

Basic Instrumentation



Purpose

- ***NOT*** to teach a specific instrument
- But to teach the basic concepts used by all the instruments in a class
- If you understand how the concept works its easy to learn which buttons to press to get it to do what you want.

What is “Basic” instrumentation?

- Can be defined as the tools to measure the basic electrical properties of a circuit.
 - Ohms
 - Volts
 - Amps
 - Frequency
 - Waveforms

Multimeter

- Most common tool
 - Comes in two forms
 - Hand held
 - Bench top



28/07/2006

Multimeter

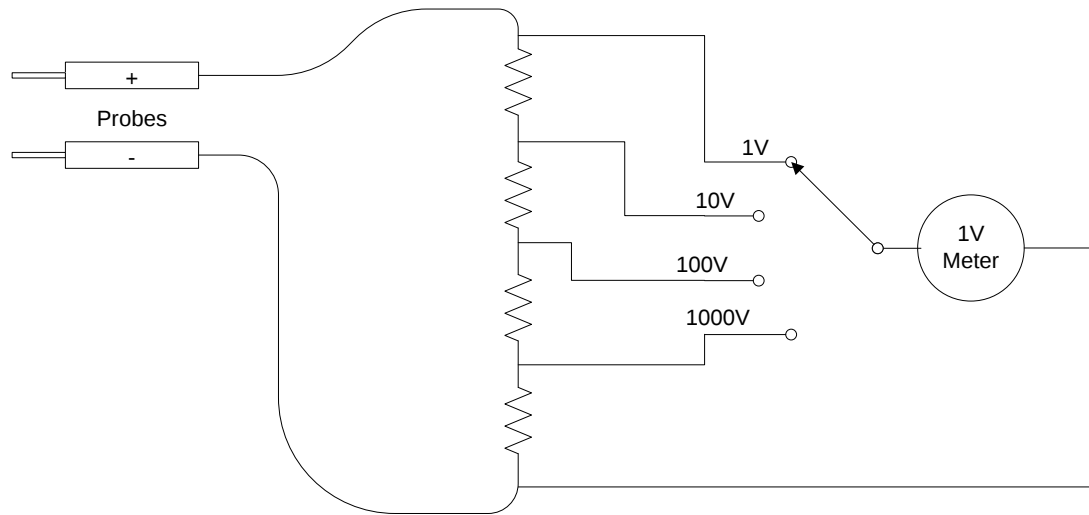
- Most common models measure
 - Voltage
 - Resistance
 - Low current levels ($<10\text{ A}$)
- Some have more advanced features
 - Frequency
 - Capacitance
 - Diode current
 - dB levels
 - Memory (Min / Max)
 - Ultra low current or Voltage $< 1\text{mA}$, $< 1\text{mV}$

Special probes

- Special probes are available for:
 - High current (up to several thousand amps)
 - Inductive pickup
 - High voltage
 - $> 1000V$
 - Temperature

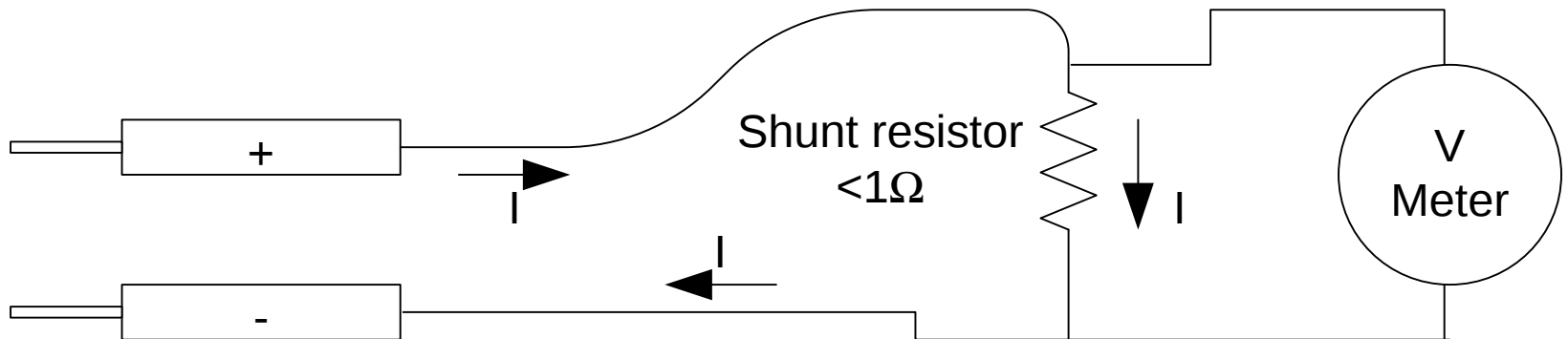
Voltage Measurements

- Meter only measures small voltages, typically ± 1 or 2 volts
- Higher voltages done through a voltage divider:



Current Measurement

- Measures voltage across a “shunt” resistor.

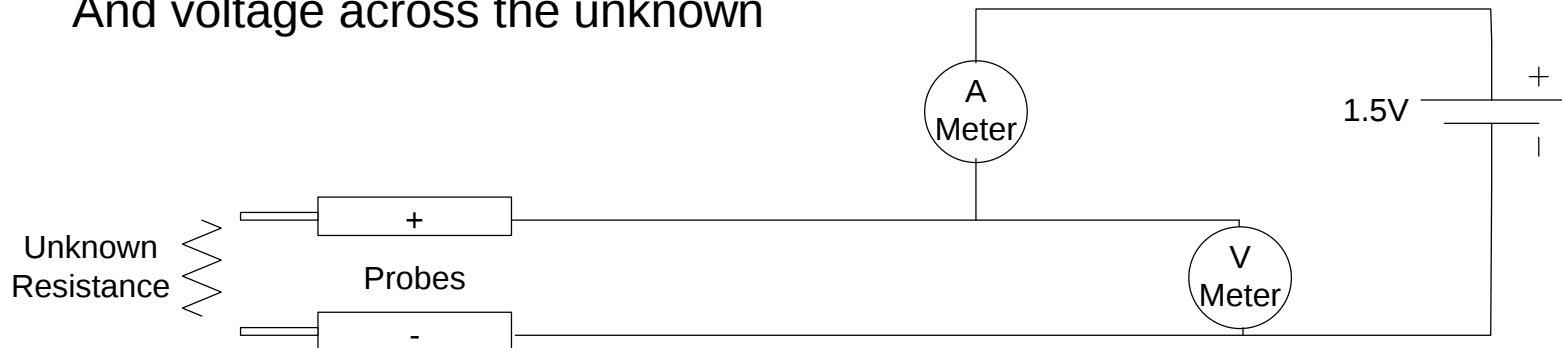


Resistance Measurement

- Measure small current through unknown to calculate resistance.

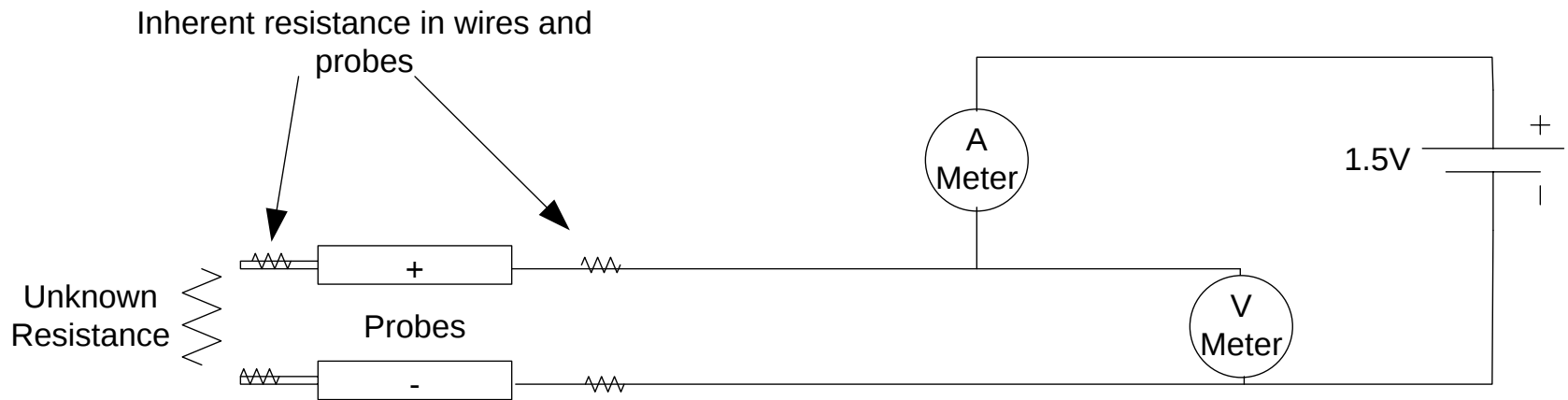
Need current through unknown

And voltage across the unknown



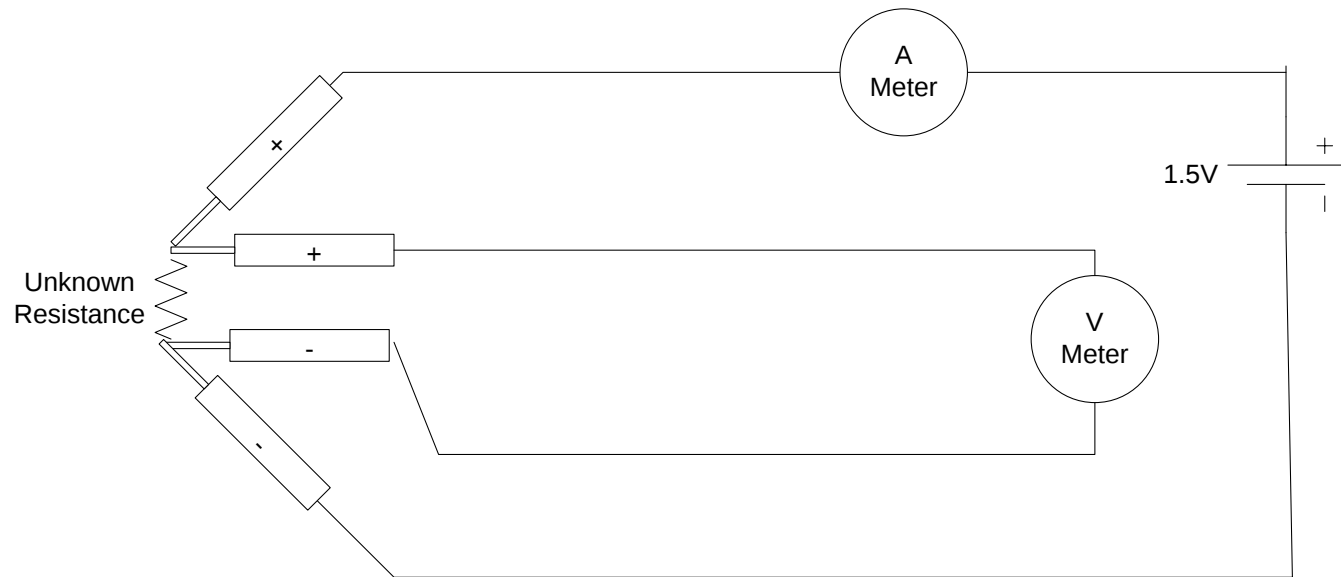
2 wire measurement error

- Probe resistance creates error

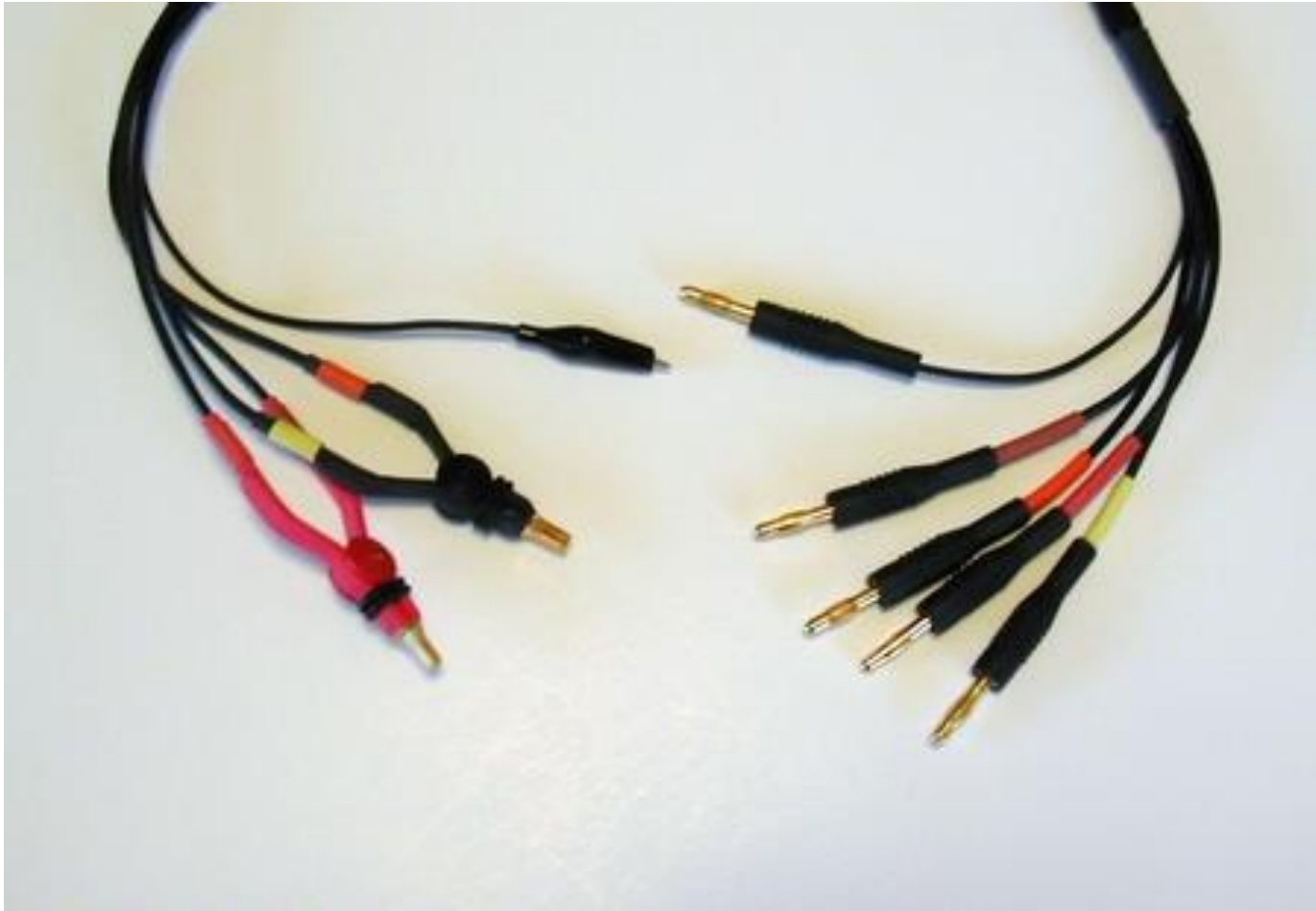


4 Wire Resistance Measurement

- Probe error reduced with 4 wire (Kelvin) measurement.
- No longer assume voltage at probes is equal to supply voltage of current circuit.



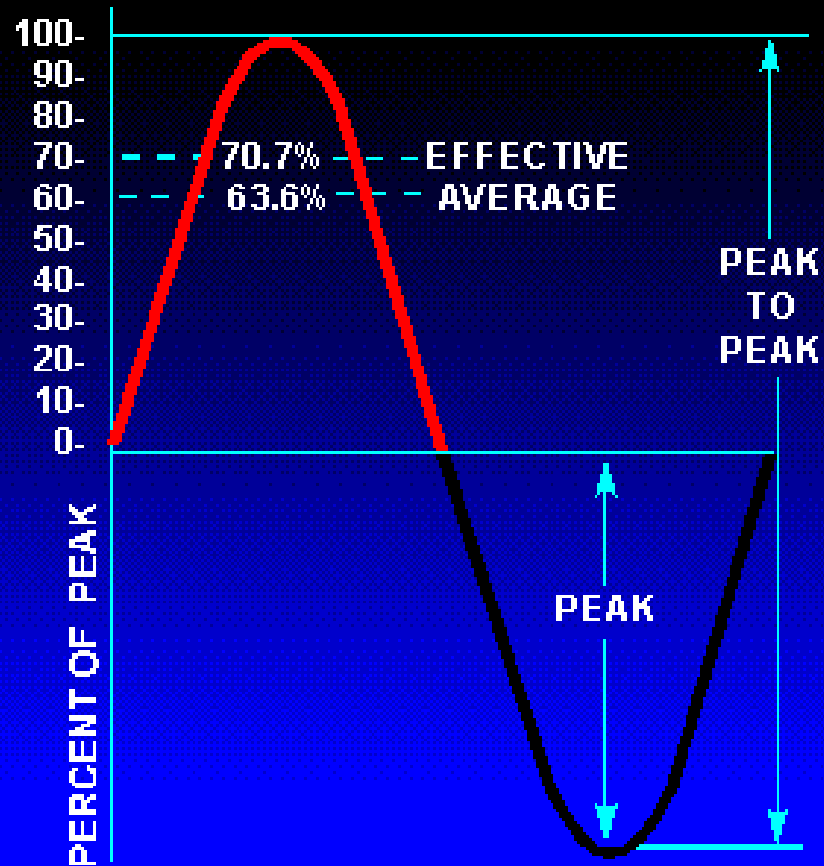
Kelvin Probes



Other AC voltage values

Average

Effective
(RMS)



RMS Voltage

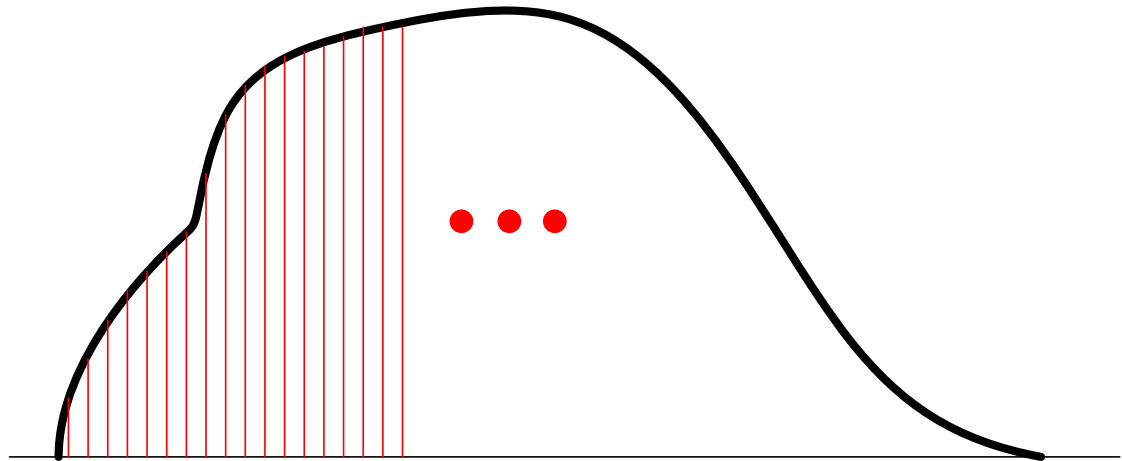
● RMS Voltage

- This is the Root-Mean-Square calculation of the AC signal.
- This is the measure of how much work can be done by the AC power source.
- $0.707 \times \text{peak}$ for sinusoidal signals ($\frac{\sqrt{2}}{2}$)
- Non-sinusoidal requires the following calculation

$$x_{\text{rms}} = \sqrt{\frac{1}{N} \sum_{i=1}^N x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_N^2}{N}}$$

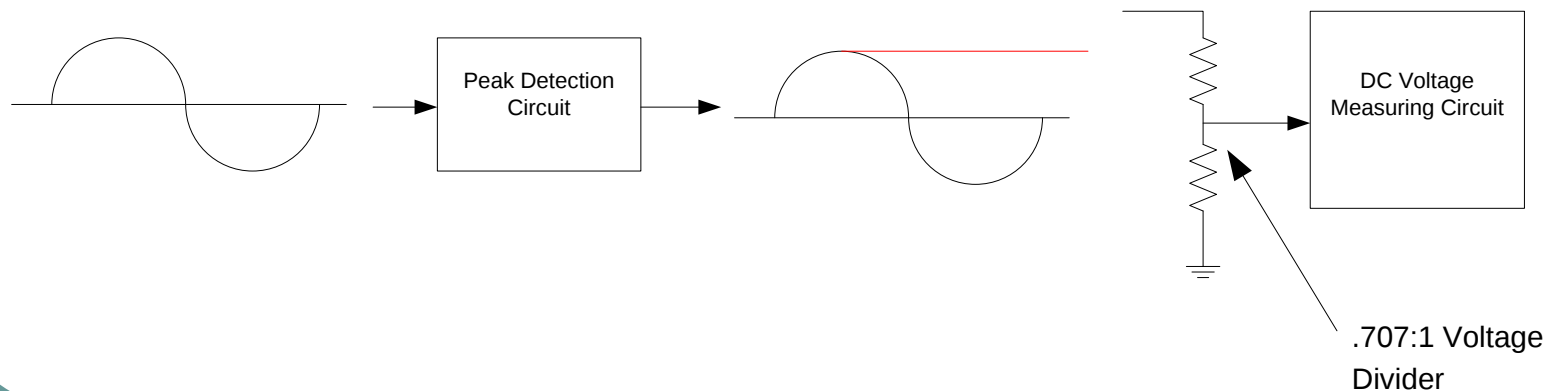
AC Voltage (RMS)

- Slice into tiny pieces at uniform time increments
- sum the amplitudes



Reading AC voltages

- Convert the AC voltage into a DC signal that represents the AC Peak value
- Multiply by .707
- Feed to DC measurement circuit



TRUE RMS Meters

- True RMS meter does this all digitally
 - Time slices at a specific frequency (typically around 10KHz)
 - Calculates the RMS on the slices
 - Display result.
-
- Is there a problem with this technique at high frequencies?

AC waveform visualization

- Chart Recorder



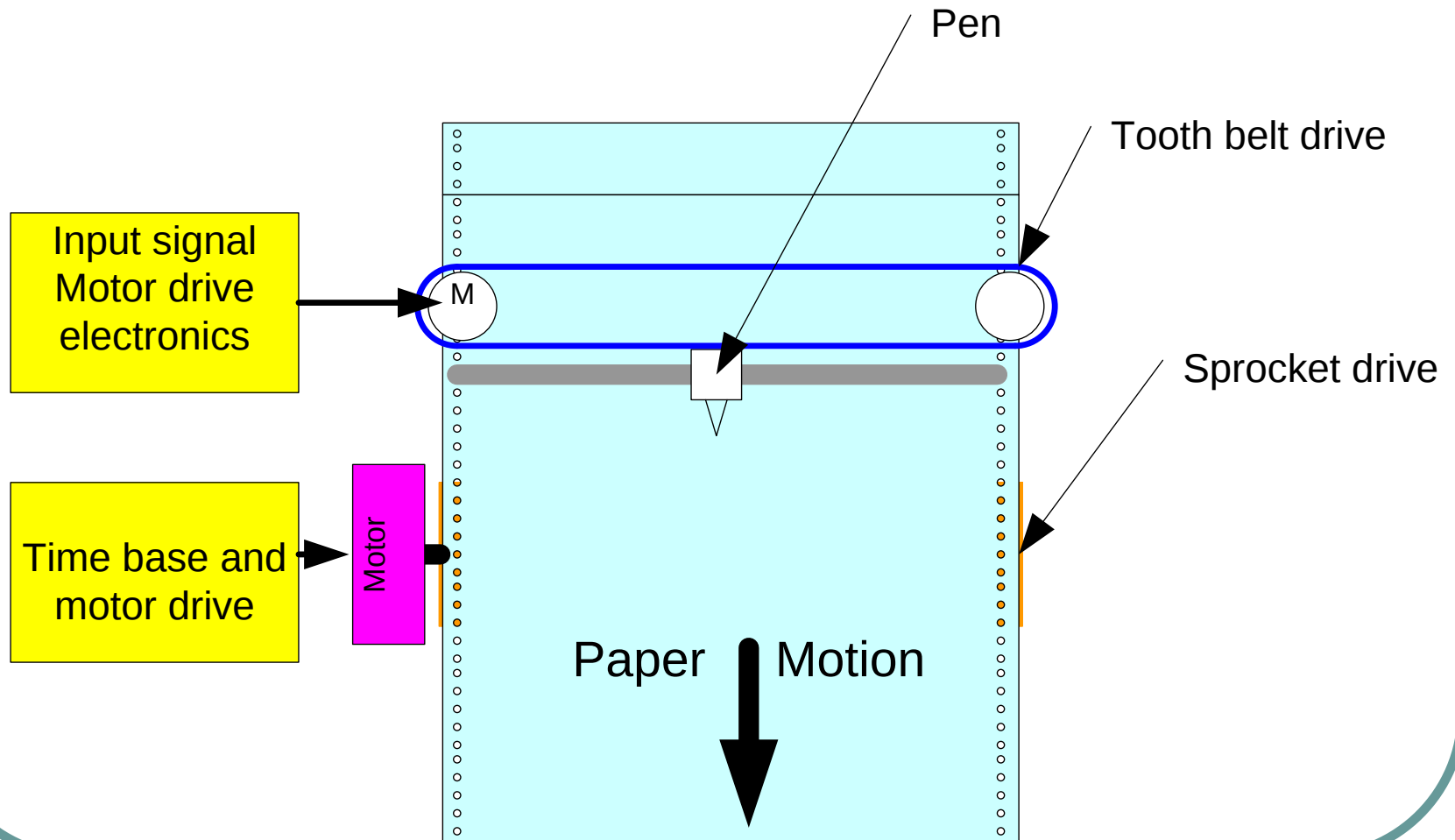
- Oscilloscope



Chart recorder

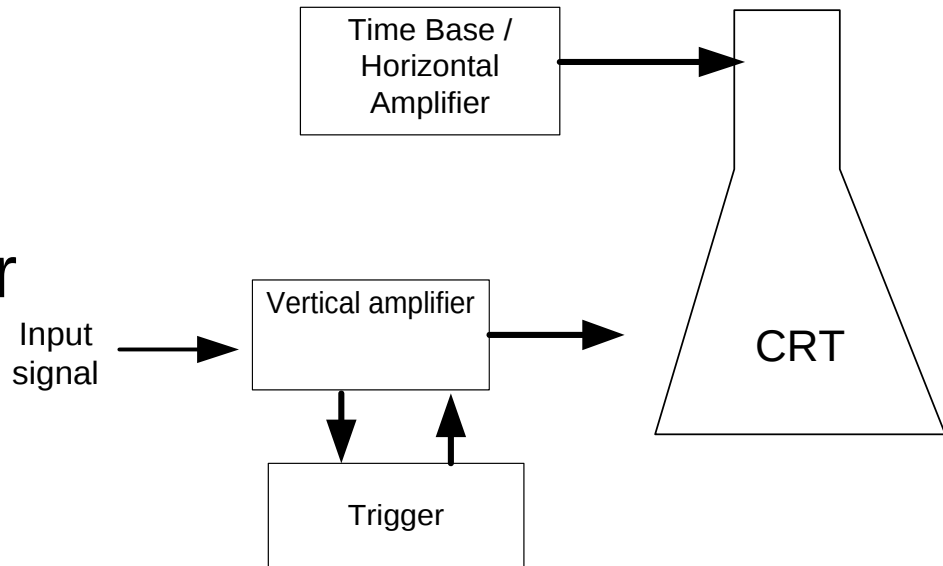
- Consists of a paper drive and pen drive
- Pen moved horizontally, normally with a cable/servo drive system.
- Paper speed typically between a few centimeters per hour to several centimeters per second
- Typically limited to less than **ten cycles per second** for full scale deflections
 - (Omega unit in lab is 5Hz [0.2s] for 5-95% deflection)

Chart Recorder

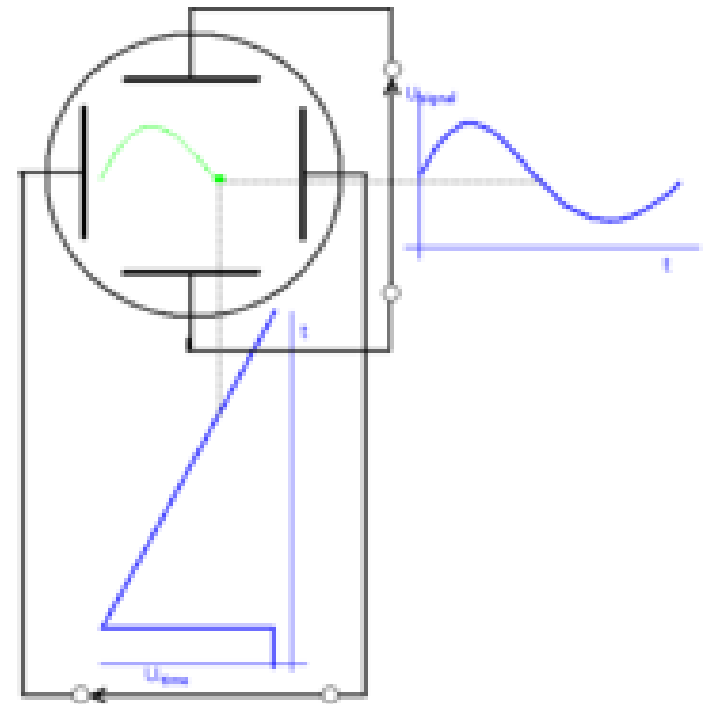
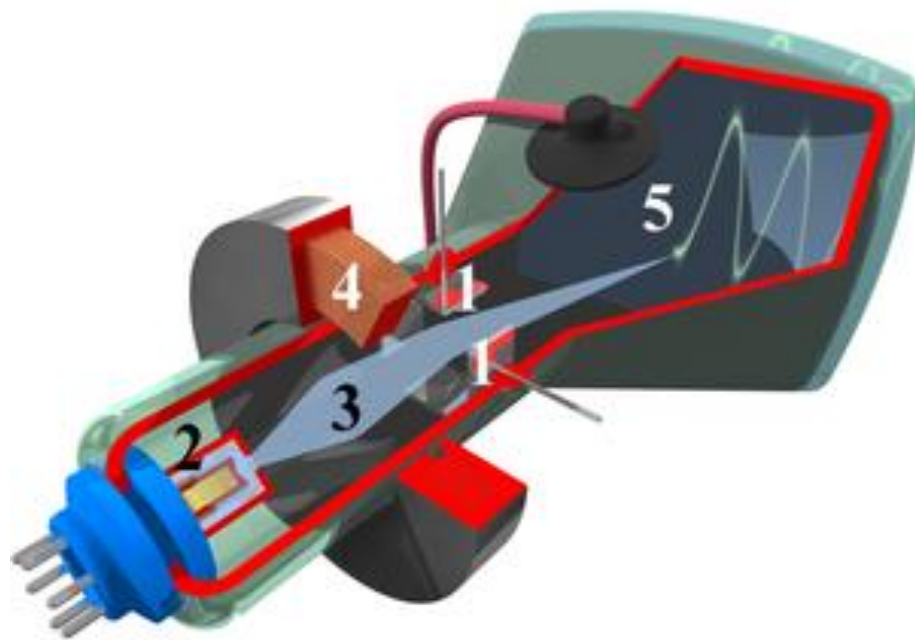


Basic Oscilloscope

- Made up of several “parts”
- Cathode Ray Tube (CRT)
- Timebase
- Vertical Amplifier
- Trigger section



CRT



CRT

- Wave painted as a line on the display

Timebase Section

- This section generates a horizontal signal that moves the electron beam across the screen at a given (calibrated) speed based on time. (Y vs Time)
- Optional horizontal drive signals:
 - Can also use an external analog input signal for this drive.
 - Use second input channel for Y vs X

Vertical Amplifier

- Amplifies / attenuates the input signal so that it fits within the vertical display limits of the screen
- Generates a drive signal to the CRT that is proportional to the scaled input signal

Trigger Section

- Takes input signal from vertical channel
- “looks” for a particular vertical value and then signals the horizontal section to begin its trace
- Holds signals stationary on the display by restarting them at the same amplitude for each “sweep”
- Can use an external signal for a trigger

DSO

- Digital Storage Oscilloscope
 - No longer uses analog drive signals to CRT
 - Now acquires and displays signals digitally “imitating” the old CRT system
 - This is effectively a self contained data acquisition and display system

DSO Display type

- LCD or similar raster display
- Screen is painted line by line instead of painting the waveform as a line

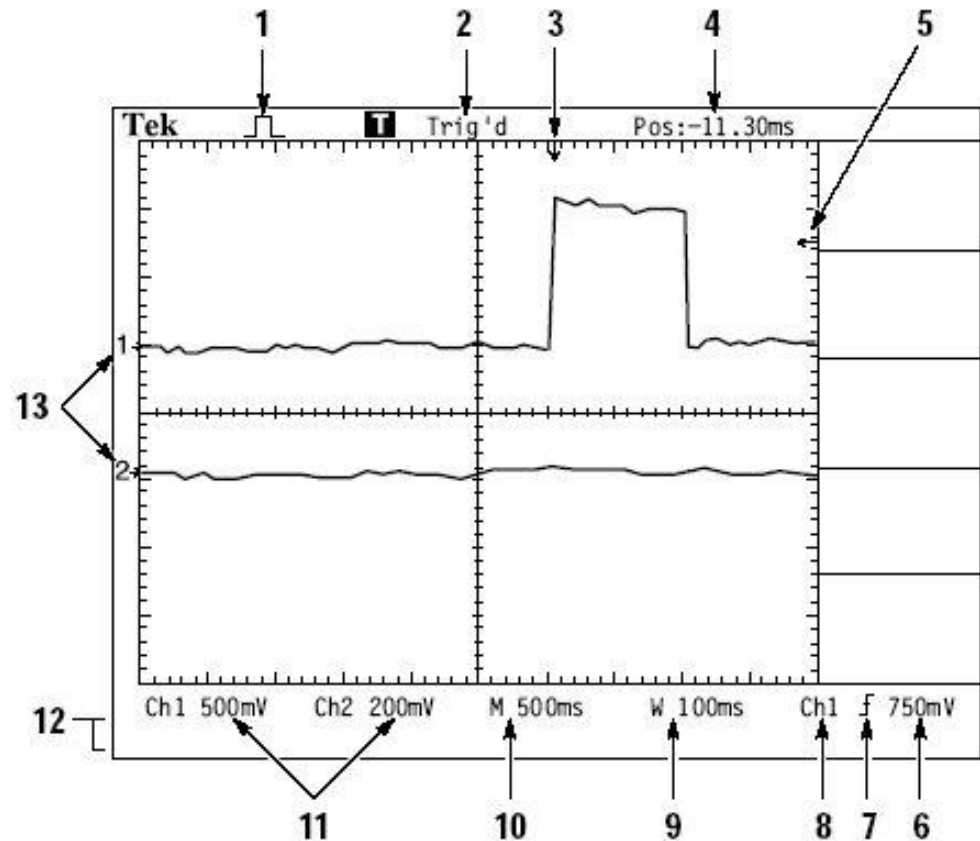


DSO

- Capable of signals from DC to GHz
(up to 70GHz depending on scope design)
- Displays signals perpetually
Signals don't "fade away" like old CRT's
- Input stage is a specialized high speed A/D converter
- Complex triggering criteria possible because of computing power
 - Video, serial communications, digital state

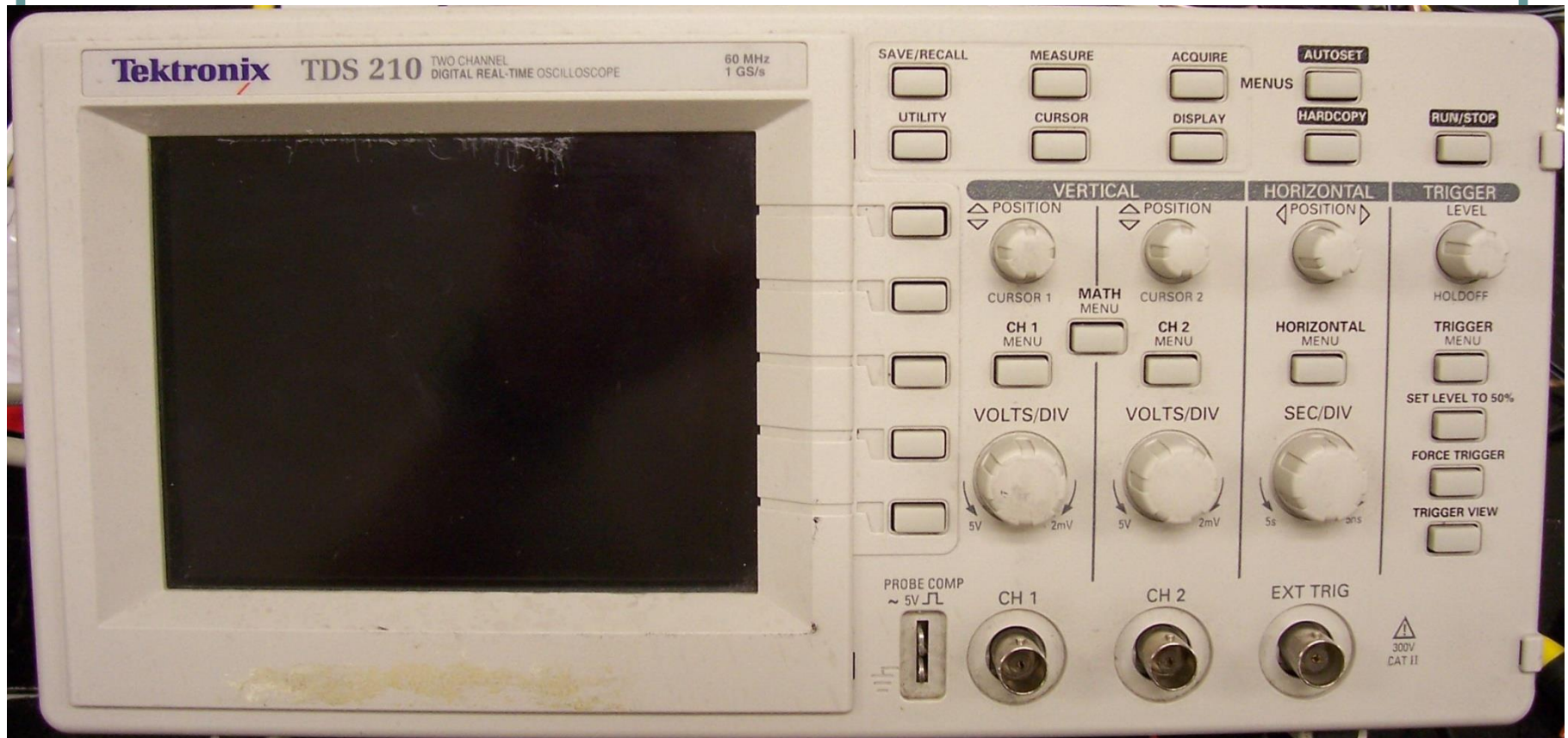
Typical DSO Display

- 2: Trigger status
- 3: Trigger position
- 5: Trigger level
- 11: Vertical scale
- 10: Horizontal scale
- 6-8: Trigger setup
- 13: Traces

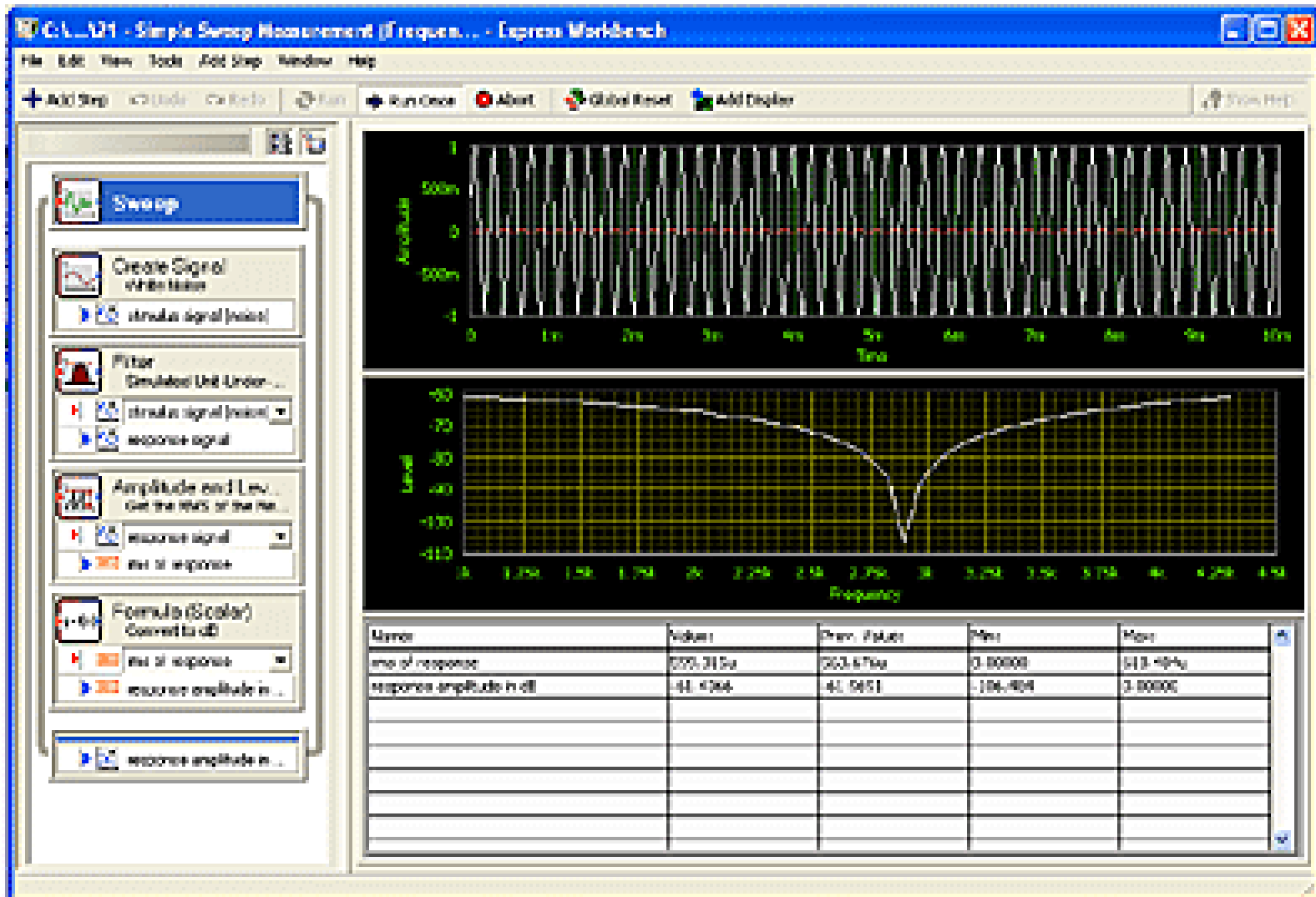


Units are always in “units / division”

TDS210



Signal Express / DAQ



Frequency measurement

- Tools available to measure frequency
 - Oscilloscope
 - Frequency Counter
 - Spectrum analyzer
 - Computer (DAQ)

Frequency Counter

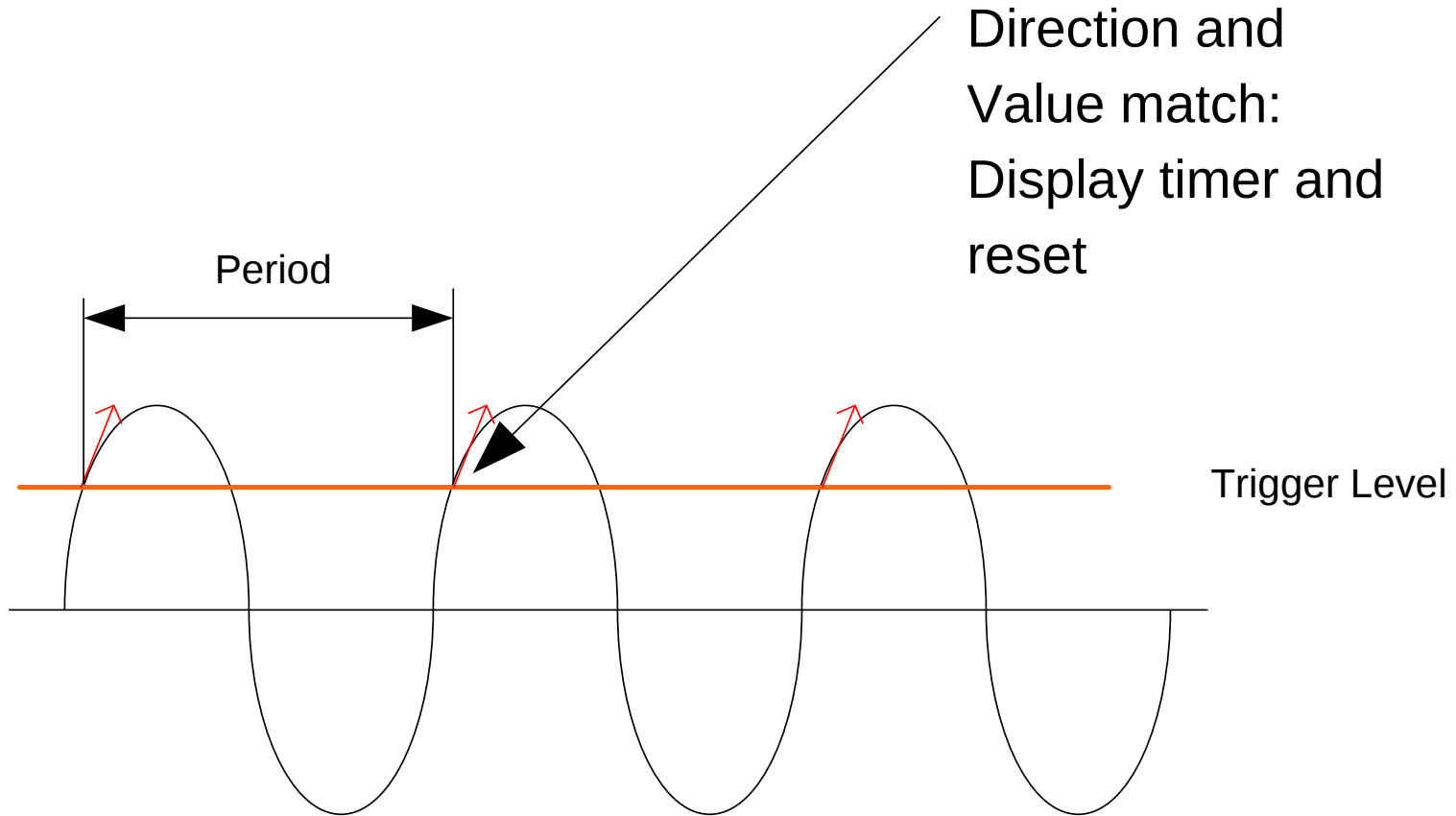
- Handheld meter
- Desktop meter



How it works

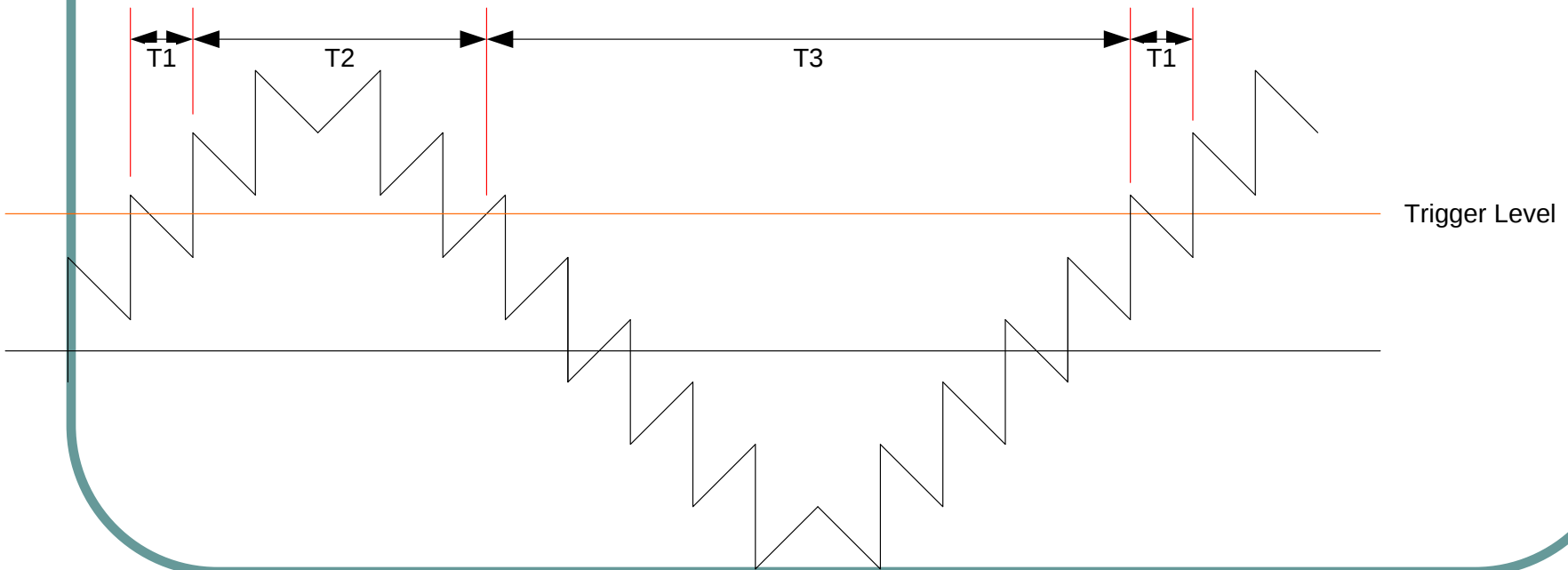
- Consists of:
 - Input section
 - Attenuate the signal to a desired level
 - Trigger section
 - Looks for the signal to cross the selected value with the correct slope
 - Timing section
 - Counts the time since the last trigger

A simple example



More complex waveform

- Which time do you count? T1, T2 or T3?



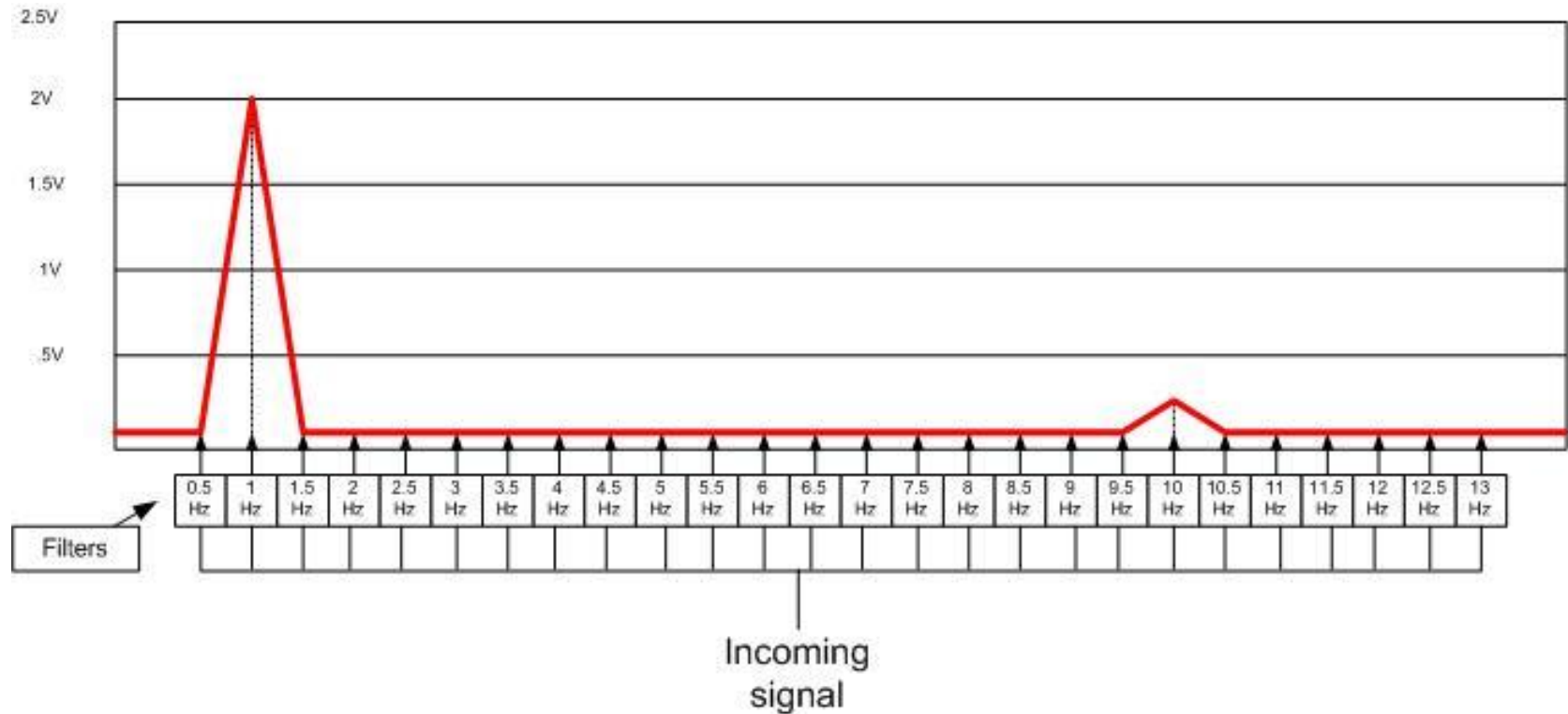
Frequency counter

- Major drawbacks
 - Can only display one frequency at a time,
 - Triggering on complex waveforms is difficult.
- Solution:
 - Spectrum analyzer
 - Oscilloscope with FFT module
 - Computer / daq

Time domain vs Freq domain

- Oscilloscope is time domain measurement
 - Horizontal axis is time
- Spectrum display
 - Frequency domain
 - Frequency on horizontal axis
 - Amplitude on vertical axis

Spectrum analysis Basic idea



Signal express (Power Spectrum)

Create Analog Signal

sine wave

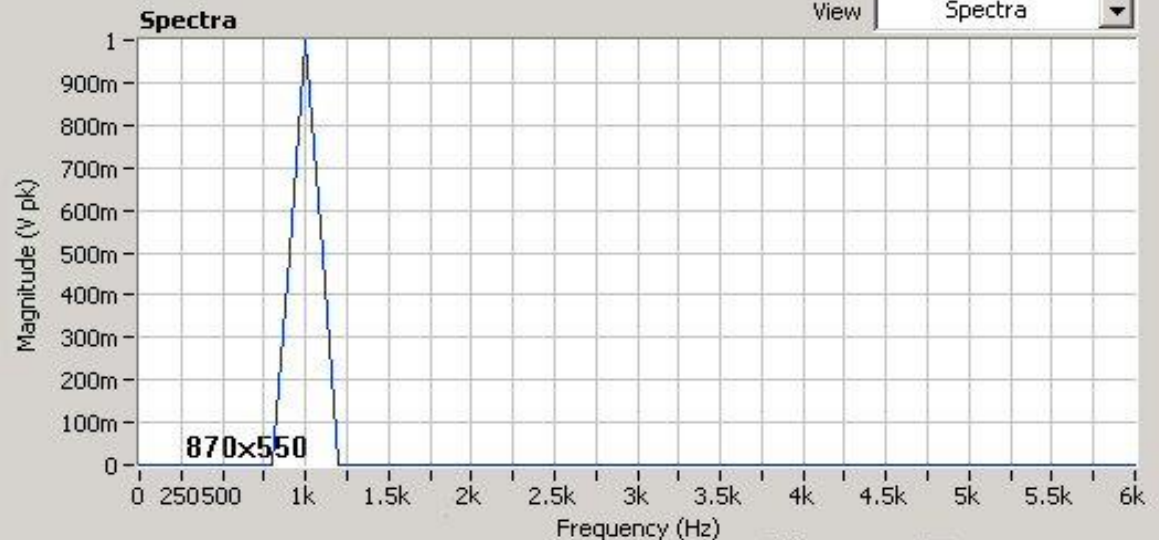
Power Spectrum

sine wave

spectrum

averaging done

averages completed



Zoom Autoscale

Input Configuration Averaging

Window

Hanning

Scaling

Spectrum type

Magnitude

Peak conversion

Peak

Magnitude scale

Linear

Spectral density

Off

Waveform Creation

- Function Generator
 - Simple function type
 - Arbitrary waveform
- Computer with D/A converter

Function generator

- Generates a waveform
 - Repetitive
 - Typically sine, triangle and square waves
 - Amplitude control
 - Some have extra features
 - Frequency sweep
 - Amplitude offsets
 - Symmetry controls

Simple Function Generator



Arbitrary waveform generator

- Program the wave shape
 - point by point
 - Downloaded point file
- Output that waveform at selected rate
- Continually repeat this wave
- Or do just once

Computer and DAQ

- Generate waveform with D/A conversion
- LabVIEW
 - Simple program
 - Signal express
- Other packages
 - C++
 - Basic
 - etc