EE 105 | Lab 1

Review of Passive Networks

…aka, How Does an Oscilloscope Probe Work?

Berkeley | EECS
Electrical Engineering and Computer Sciences

Prelab Review

Basic low pass filter

- Frequency domain transfer function:

$$H(s) = \frac{V_o(s)}{V_i(s)} = \frac{1}{1 + sRC}$$

Where we can define the time constant, $\tau = RC\ [sec]$

and the pole frequency, $\omega_p = \frac{1}{RC} \left[\frac{rad}{sec}\right]$

- In the time domain:

$$V_o(t) = V_I\left(1 - e^{-t/RC}\right)$$

Where V_I indicates the magnitude of an input step function,

and the rise time $t_r = t_{0.9V_I} - t_{0.1V_I} \approx 2.197\tau$

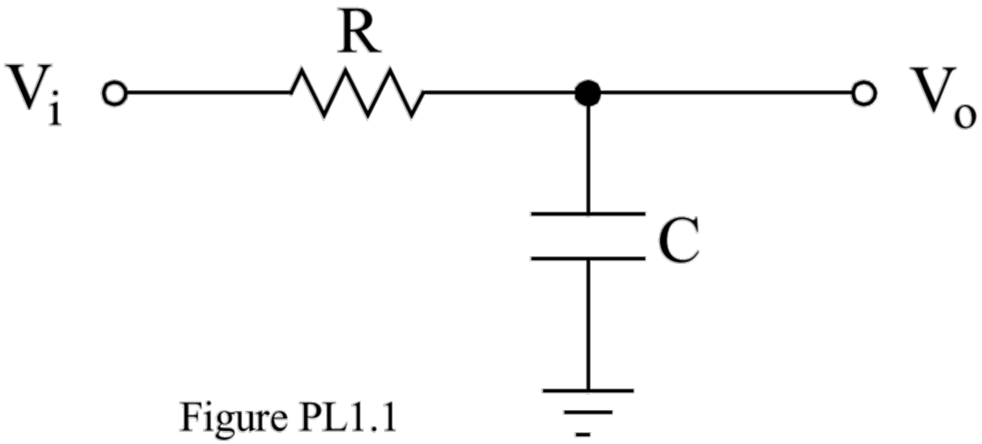
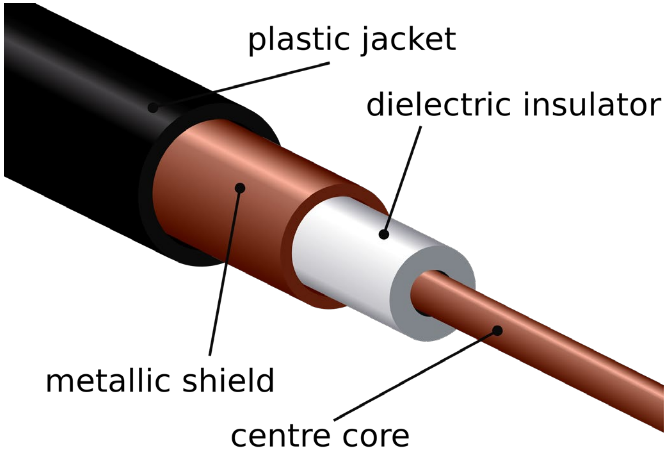


Figure PL1.1

Coaxial Parasitics

- Any measurement tool is really a circuit
  - May seem obvious, but this means you are changing your circuit when you connect it to a tool!
  - This circuit consists of both intentionally chosen elements and *parasitics*
  - Most AC circuits will benefit from measurement with coaxial cables
    - Protection from electromagnetic interference (EMI)
    - Low loss in transmission line applications
    - Large parasitic capacitance!



Oscilloscope Loading

- Our oscilloscopes use coaxial probes with high input impedance
  - This capacitively loads any circuit we want to measure!

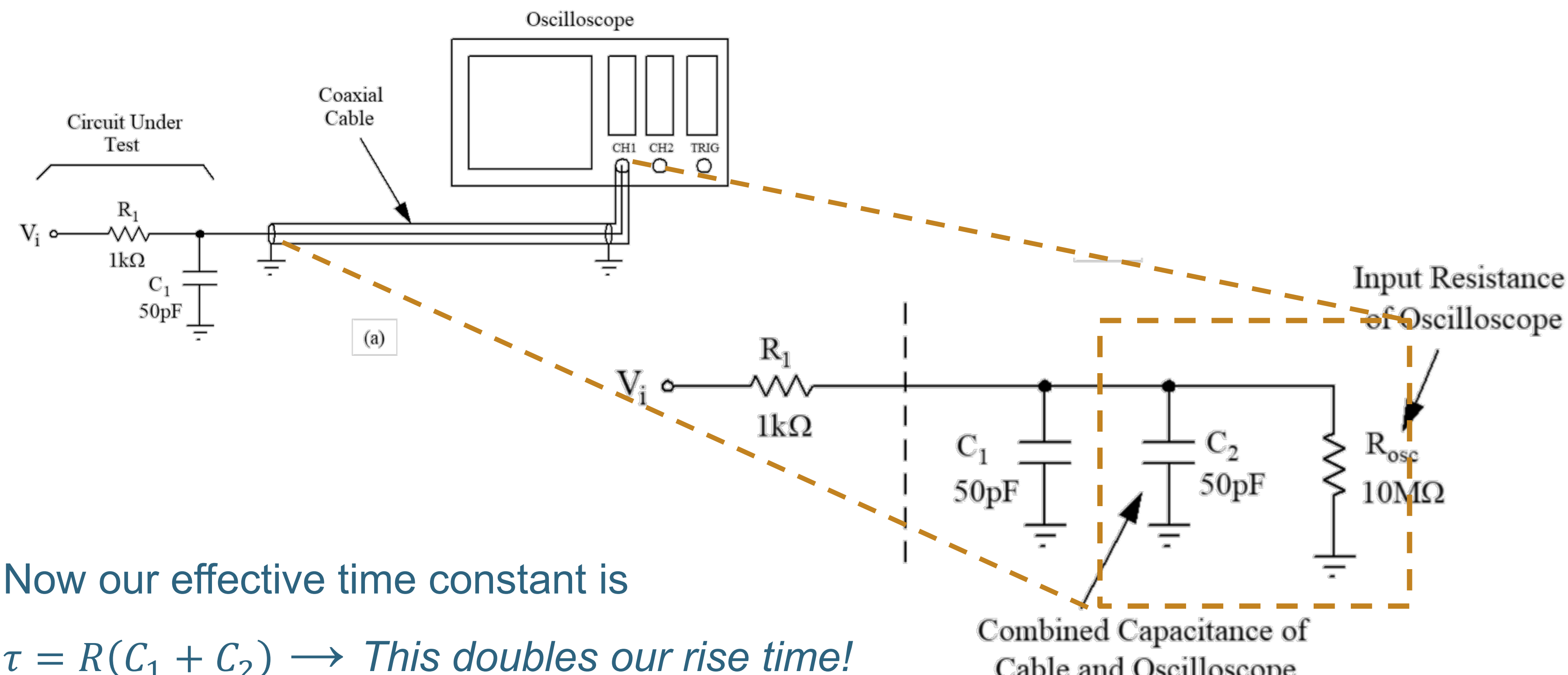


Figure PL1.2

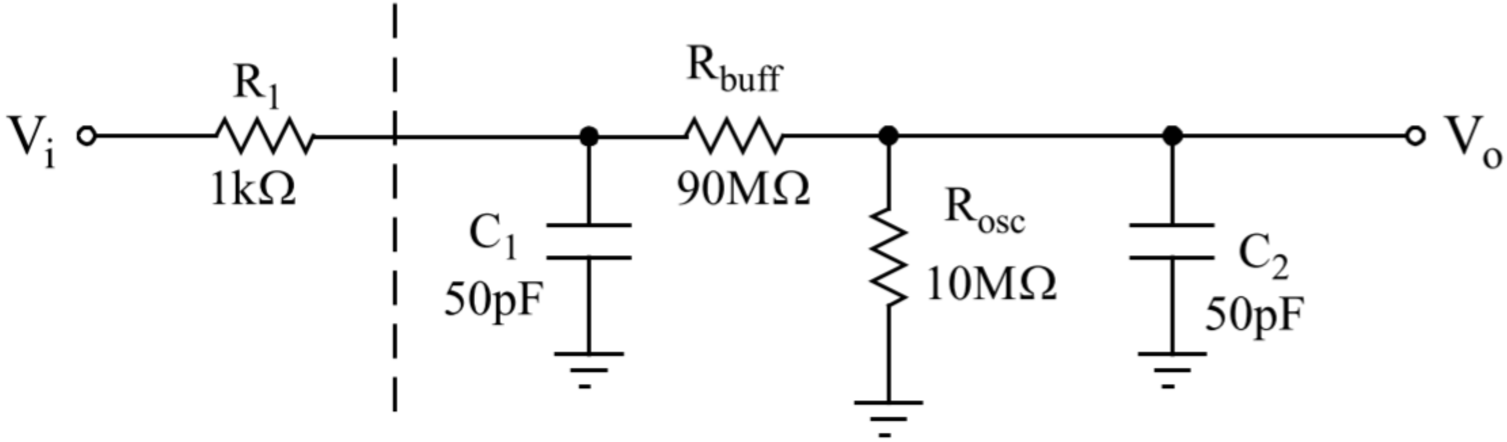
Now our effective time constant is

$\tau = R(C_1 + C_2) \longrightarrow$ *This doubles our rise time!*

Loading Effects on Rise Time

Q: If the probe capacitance introduces 100% error, how can it measure any arbitrary response accurately?

A: Clever circuit design!



By using a buffer resistor in series with the input, the effective voltage across C_2 is reduced by the voltage divider ratio

$$C_{2,eff} = \frac{R_{osc}}{R_{osc} + R_{buff}} C_2$$

*This means for a given step/cycle, much less charge needs to be stored on C_2 → **faster response!***

Compensated Attenuators

Problem: R_{buff} actually increases the rise time of the oscilloscope circuit through the resistive component of τ

$$\tau_{osc} = \left(R_{osc} \,||\, R_{buff}\right)C_2$$

Solution: "Compensate" the probe by creating a parallel path at high frequencies

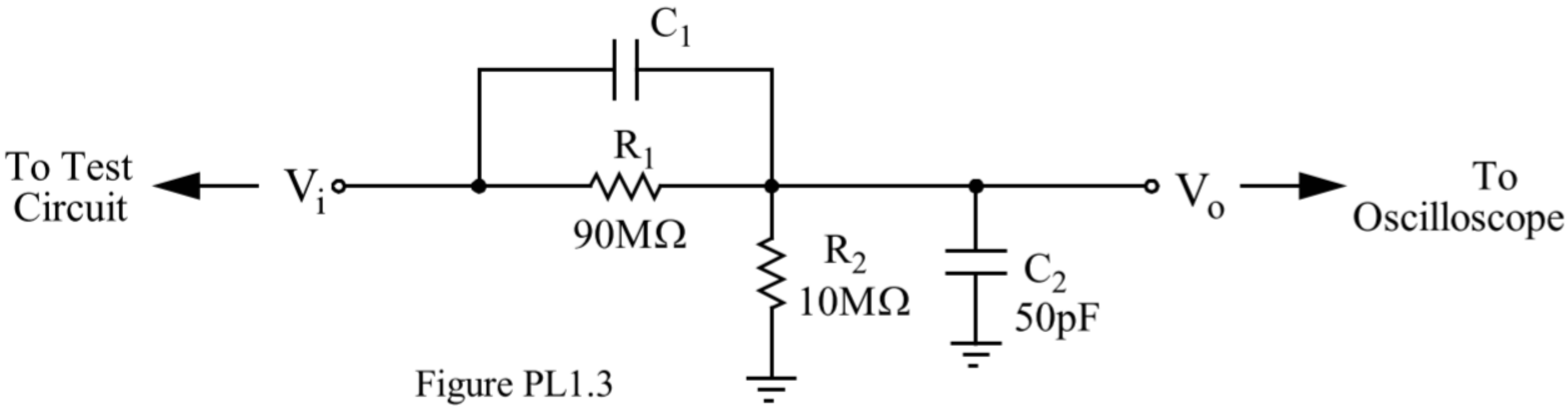


Figure PL1.3

Compensated Attenuators

Prelab Review

- At low frequencies, we have a resistive divider (i.e., **attenuator**)
  - $V_o = \frac{R_2}{R_1+R_2} V_i$
- At high frequencies, we have a capacitive divider (the capacitor impedances will be much lower than R_1 & R_2 resistances)
  - $V_o = \frac{C_1}{C_1+C_2} V_i$

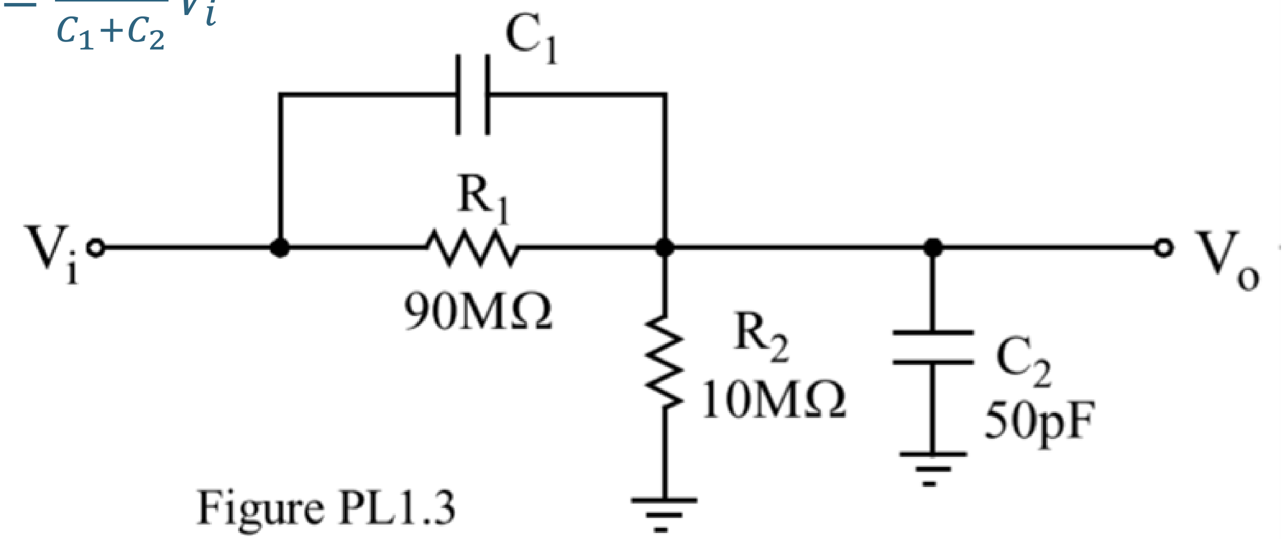


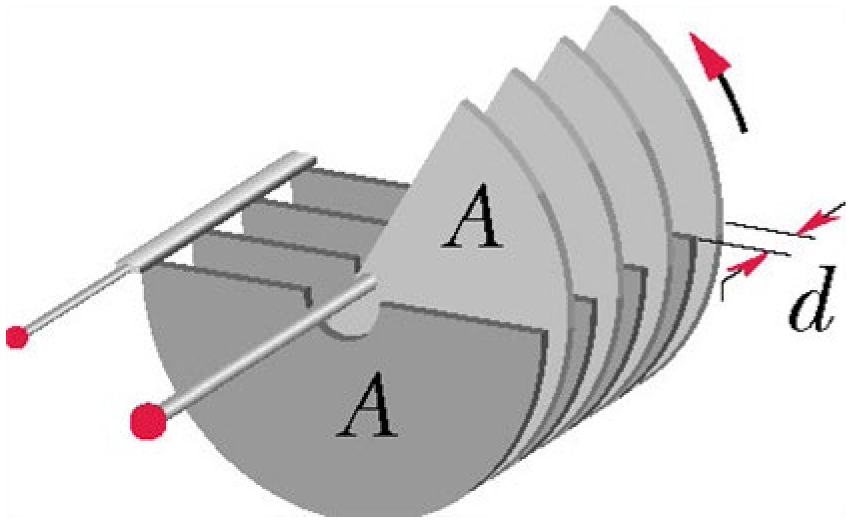
Figure PL1.3

If $\boldsymbol{C_1 = \frac{R_2}{R_1} C_2}$, we will have the same transfer function across all frequencies, giving us a theoretical rise time of 0!

Practical Considerations

- Previous analysis depends on precisely picking the value of C_1 based on R_1, R_2 & $C_2 \rightarrow$ **these values cannot be reliably controlled or predicted**
- **Real oscilloscope probes allow for adjustment of C_1** (variable capacitor) to precisely tune the network
- We will use variable resistors instead…how could this work?

One more thing…



Lab Overview

- Lab equipment
- Breadboard circuits

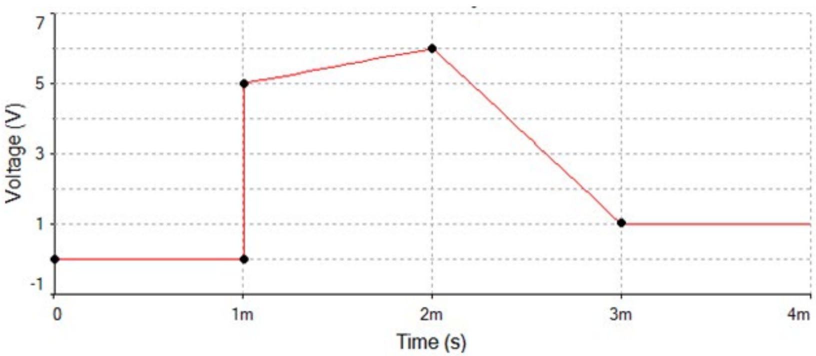
Lab Equipment

- Arbitrary Function Generator
  - Agilent 33120A
- Digital Oscilloscope
  - Agilent DSO5014A

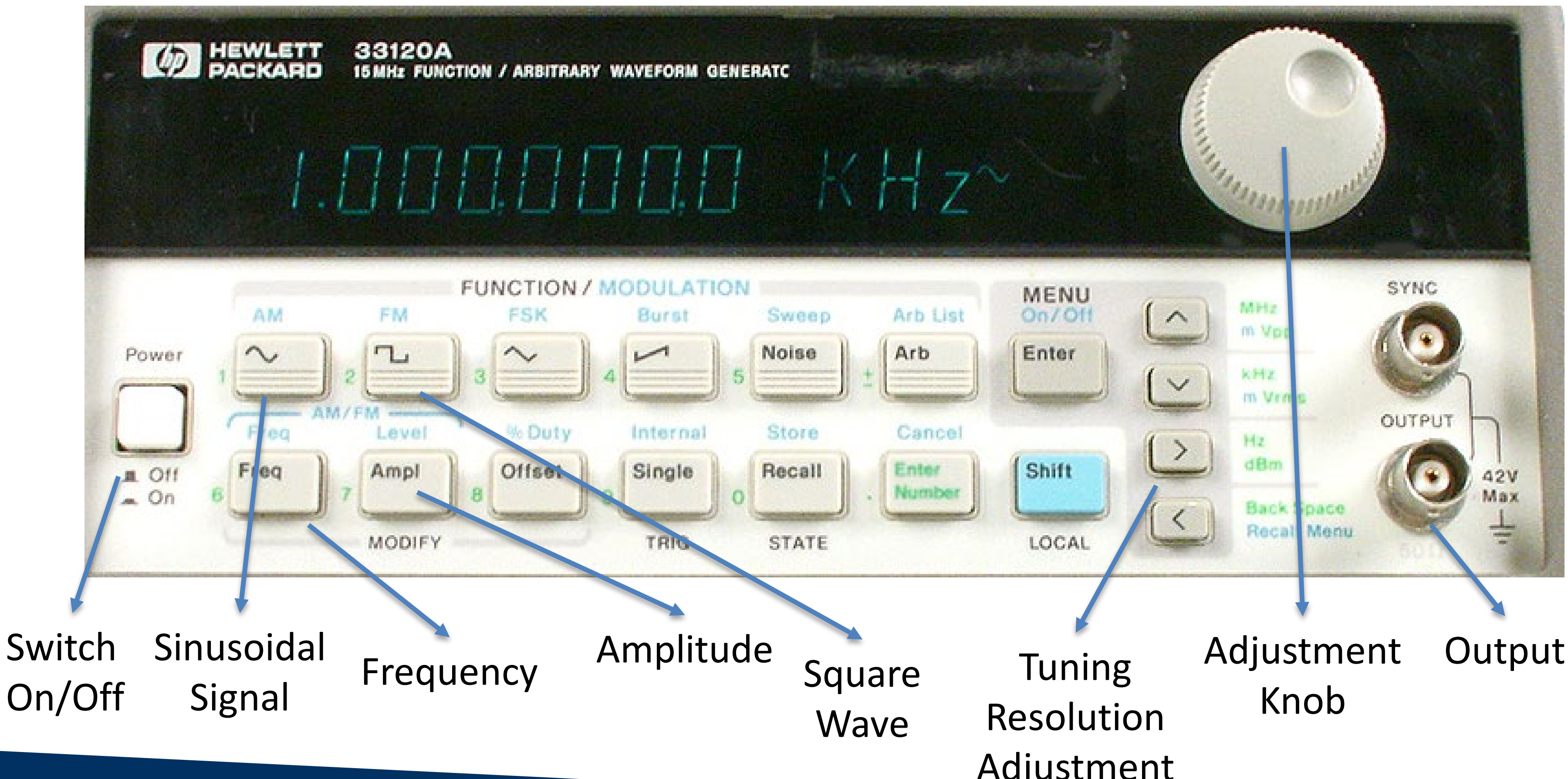
Use proper cables!

Arbitrary Function Generator

- Generates arbitrary waveforms
  - Sinusoidal
  - Square
  - Triangle
  - Piecewise

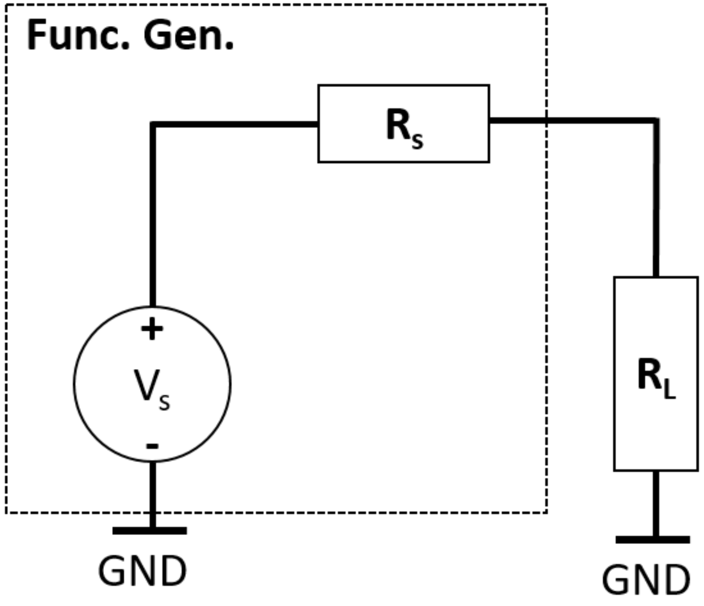


Arbitrary Function Generator

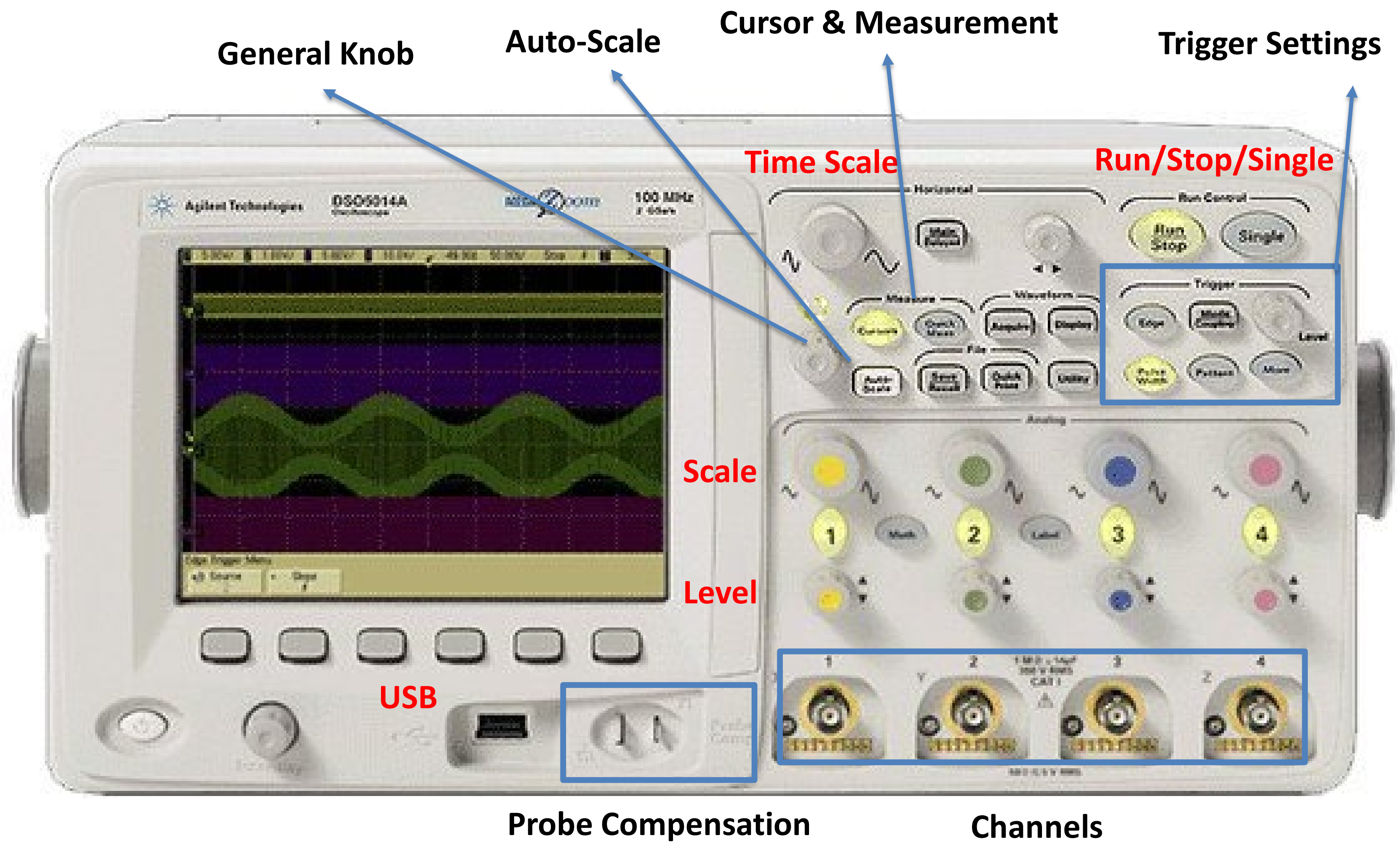


Arbitrary Function Generator

- Frequency Range
  - ~15 MHz
- Output Impedance
  - **Figure it out!**



Digital Oscilloscope


General Knob
Auto-Scale
Cursor & Measurement
Trigger Settings
Time Scale
Run/Stop/Single
Scale
Level
USB
Probe Compensation
Channels
Agilent Technologies
DSO5014A
100 MHz
Horizontal
Run Control
Run Stop
Single
Trigger
Measure
Waveform
File
Analog
Level

Digital Oscilloscope

- Need to compensate probes
  - Otherwise your measurement will be incorrect

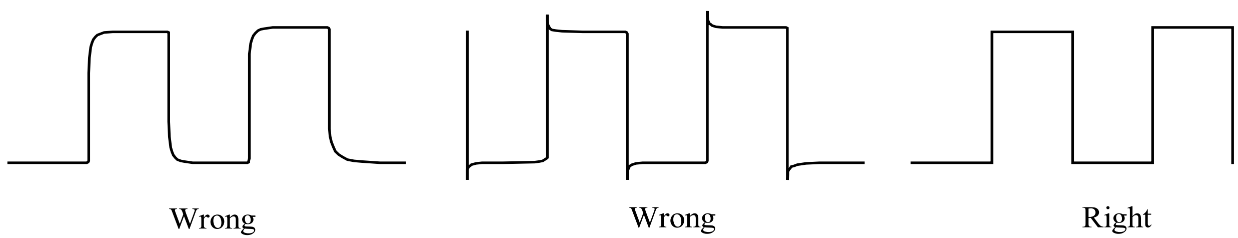


Figure L1.1

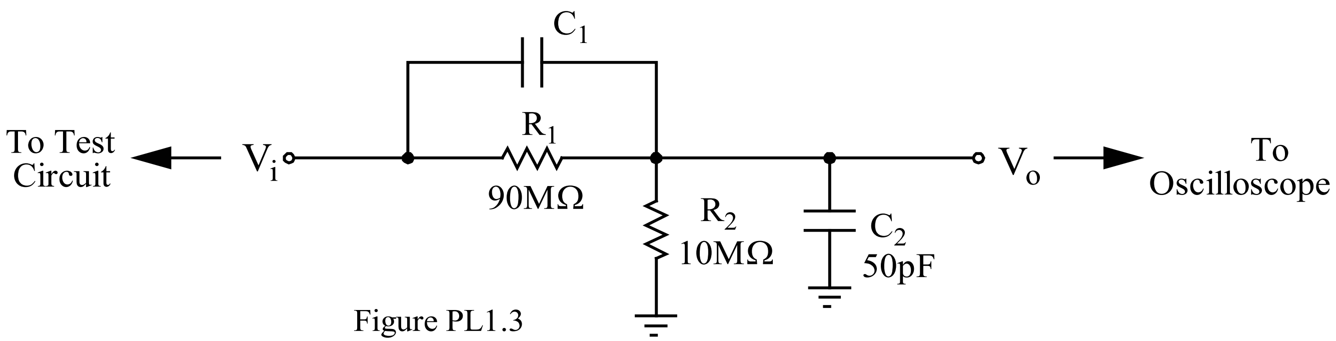
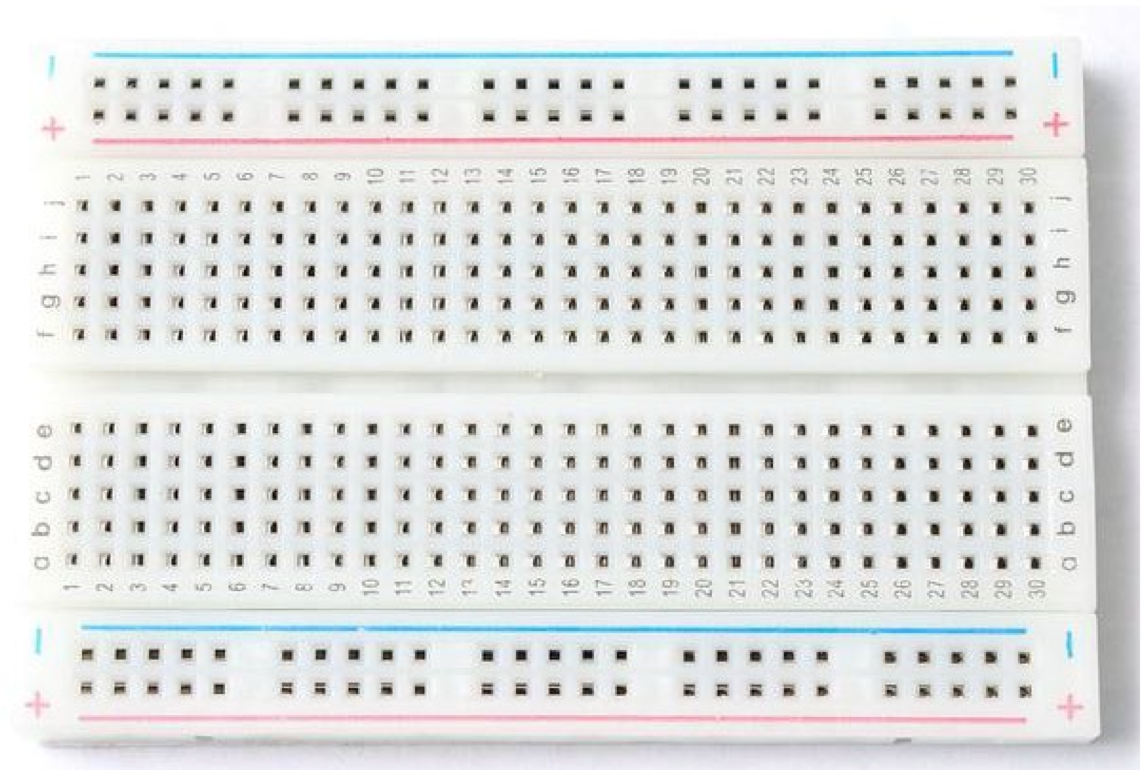


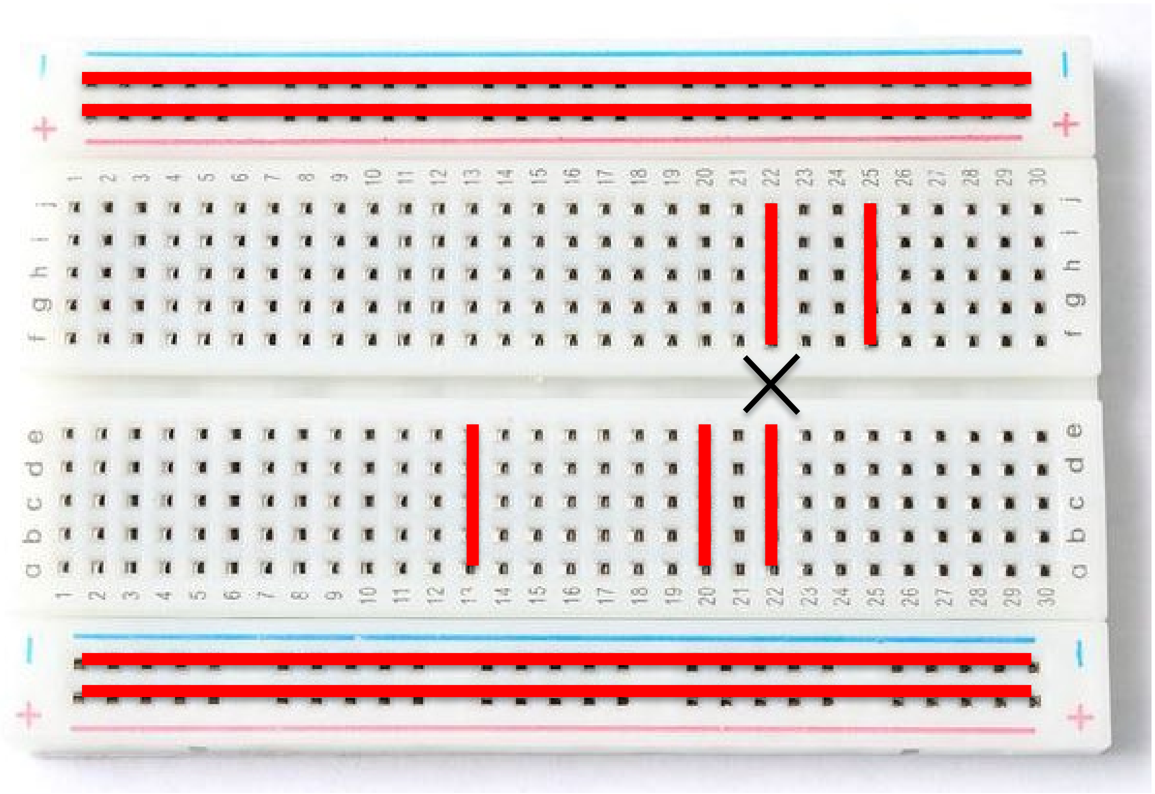
Figure PL1.3

Breadboard Circuits

- Proto-board
  - ‘Bread-board’



Breadboard Circuits



Proto-board wiring

- Short wires
- Short legs
- Clear and Clean