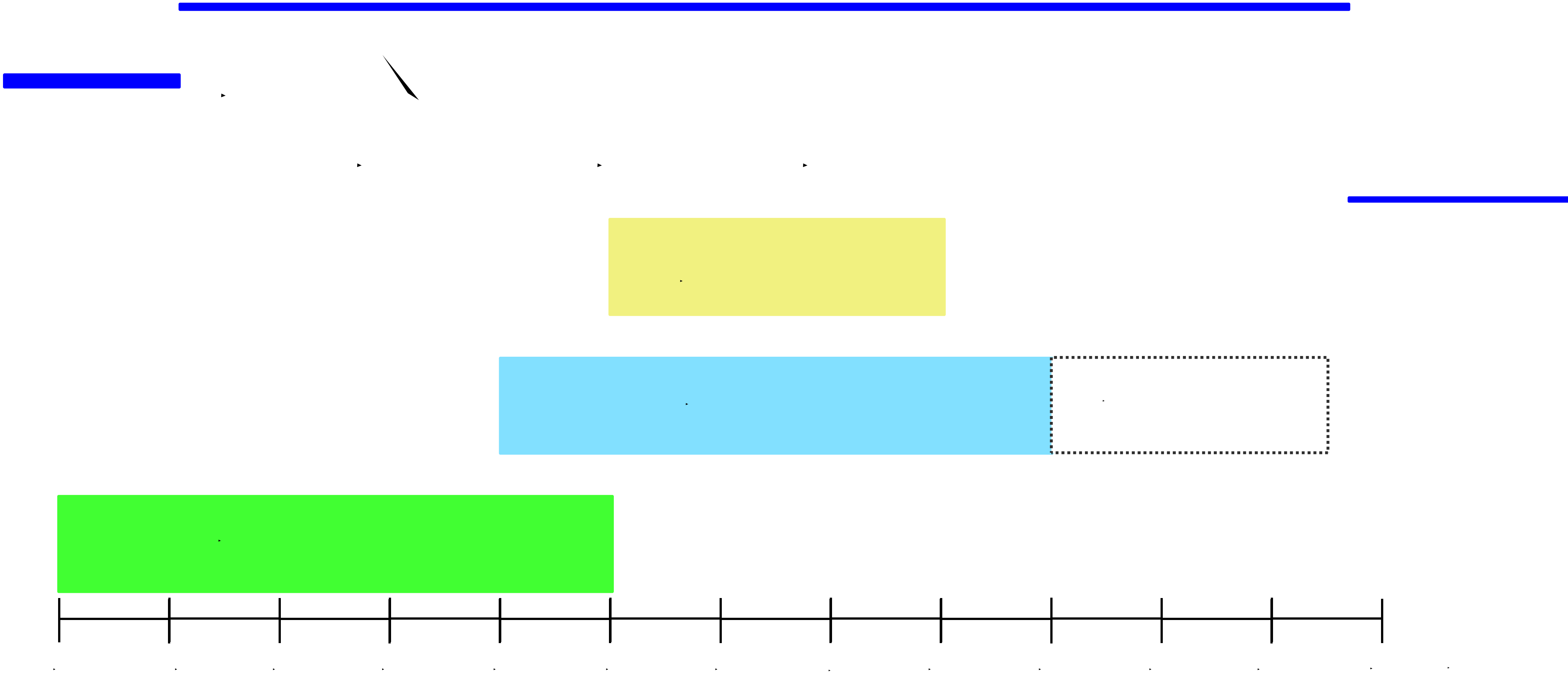


H

H


Microcalorimeter National Reference Standard
Working Standards
Measurement Reference Standard
Transfer Standard
General Test Equipment

H

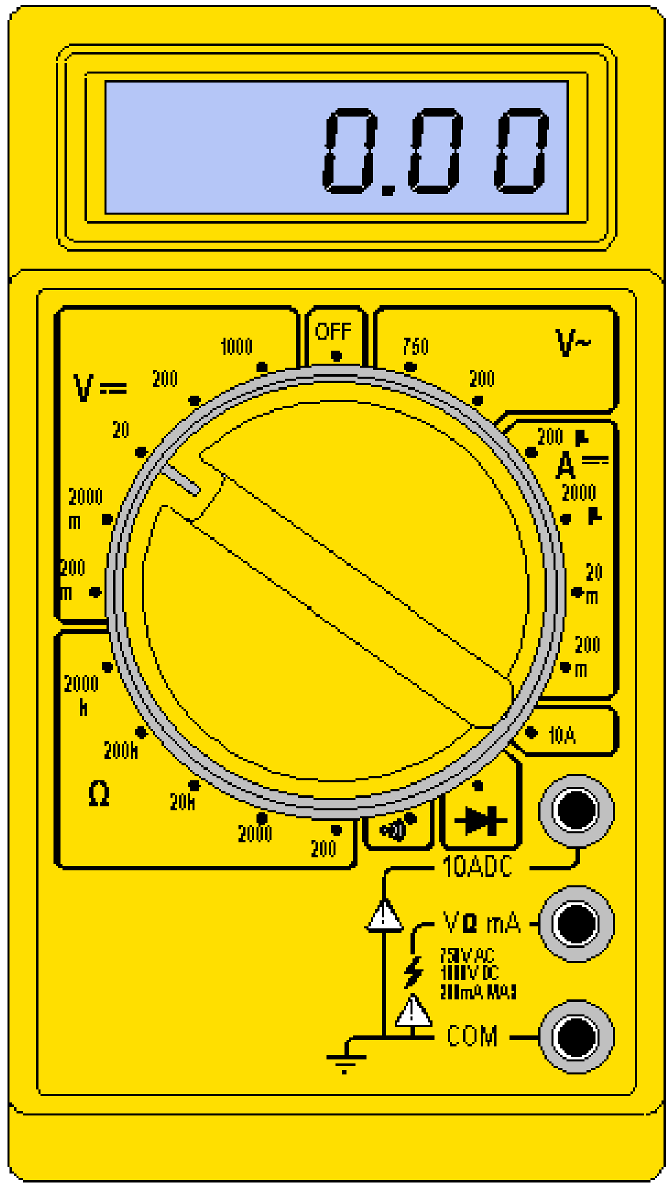


H

Digital Multimeter

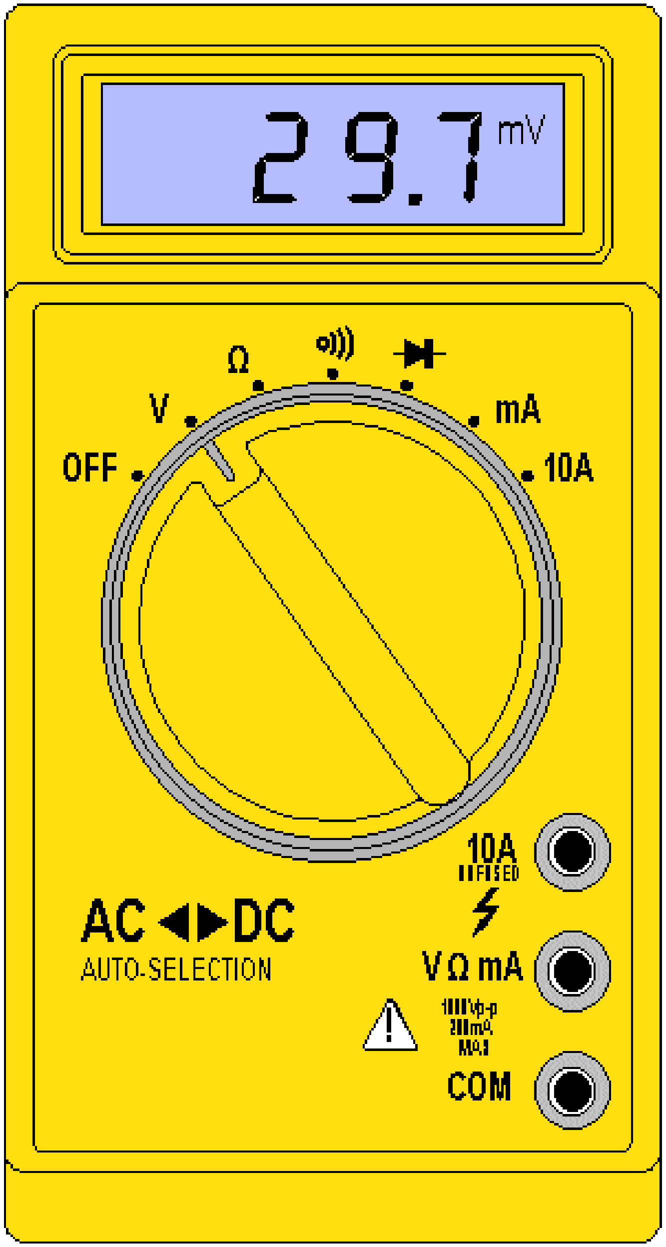
Multimeters are designed and mass produced. The simplest and cheapest types may include features which are not likely to use. Digital meters give an output in numbers, usually on a liquid crystal display.

Switched

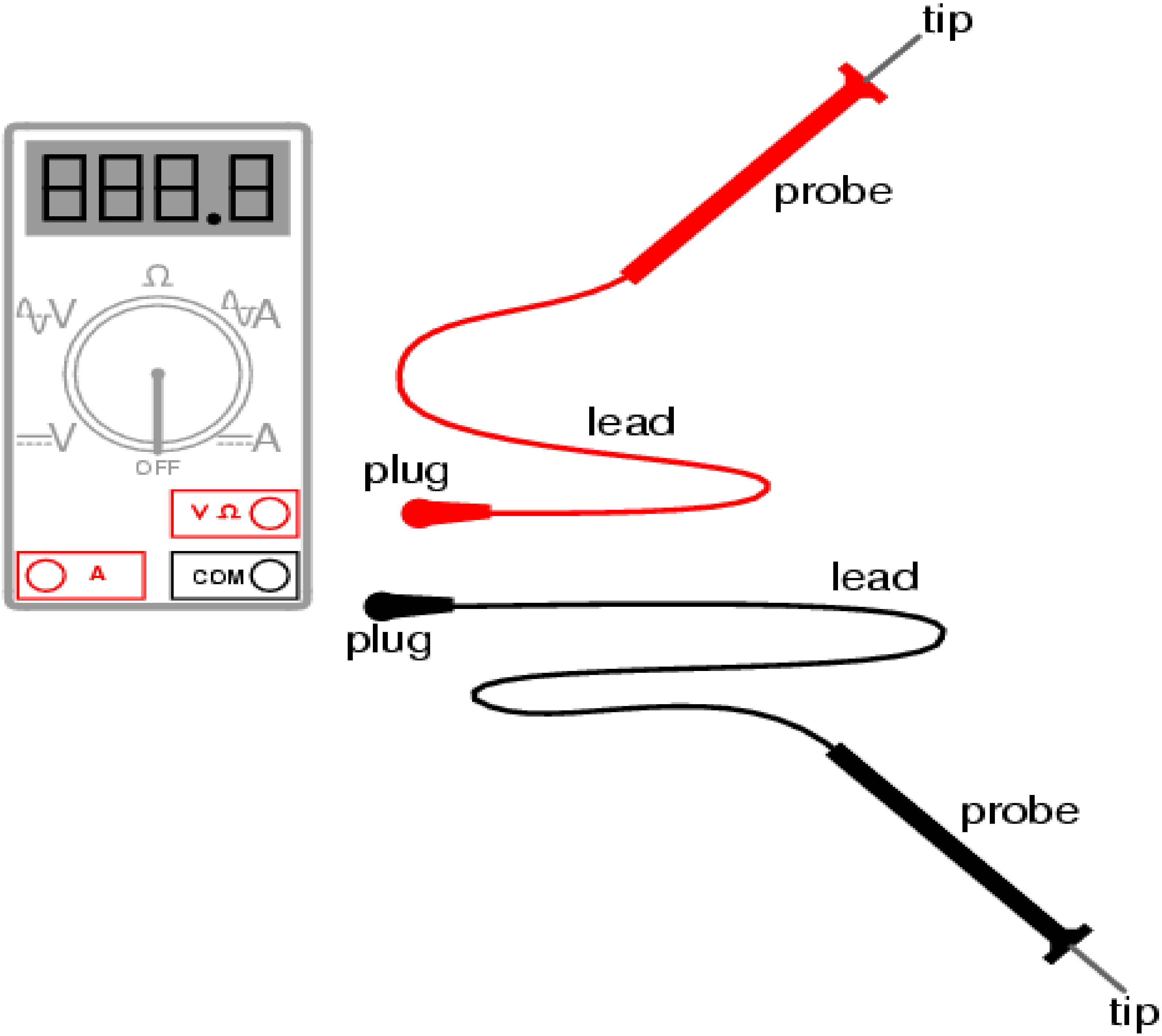

0.00
OFF
1000
200
20
2000 m
200 m
V
750
200
V~
A
2000
20 m
200 m
10A
2000 k
200k
20k
2000
200
Ω
10ADC
VΩ mA
COM

H

Autoranging



H


888.8
Ω
V
A
V
A
OFF
V Ω
A
COM
tip
probe
lead
plug
lead
plug
probe
tip

H

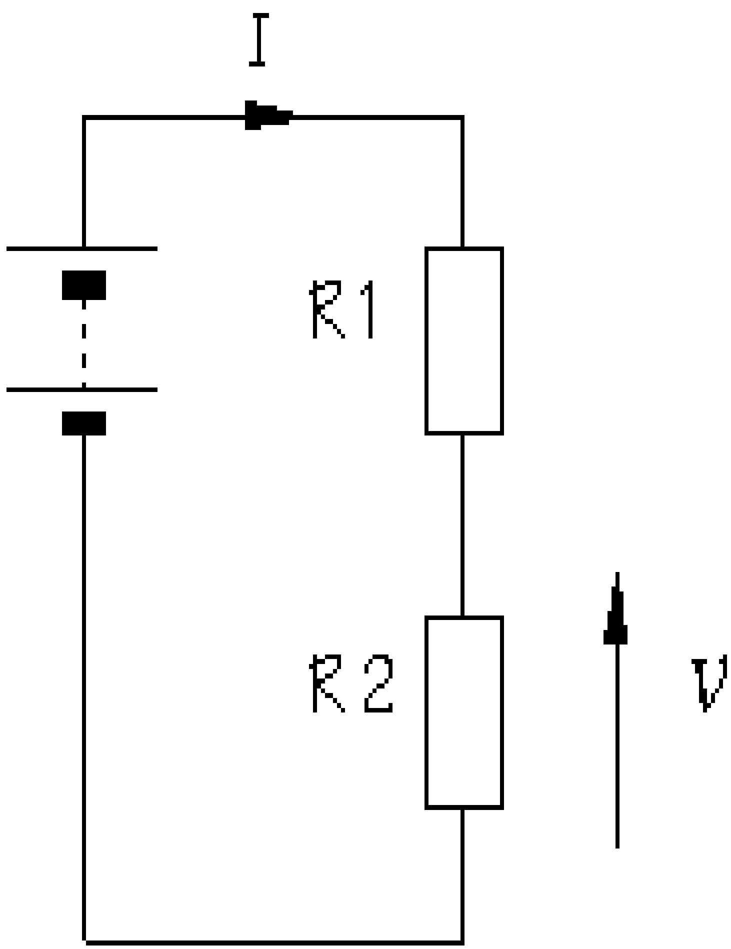
What do meters measure?

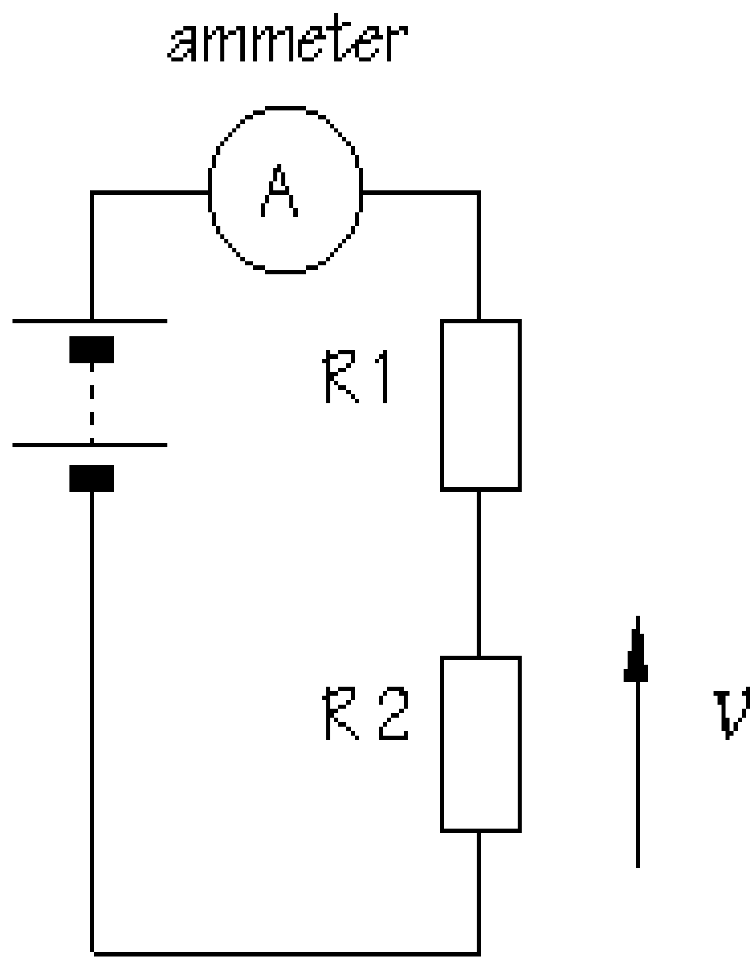
- A meter is a measuring instrument. An **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points, and an **ohmmeter** measures resistance. A **multimeter** combines these functions, and possibly some additional ones as well, into a single instrument.

Multimeter as a Ammeter

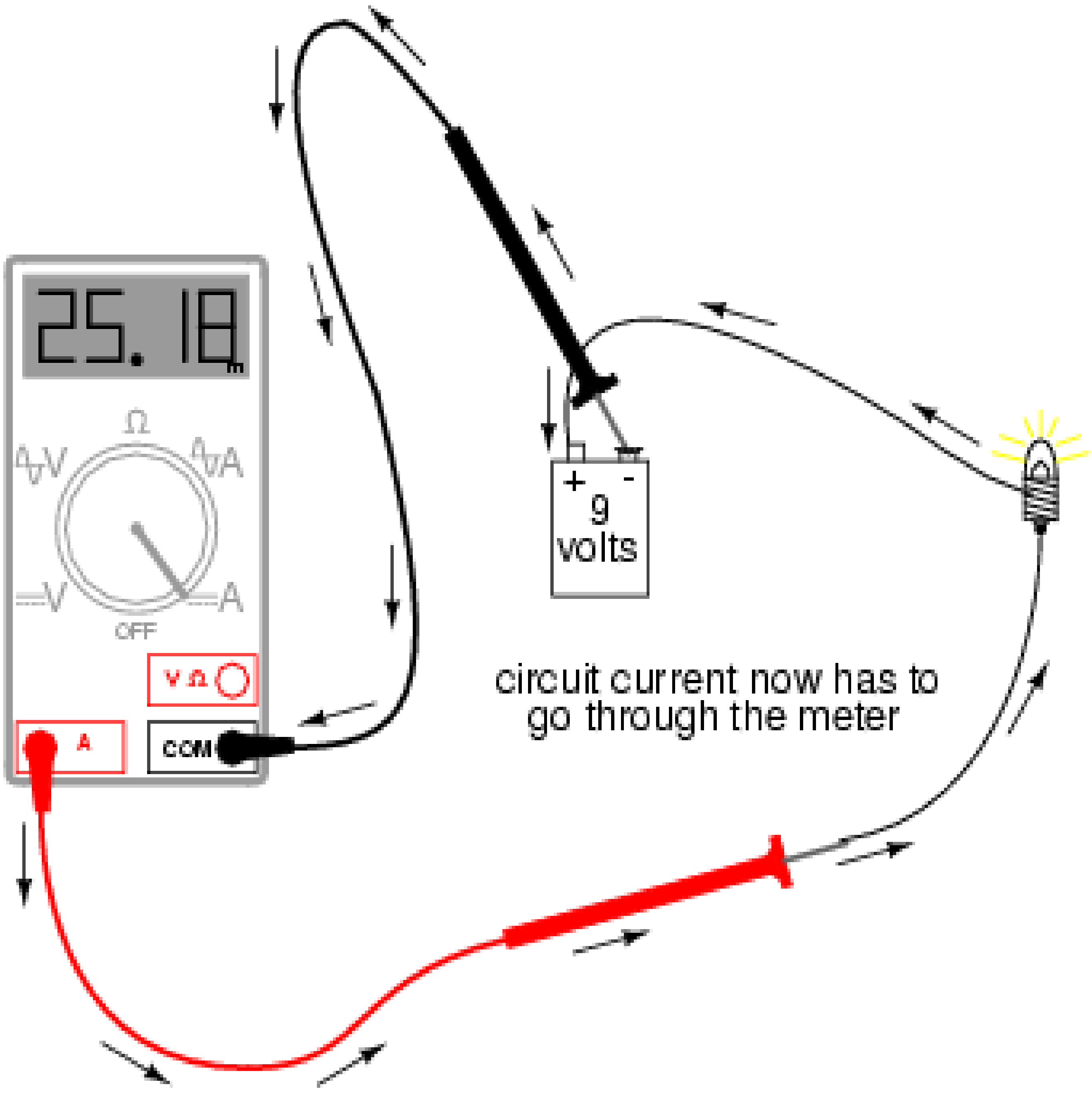
- Turn Power Off before connecting multimeter
- Break Circuit
- Place multimeter in series with circuit
- Select highest current setting, turn power on, and work your way down.
- Turn power off
- Disconnect multimeter.
- Reconnect Circuit

Ammeter mode measures current in Amperes. To measure current you need to power off the circuit, you need to *break the circuit* so that the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behavior of the circuit, so the ammeter must have a very LOW resistance. The diagrams below show the connection of a multimeter to measure current.





H



25. 18
m
Ω
V
A
V
A
OFF
V Ω
A
COM
+
-
9
volts
circuit current now has to
go through the meter

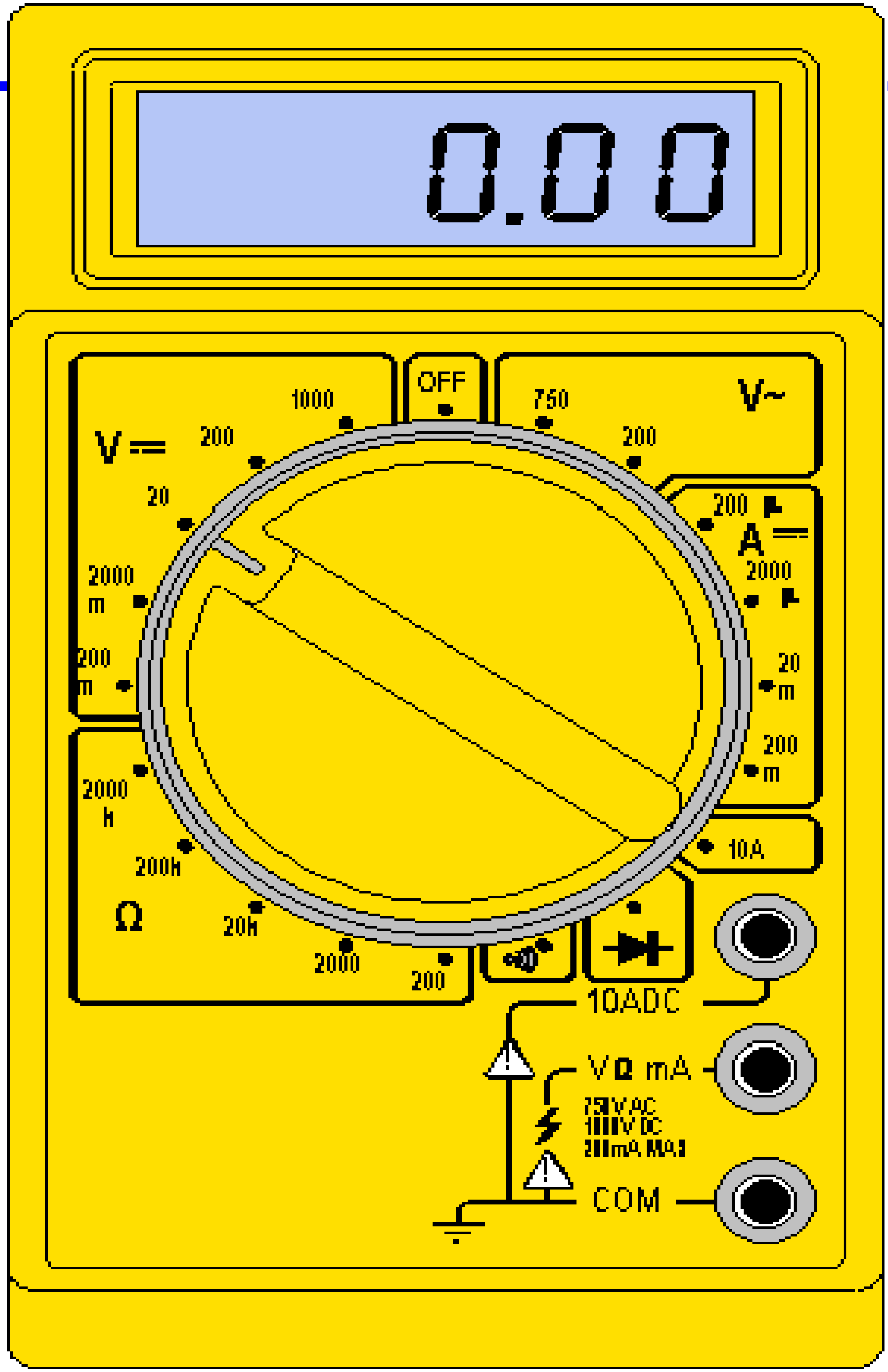
H

Multimeter as a Voltmeter

To use a multimeter as a voltmeter it is connected in parallel between the two points where the measurement is to be made. The voltmeter provides a parallel pathway so it needs to be of a high resistance to allow as little current flow through it as possible. Voltage measurements are the most common measurements. Processing of electronic signals is usually thought of in voltage terms. Voltage messurements are easy to do because you do not need to change the original circuit you only need to touch the points of interest.

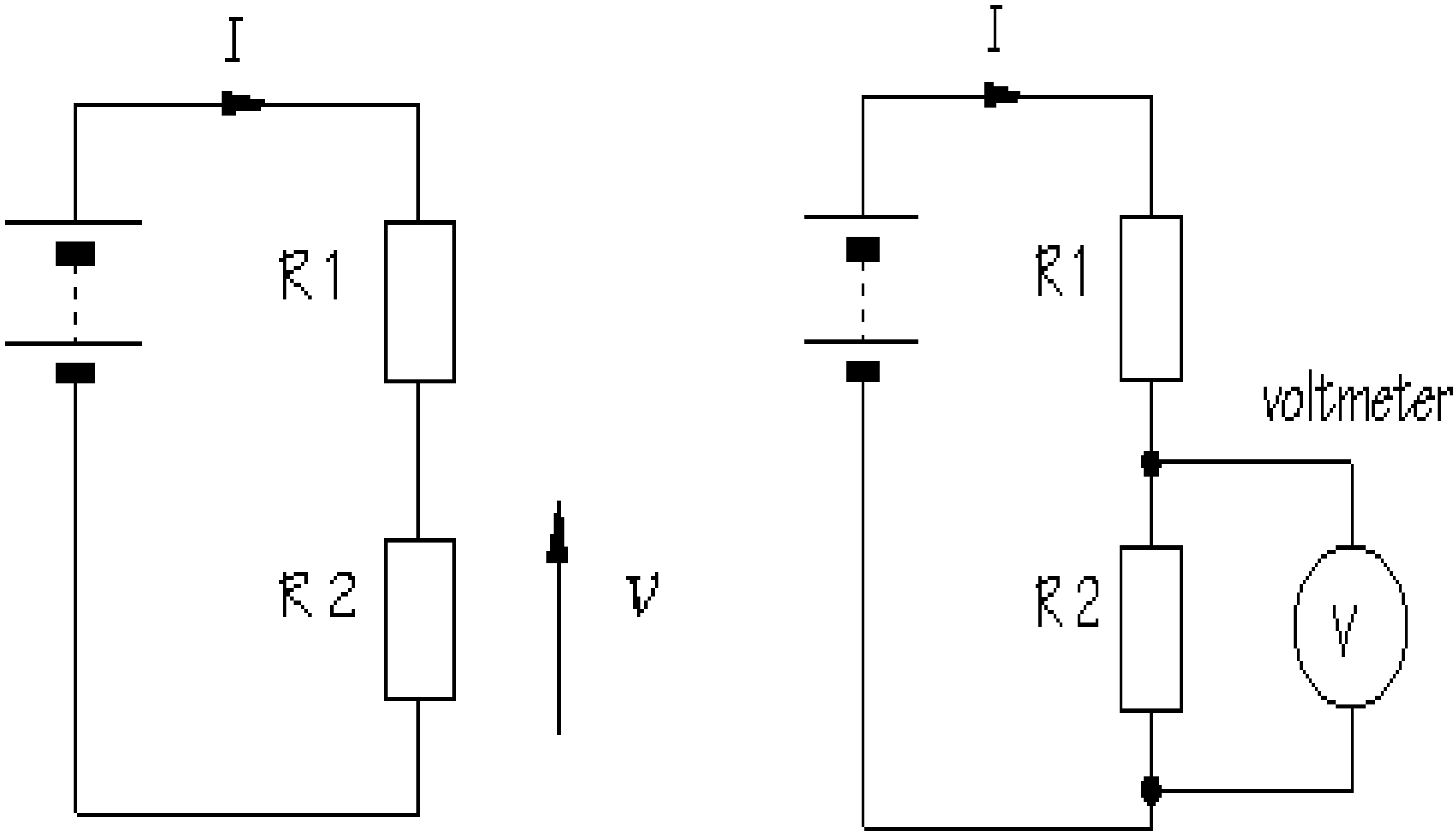
Mutimeter as a Voltmeter

- Select the DC or AC Volts
- If not a auto-ranging mutimeter then start at the highest volts scale and work your way down.
- Be very careful to not touch any other electronic components within the equipment and do not touch the metal tips.

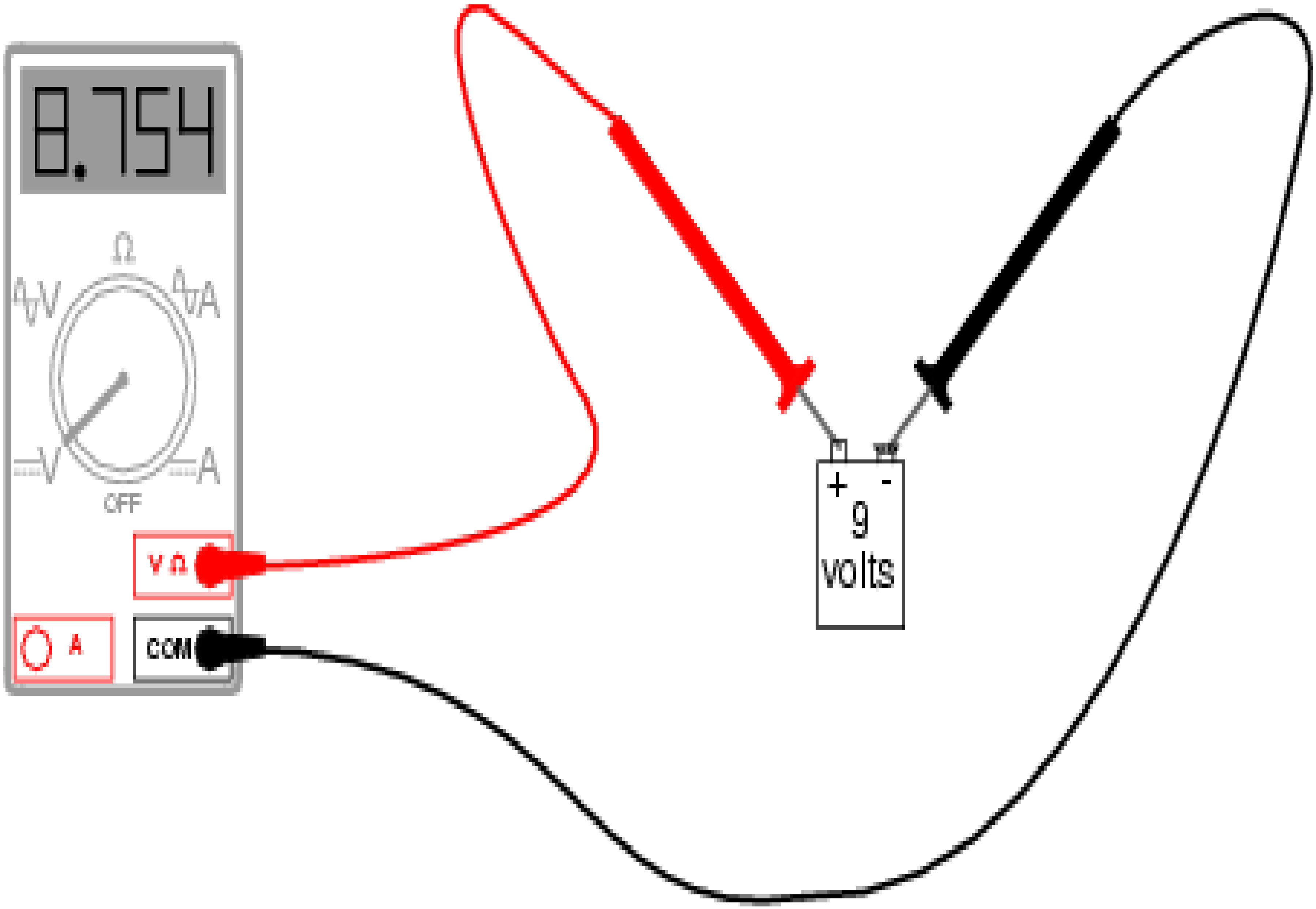

0.00
OFF
V
1000
200
20
2000 m
200 m
V~
750
200
A
200
2000
20 m
200 m
10A
Ω
2000 k
200k
20k
2000
200
10ADC
V Ω mA
COM

H

Mutimeter as a Voltmeter



H

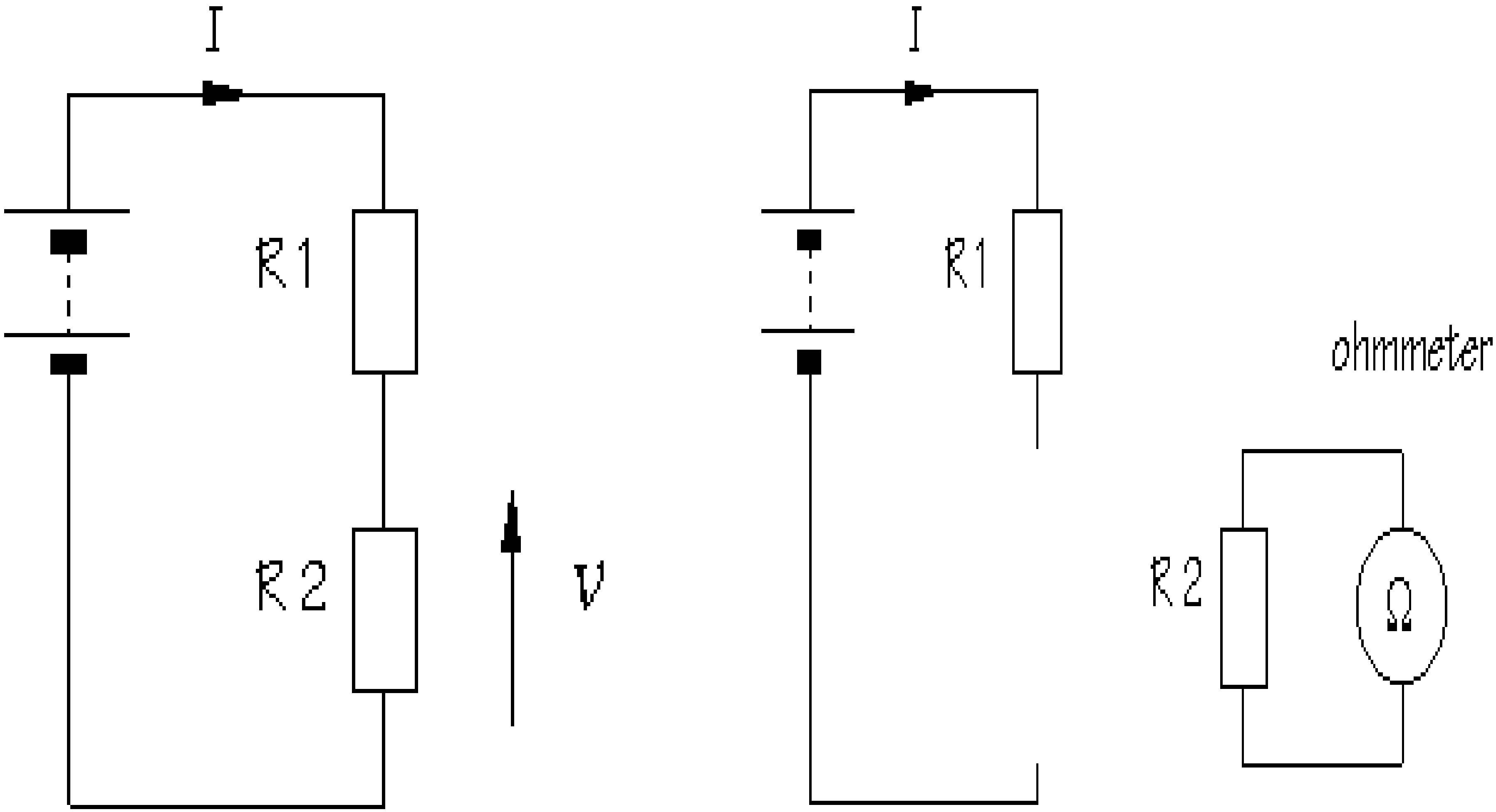


H

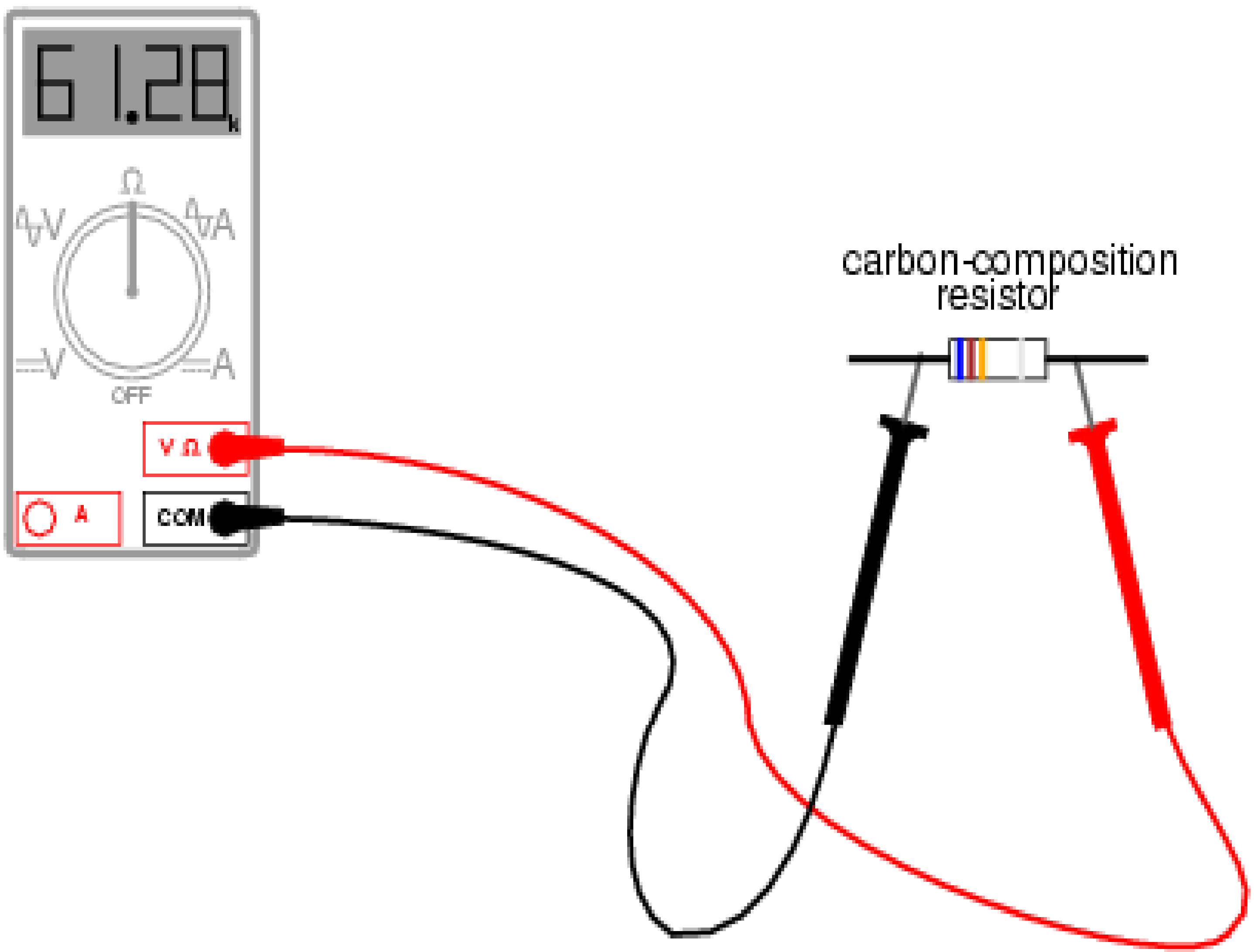
Multimeter as a Ohmmeter

- Power always has to be off
- Component has to be removed from circuit
- Start at lowest Ohm setting

Multimeter as a Ohmmeter



Multimeter as a Ohmmeter



H

Review

- A meter capable of checking for voltage, current, and resistance is called a *multimeter*,
- As voltage is always relative between two points, a voltage-measuring meter ("voltmeter") must be connected to two points in a circuit in order to obtain a good reading. Be careful not to touch the bare probe tips together while measuring voltage, as this will create a short-circuit!
- Remember to always check for both AC and DC voltage when using a multimeter to check for the presence of hazardous voltage on a circuit. Make sure you check for voltage between all pair-combinations of conductors, including between the individual conductors and ground!

Review

- When in the voltage-measuring ("voltmeter") mode, multimeters have very high resistance between their leads.
- Never try to read resistance or continuity with a multimeter on a circuit that is energized.
- Current measuring meters ("ammeters") are always connected in a circuit so the electrons have to flow *through* the meter.
- When in the current-measuring ("ammeter") mode, multimeters have practically no resistance between their leads. This is intended to allow electrons to flow through the meter with the least possible difficulty. If this were not the case, the meter would add extra resistance in the circuit, thereby affecting the current.