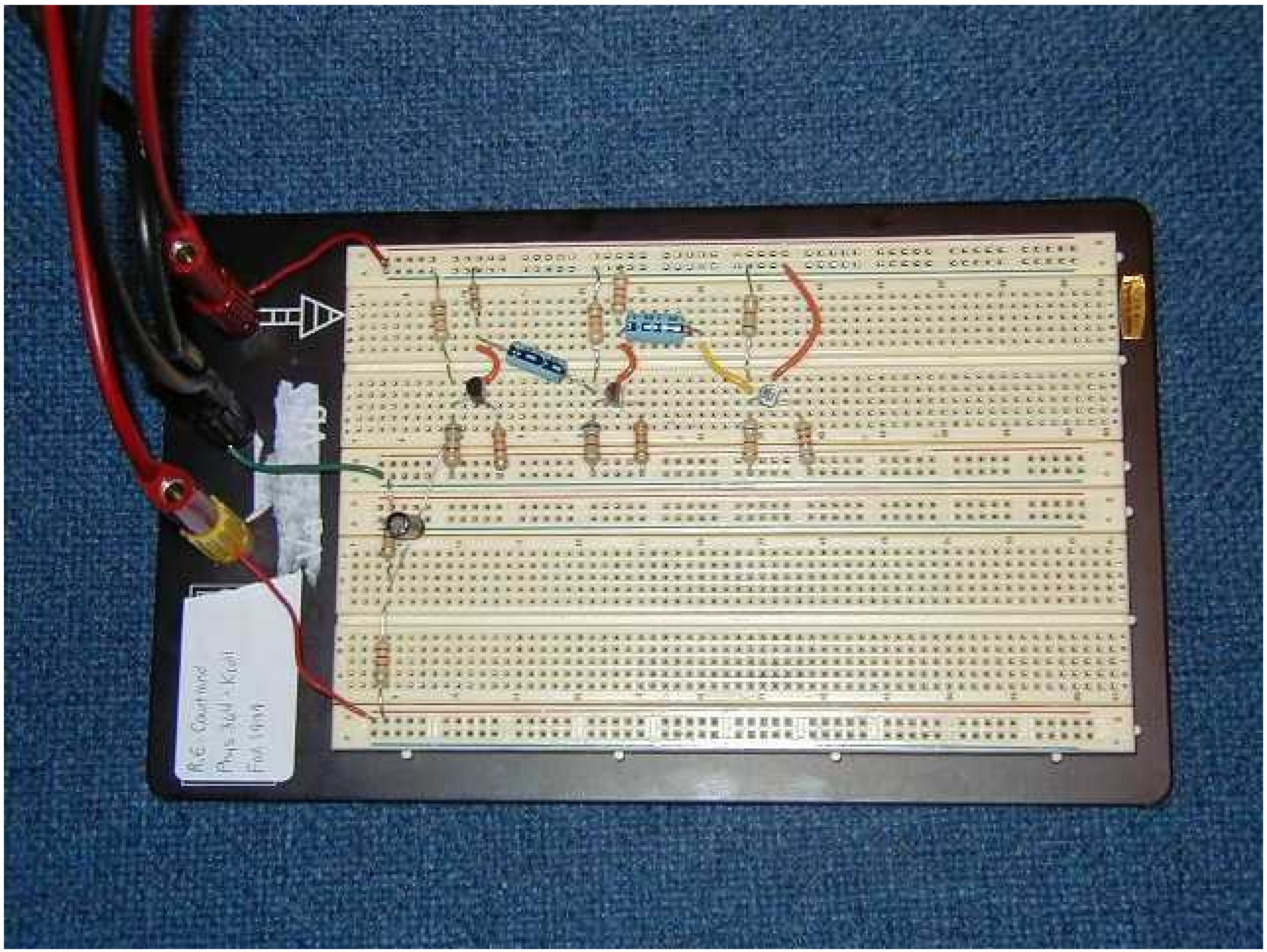
Physics 364 – Fall 2010



~~Lectures: M,W 2:00-3:30~~
~~Lab: M 5:00-9:00~~

Lecture: M 2:00-3:00
Lab: Mon,Thu 5:00-9:00

Instructor:
Bill Ashmanskas

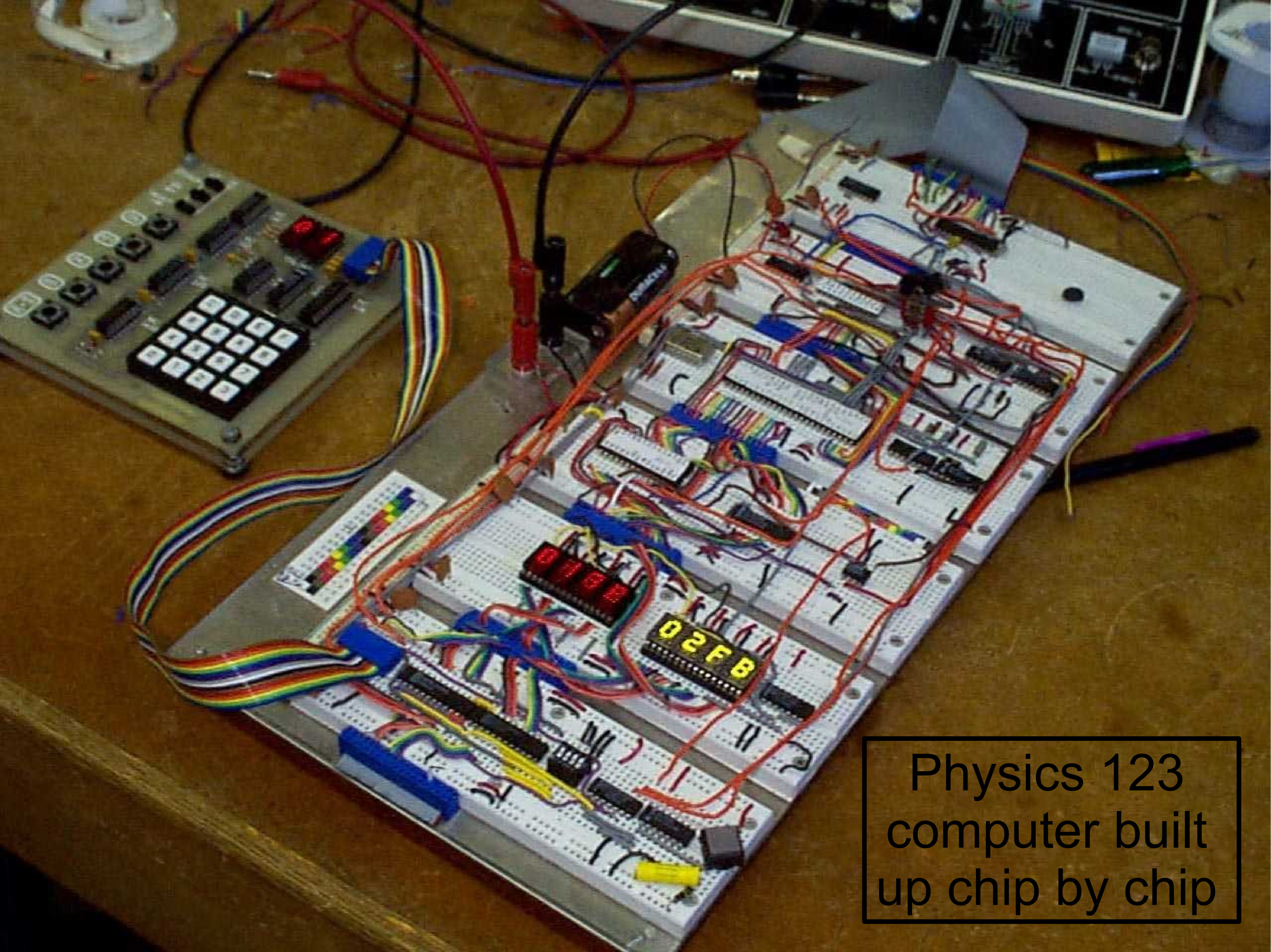
Lab Instructor:
Jose Vithayathil

Goal: fun & useful course

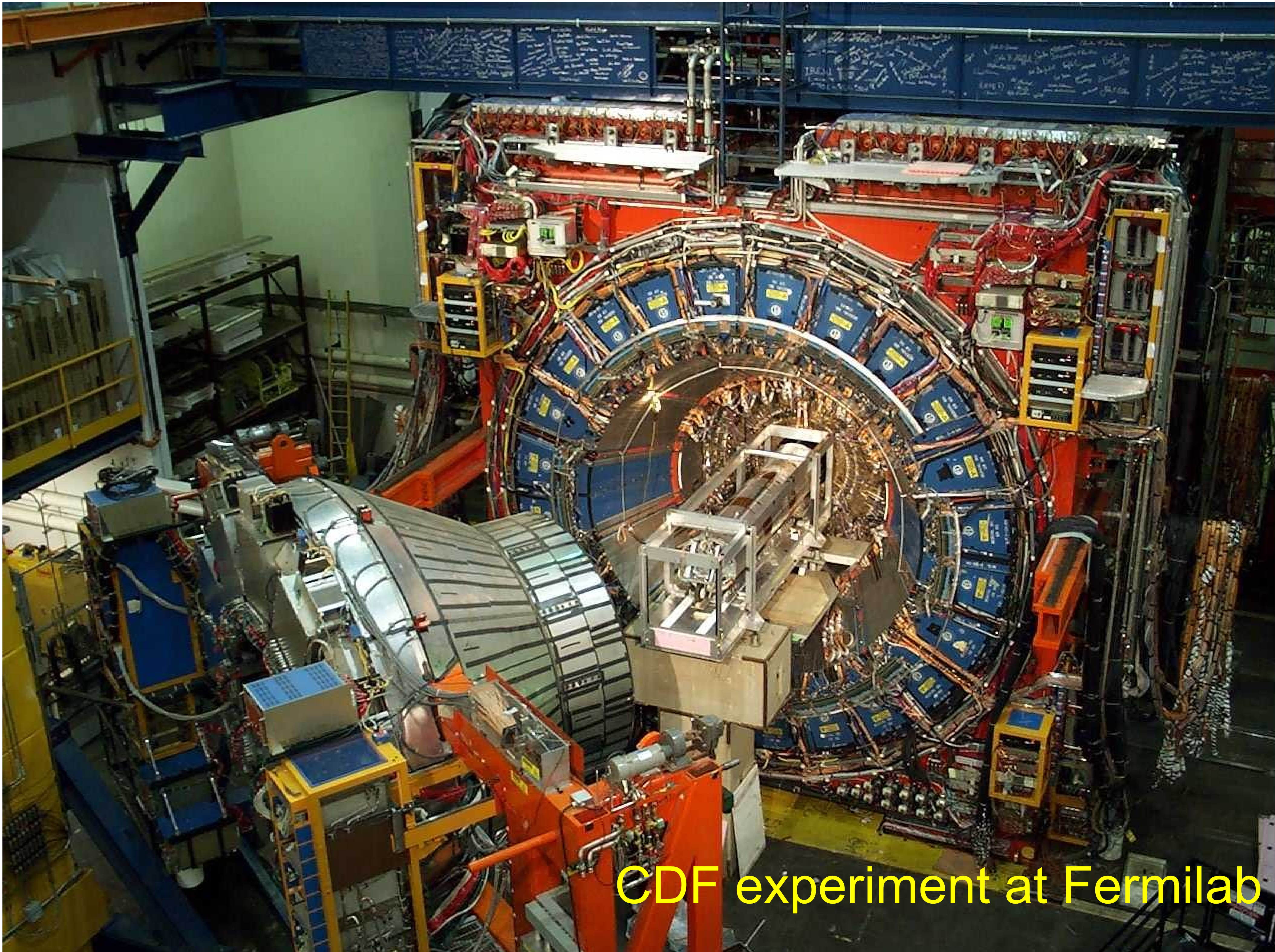
- understand what electronics is good for
- know how to use common components & instruments: oscilloscope, op-amp, ADC/DAC, digital logic, ….
- know enough to be confident learning more on your own
- know how to build solutions to lab/project problems you may encounter later in your career
- enjoy time spent in lab -- change of pace
- develop your debugging skills

Who am I?
Why am I here?

- Was student in 1991 Horowitz/Hill/Hayes electronics course ("physics 123") at Harvard.
  - It's so much fun that MIT students cross-register!
- Was teaching assistant in 1992 for similar course at U.C. Berkeley
  - UCB course put less emphasis on fun, regrettably, but I enjoyed helping students debug circuits
- Have spent most of my 12 years since Ph.D. doing physics-related instrumentation ....
- Prof. Kroll arranged for me to teach P364 during his sabbatical



Physics 123 computer built up chip by chip

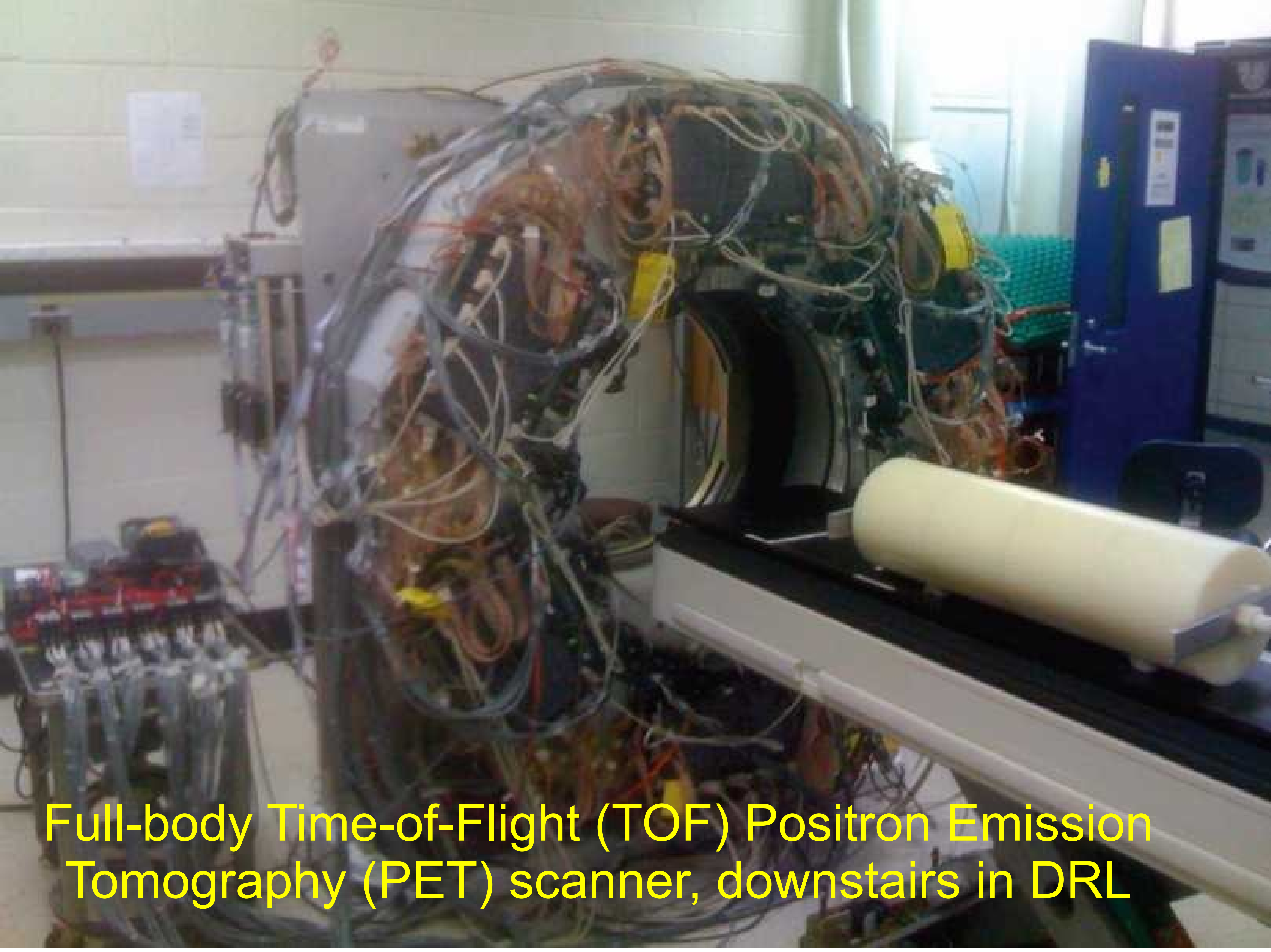

CDF experiment at Fermilab

Reduces gigabytes/second to megabytes/second

Peak (avg): 20 (0.5) GB/s ⟶ 100 (1.5) MB/s


x 3
THE UNIVERSITY OF CHICAGO

Fermilab accelerator complex, about 30 miles west of Chicago


Full-body Time-of-Flight (TOF) Positron Emission
Tomography (PET) scanner, downstairs in DRL

- To a large degree, pace of experimental science is set by progress in instrumentation
  - Example: the LHC is about to open a new window into the physics of weak interactions, dark matter, ...
- Electronics is a key component of instrumentation:
  - recording physical phenomena for analysis;
  - manipulating beams, telescopes; ....
- To be a good experimenter, it can be a big help to be comfortable with electronics
- Even if you're not an experimenter, part of the joy of being a physicist is understanding how things work, to decompose things to building blocks
  - I think this curiosity can encompass both natural phenomena and human-made gadgets

Syllabus – what I aim to cover

- Ohm, Kirchoff, voltage dividers, equivalent circuits, input & output resistance; lab intro; LTspice; diodes
- impedance (complex), filters, frequency domain; transformer, diode rectification, power supply
- op amps, feedback; applications; limitations
- transistors (bipolar junction), transistor amplifiers
- FETs, analog switches, sample & hold
- binary numbers, digital representation, sampling, using ADC and DAC in LabView
- digital logic, CMOS gates, logic families, combinational logic

Syllabus – continued

- flip-flops, counters, shift registers, other basic sequential logic
- RAM, FSM, microprocessor (concept anyway), programmable logic
- ADCs, DACs
- final projects
- if time/interest:
    - noise, interference, grounding/shielding
    - phase-locked loops, frequency modulation
    - synthesizer, mixer, heterodyne receiver
    - microcontrollers
    - data buses, parallel & serial interconnects

Grading

35% – lab write-ups (do ~ 90% in lab)

35% – weekly homework problems, SPICE simulations, etc.

15% – reading quizzes (start of lecture) or online questions (day before lecture)

15% – final project

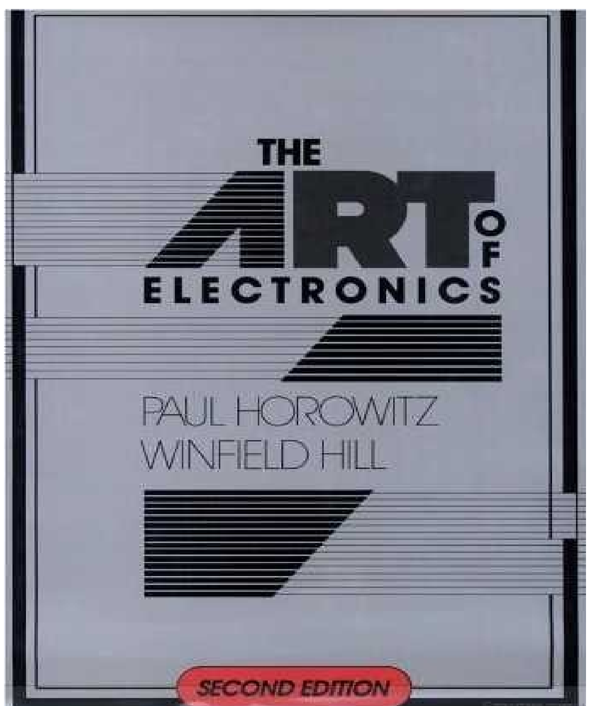
no exams

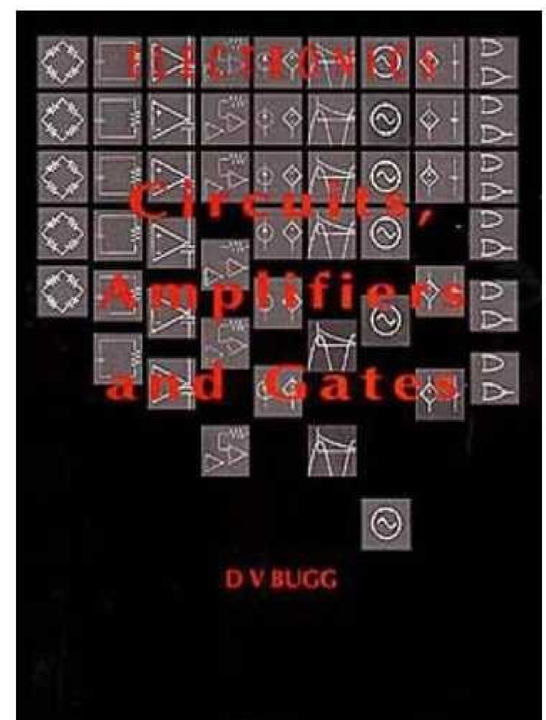
no cramming – need to keep up week by week

no stress – but lots of material to cover

Textbook

- If it existed already, we would probably use the 3rd edition of Horowitz & Hill, due out next year or so
  - HH is a handy reference to keep on one's shelf, but the 2nd edition is 20 years old now
- Instead, I bought a dozen used copies of D.V. Bugg's book, <u>1st edition</u>, online – will loan out for semester





Labs

- First lab will be Monday evening, 9/13, 5-9pm.
  - measuring I vs. V; voltage dividers; lab instruments; diodes as nonlinear circuit elements
- If you have a notebook computer, it may be helpful to bring it on Monday:
  - take lab notes using whatever program you prefer
  - I can help you to download & install LTspice
    - runs natively on windows
    - works well under WINE on Linux
    - can be made to run on Mac using WINE or in virtual machine
- USB memory stick will be helpful for using the lab's built-in PCs
-

Important scheduling question!

- Thursday evening lab time slot is also available

- I think you will learn far more from time in lab than from lectures
  - actively building and debugging circuits with instructor(s) and lab partners
    - vs.
  - passively listening to lectures

- If everyone agrees, we can do 2 labs + 1 lecture per week instead of 1 lab + 2 lectures.
  - Decide by consensus 1~2 weeks from now

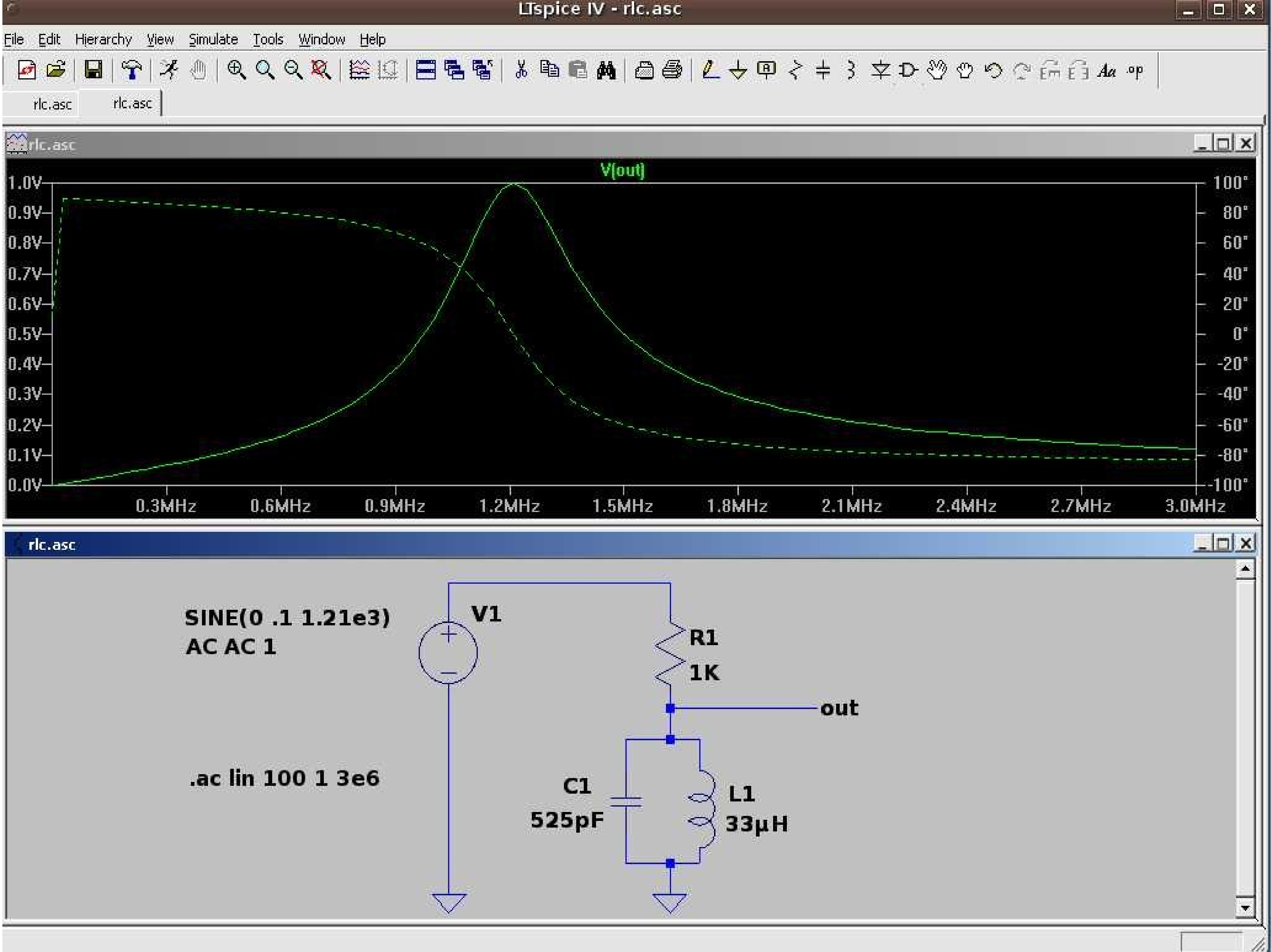
First assignment

- You will find Chapter 1 of Horowitz & Hill on the course Blackboard site
  - Read pages 1—20 (first half of chapter)
- Also read Bugg ch1, ch2, and sections 9.1-9.4
- Read all of this before Monday's lecture

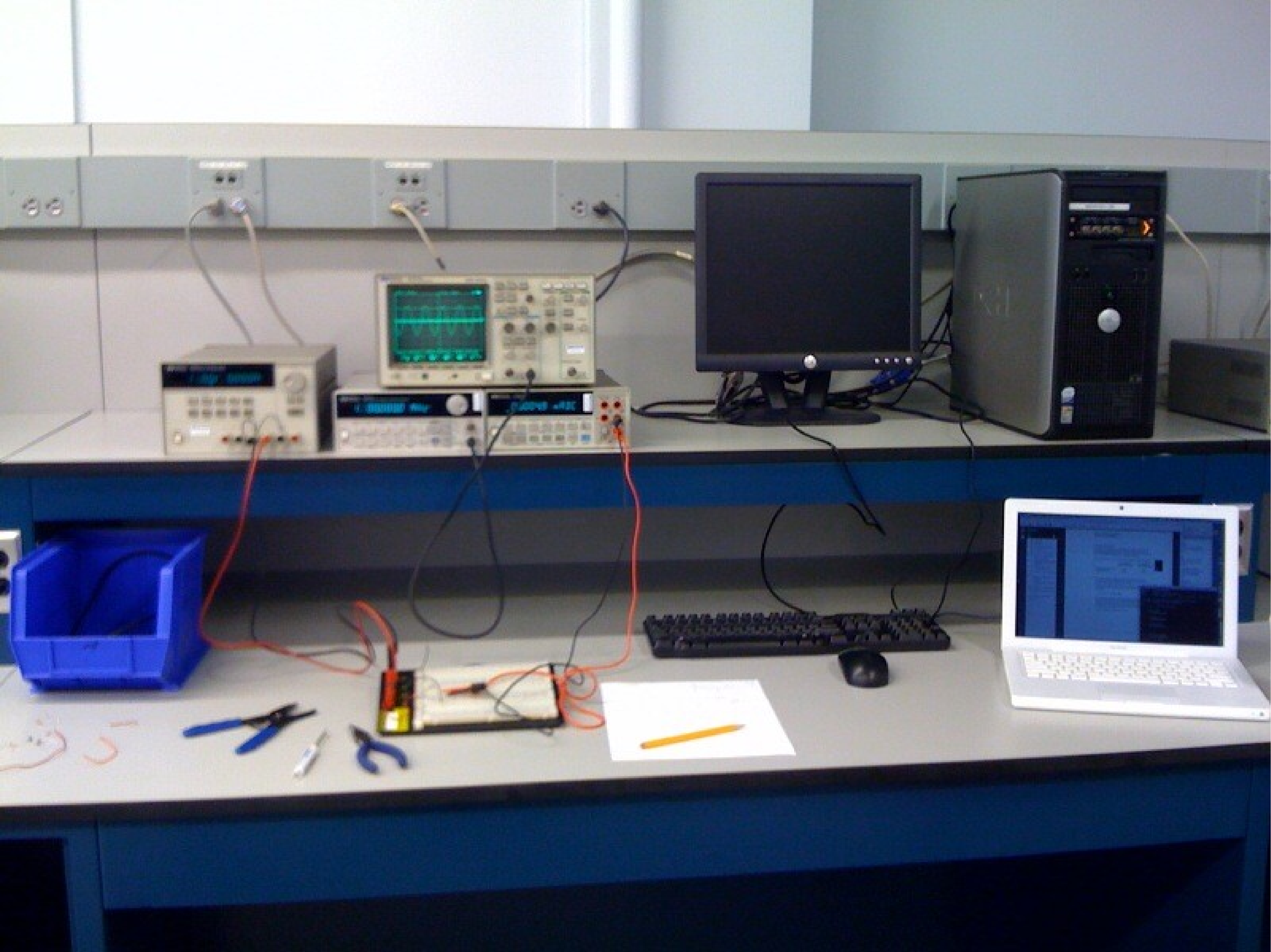
- Homework #1 – on blackboard site, due at start of next Wednesday's lecture
  - If you've done the reading, the homework should take you less than an hour

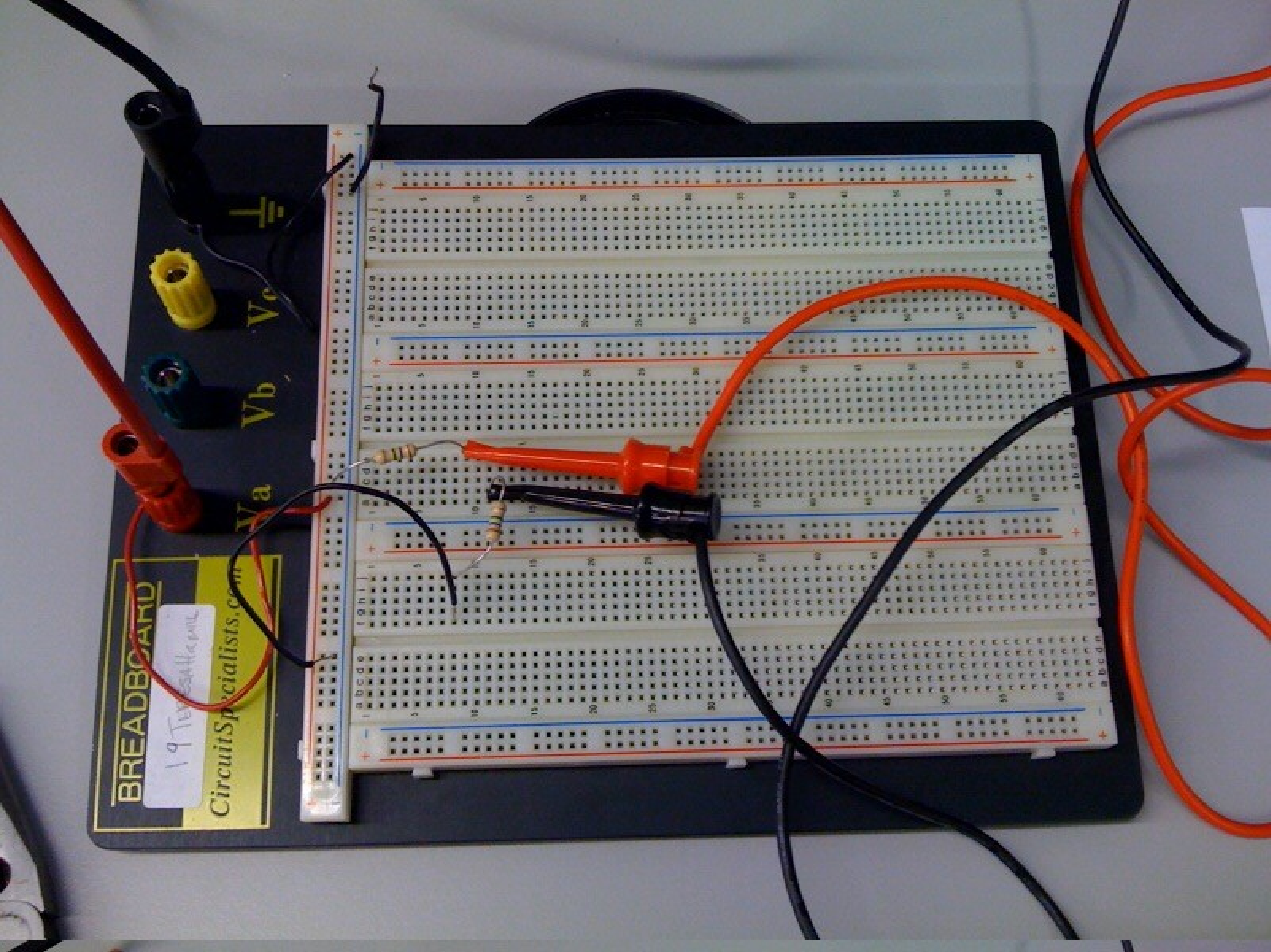
Open ended

- Poll – what do you want to learn in this course?
  - What do you already know about electronics?
- LTspice demo
- Radio demo?
- Content of lab reports


LTspice IV - rlc.asc
File Edit Hierarchy View Simulate Tools Window Help
rlc.asc
rlc.asc
rlc.asc
V(out)
1.0V
0.9V
0.8V
0.7V
0.6V
0.5V
0.4V
0.3V
0.2V
0.1V
0.0V
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
-100°
0.3MHz
0.6MHz
0.9MHz
1.2MHz
1.5MHz
1.8MHz
2.1MHz
2.4MHz
2.7MHz
3.0MHz
rlc.asc
SINE(0 .1 1.21e3)
AC AC 1
V1
R1
1K
out
.ac lin 100 1 3e6
C1
525pF
L1
33µH

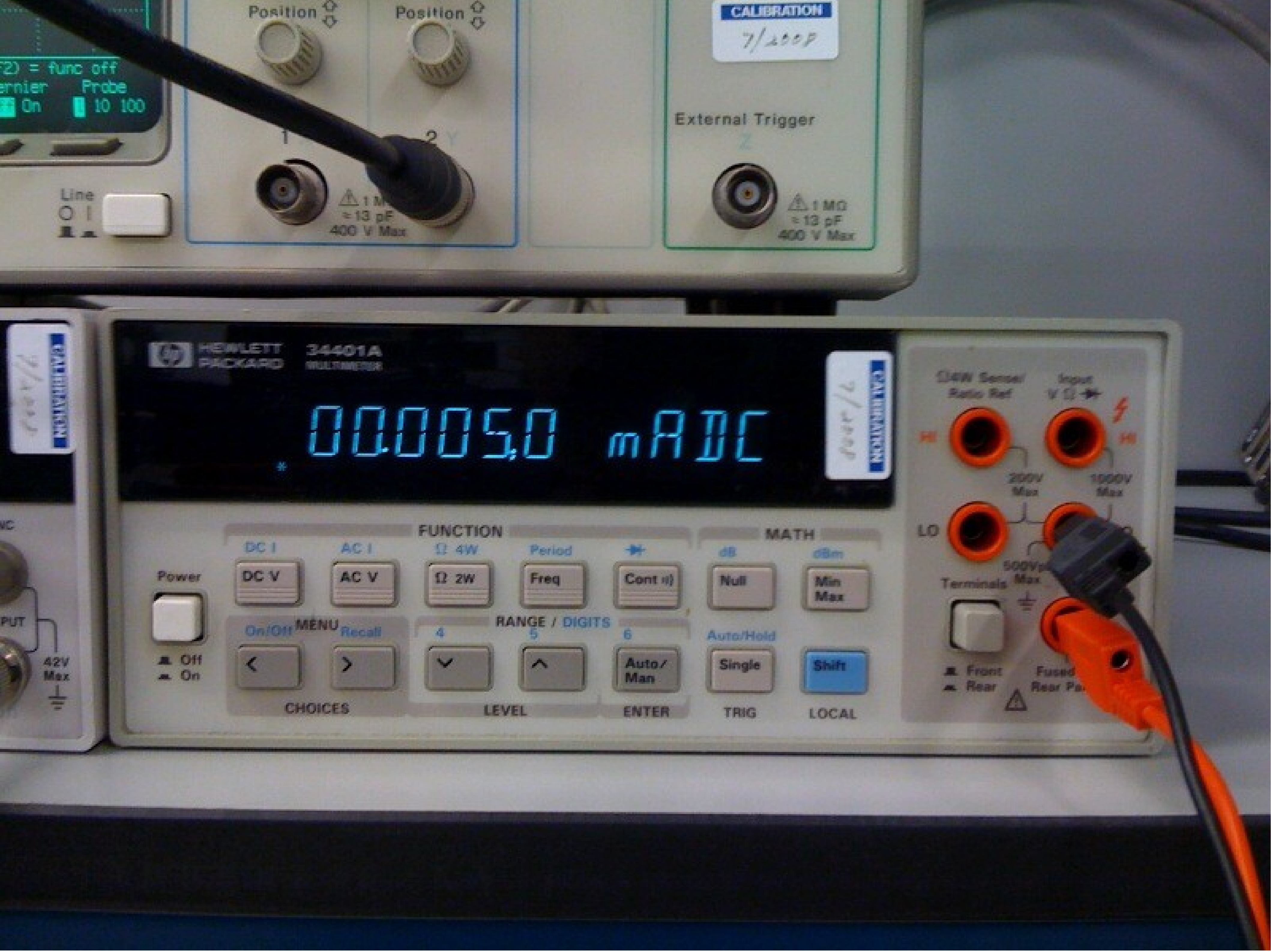
- voltage (potential), current, ohm's law
- kirchoff's laws – conservation of energy, charge
- series, parallel reductions – eqns seldom necessary
- tricks: r+R~R, r//R~r, R||R=R/2, R||(R/2)=R/3
- voltage divider (ubiquitous)
- model “black box” signal sources with thevenin (or norton) equivalents
  - leads to *output resistance* concept (later, *impedance*)
  - can the source easily drive the load? or does the load cause the source to droop?
    - later, see how to fix this with *buffer amplifier*
- diode: example of non-ohmic device
  - often taylor expand → quiescent + small signal



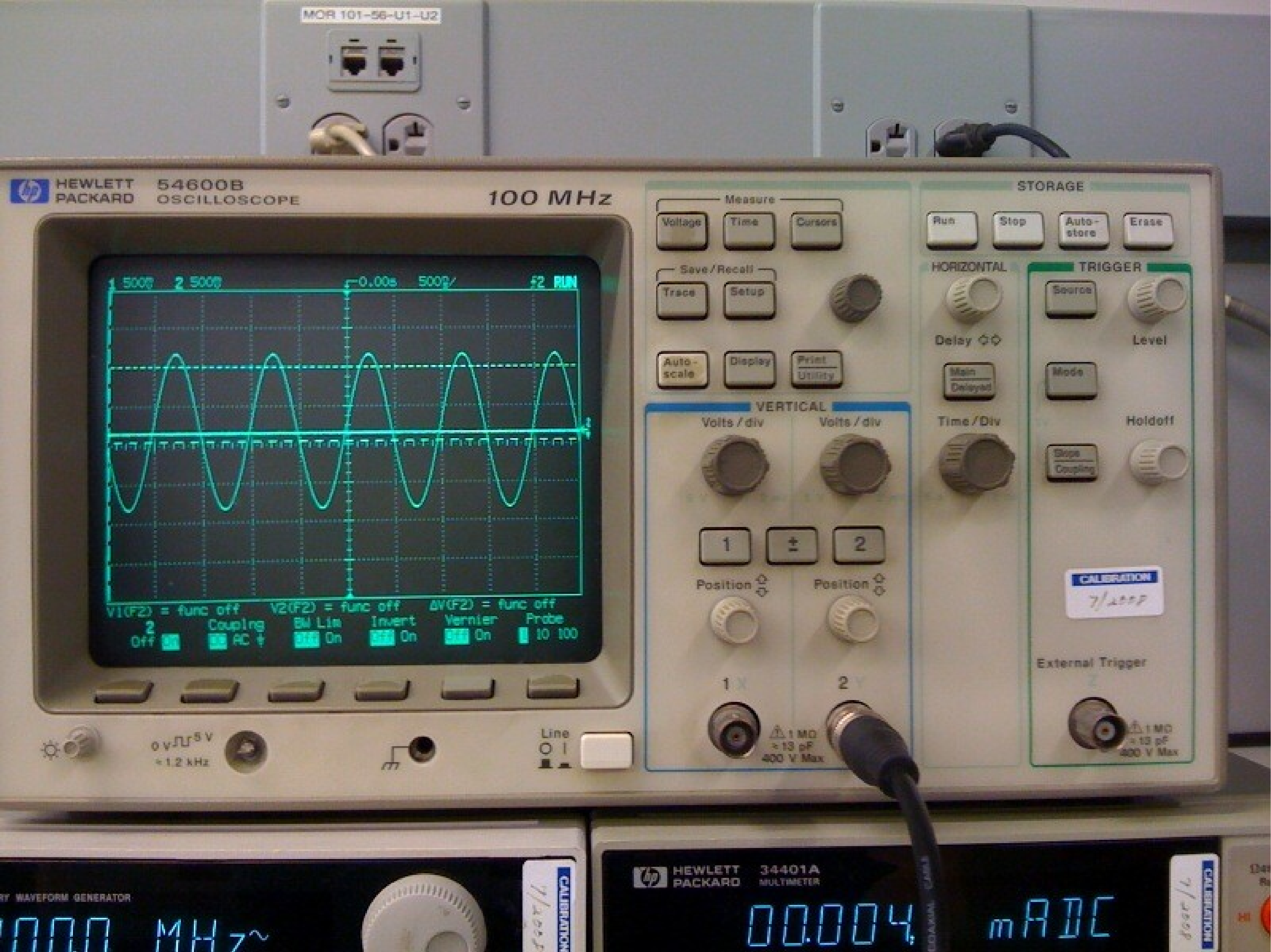


Vc
Vb
Va
BREADBOARD
CircuitSpecialists.com


HEWLETT PACKARD
E3631A 0-6V,5A/0-±25V,1A
TRIPLE OUTPUT DC POWER SUPPLY
16.00V 0.000A CV
+25V
ADJUST
FUNCTION
SELECT
+6V
+25V
−25V
Track
Display Limit
Recall
Store
Error
I/O Config
Output On/Off
Local
Calibrate
Secure
Voltage
Current
CALIBRATION
7/2008
Power
On
Off
6V
+
−
±25V
COM
+
−

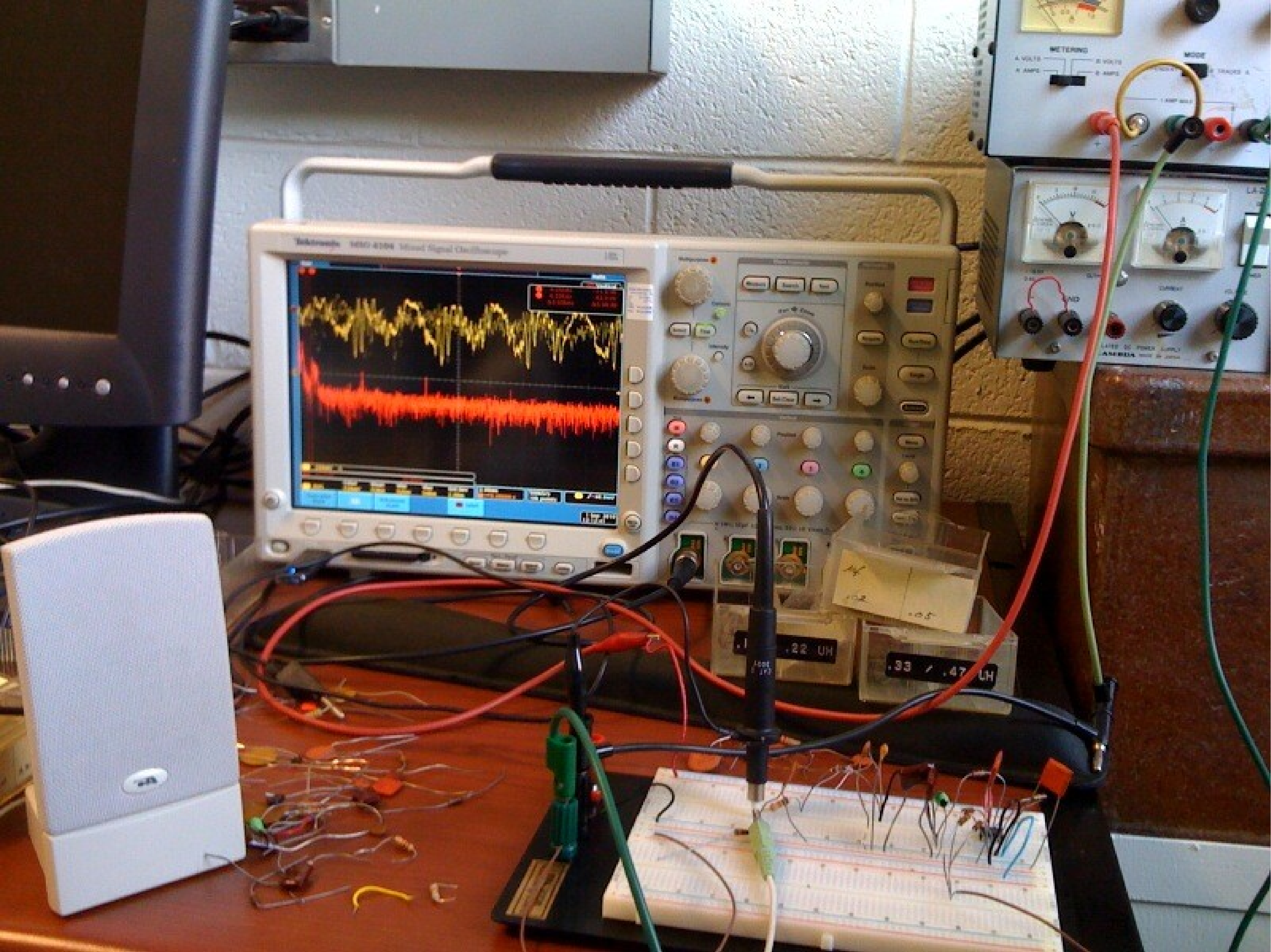

Position
Position
CALIBRATION
External Trigger
400 V Max
Line
HEWLETT PACKARD
34401A
00.0050 mADC
FUNCTION
DC I
AC I
Ω 4W
Period
DC V
AC V
Ω 2W
Freq
Cont
MATH
dB
dBm
Null
Min Max
Power
Off
On
On/Off
MENU
Recall
RANGE / DIGITS
4
5
6
Auto/ Man
Auto/Hold
Single
Shift
CHOICES
LEVEL
ENTER
TRIG
LOCAL
Input
HI
LO
200V Max
1000V Max
Terminals
Front
Rear

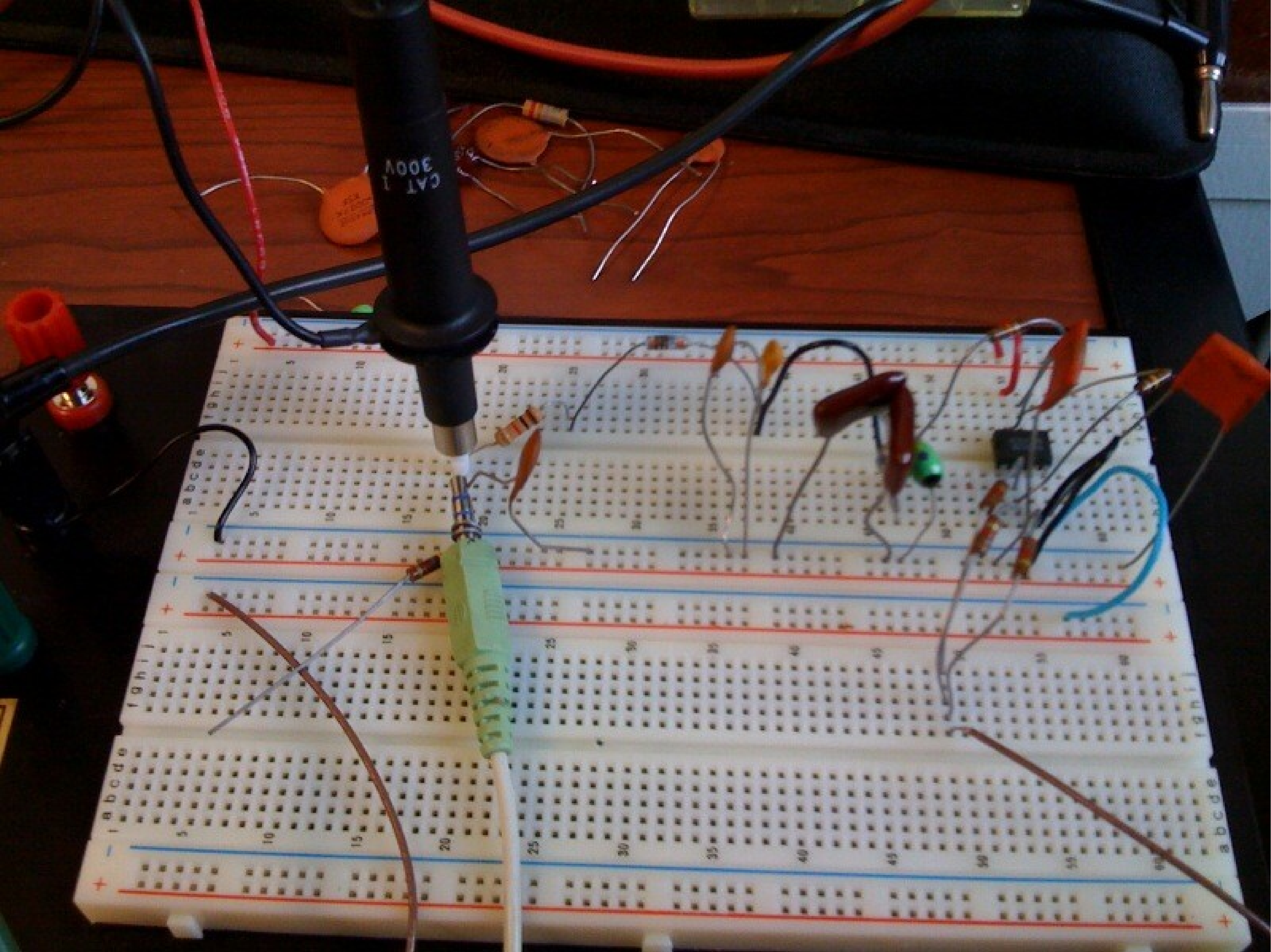

HEWLETT PACKARD
33120A
15 MHz FUNCTION / ARBITRARY WAVEFORM GENERATOR
1.000,000,0 MHz
FUNCTION / MODULATION
AM
FM
FSK
Burst
Sweep
Arb List
Noise
Arb
MENU
On/Off
Enter
Power
Off
On
AM/FM
Freq
Level
% Duty
Internal
Store
Cancel
Freq
Ampl
Offset
Single
Recall
Enter Number
Shift
MODIFY
TRIG
STATE
LOCAL
MHz
m Vpp
kHz
m Vrms
Hz
dBm
Back Space
Recall Menu
SYNC
OUTPUT
CALIBRATION
Coupling
BW Lim
Invert
Vernier
Probe
Line


MOR 101-56-U1-U2
HEWLETT PACKARD
54600B OSCILLOSCOPE
100 MHz
STORAGE
Measure
Voltage
Time
Cursors
Run
Stop
Auto-store
Erase
Save/Recall
Trace
Setup
HORIZONTAL
TRIGGER
Source
Delay
Level
Auto-scale
Display
Print Utility
Main Delayed
Mode
VERTICAL
Volts/div
Volts/div
Time/Div
Holdoff
Slope Coupling
1
±
2
Position
Position
CALIBRATION
External Trigger
1 X
2 Y
1 MΩ ≈13 pF 400 V Max
Line
≈1.2 kHz
0.00s
RUN
V1(F2) = func off
V2(F2) = func off
ΔV(F2) = func off
Coupling
BW Lim
Invert
Vernier
Probe
Off
AC
On
On
On
10 100
WAVEFORM GENERATOR
MHz~
HEWLETT PACKARD
34401A MULTIMETER
00.004
mADC

1 K
1.5KΩ
3K
5.1 KΩ, 1/2 watt
5.6 KΩ
8.2 KΩ
12 KΩ
15 KΩ, 1/2 watt
20 KΩ, ½ Watt
27 KΩ
30 KΩ
47 KΩ
68 KΩ
100 KΩ 1/2 watt
150 KΩ, 1/2 watt
330 KΩ, 1/2 watt
470 KΩ, 1/2 watt
510 KΩ, 1/2 watt
POTENTIOMETER 1K
2kΩ Pot
POTENTIOMETER 20K
Potentiometer 50KΩ
POT 1 MΩ


240 KΩ
watt


METERING
MODE
.33 / .47 UH


CAT I 300V