HAM Radio Board of Education

NEVER STOP LEARNING

Antenna Summit

Sponsored by

Session 3 – Components

Chapter 4.1 to 4.5.6

+ Other Material

Instructor:

Phil Brunner – AE7OH (was K9DTD, W6GOL)

- ARRL HANDBOOK for Radio Communications
- – (Reference for detailed information)
- Q & A via Chat or at the end of each hour
- Email questions to: phil.brunner@gmail.com
- Viewgraphs are at http://HamRadioEdu.com

Chapter 4 – Components

- The World of electronics is changing rapidly
  - Landlines replaced by Cell Phone, Zoom, Skype
  - Vacuum Tubes Disappearing – (Light Bulbs, CRTs, Radio Tubes)
- Computers and DSPs are replacing individual components and units.
- Software Defined Radios are available today.
- We will concentrate on characteristics and skip the details!

Components Characteristics

- Practical Resistors, Capacitors and Inductors
- Transformers
- Semiconductors
- Amplifiers
- Vacuum Tubes

- Circuit Simulation and AnalysisTools
- Antennas and Tuners
- Software Defined Radios and Units

Starting Big - 112-foot

112-foot Goldstone Deep Space Antenna
with Subreflector

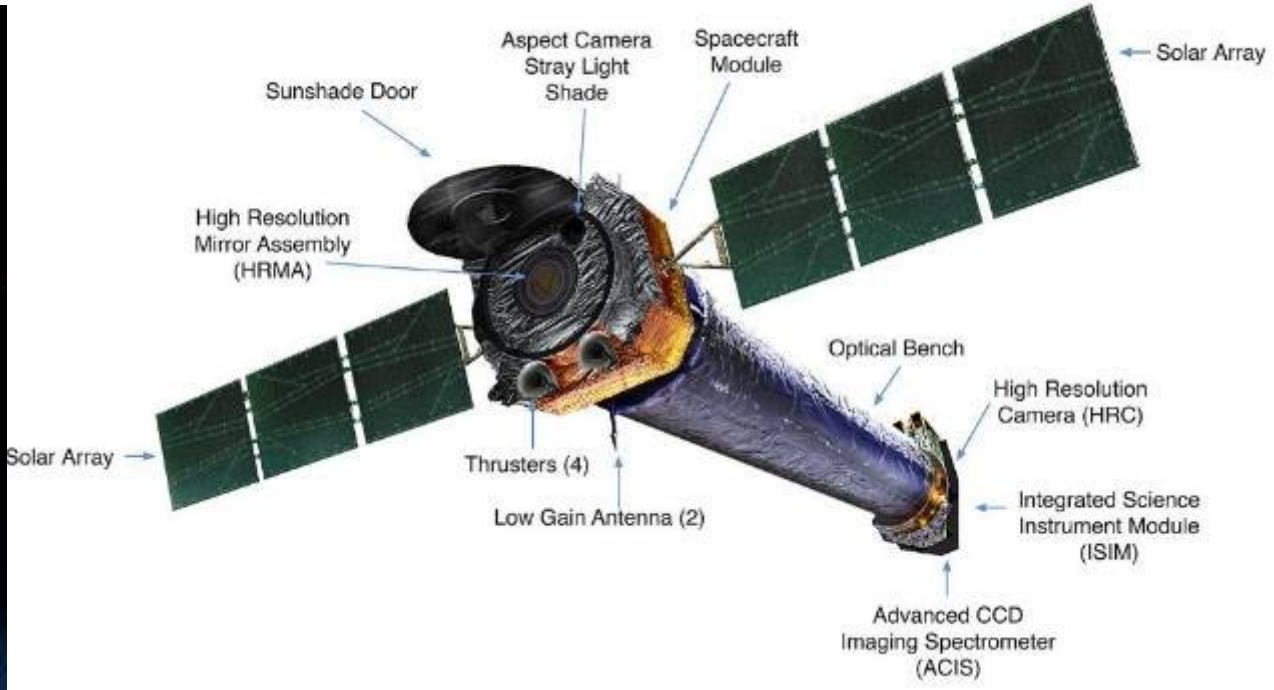
Satellite Antennas

Defense Support Program

https://en.wikipedia.org/wiki/Defense_Support_Program

Chandra Xray Telescope

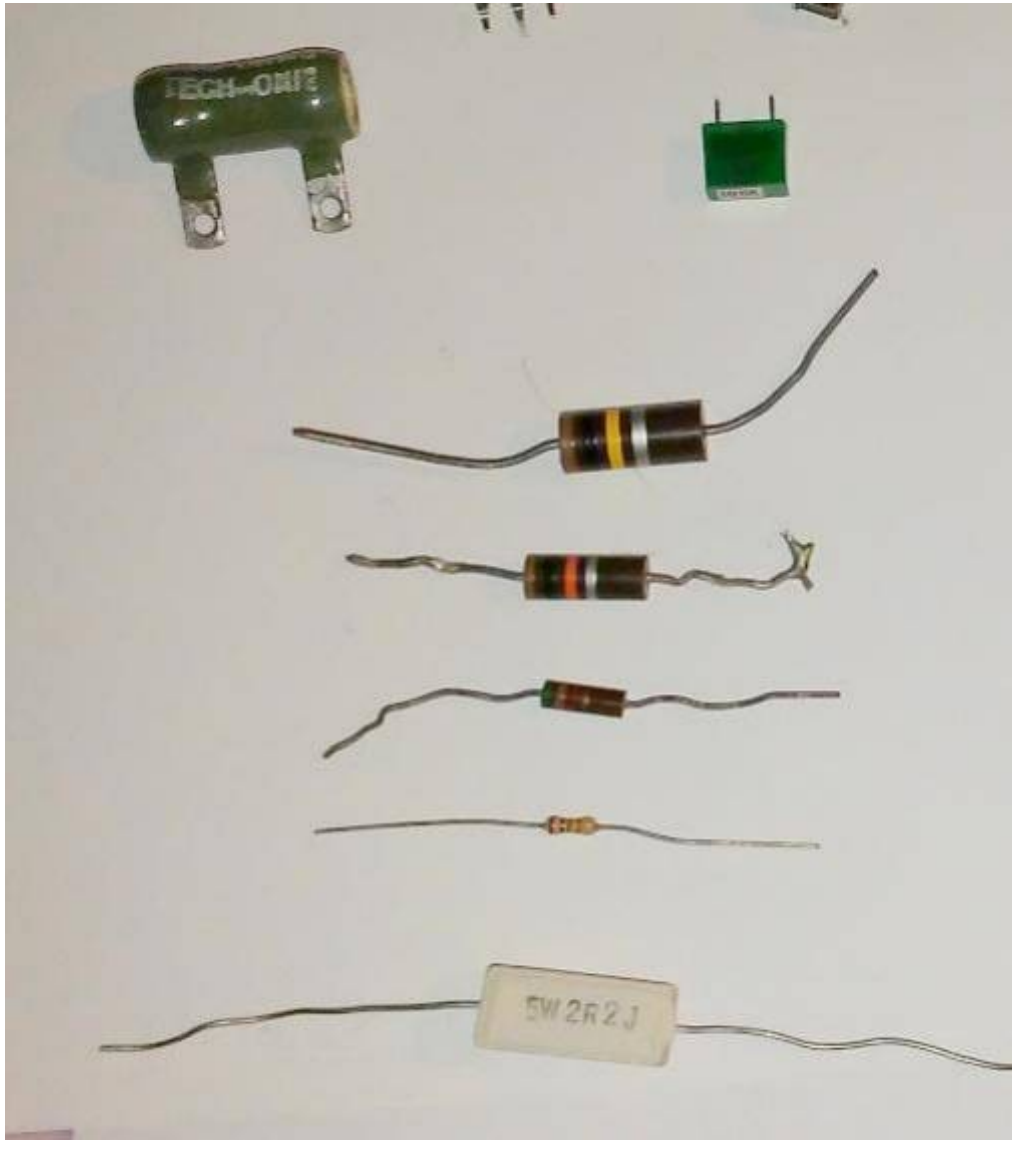
https://en.wikipedia.org/wiki/Chandra_X-ray_Observatory



Resistors

- Wire size suitable for max current
- Resistance usually increases with temperature
- Component Resistors
  - Carbon, Metal-oxide
  - Wirewound- low-frequency due to inductance
  - Metal-film, Carbon-film – deposit on insulating substrate
- Power rating and temperature stability are considerations
- Tolerance often unimportant – 20%, 10%, 5%, 1%
- Potentiometers – variable resistors

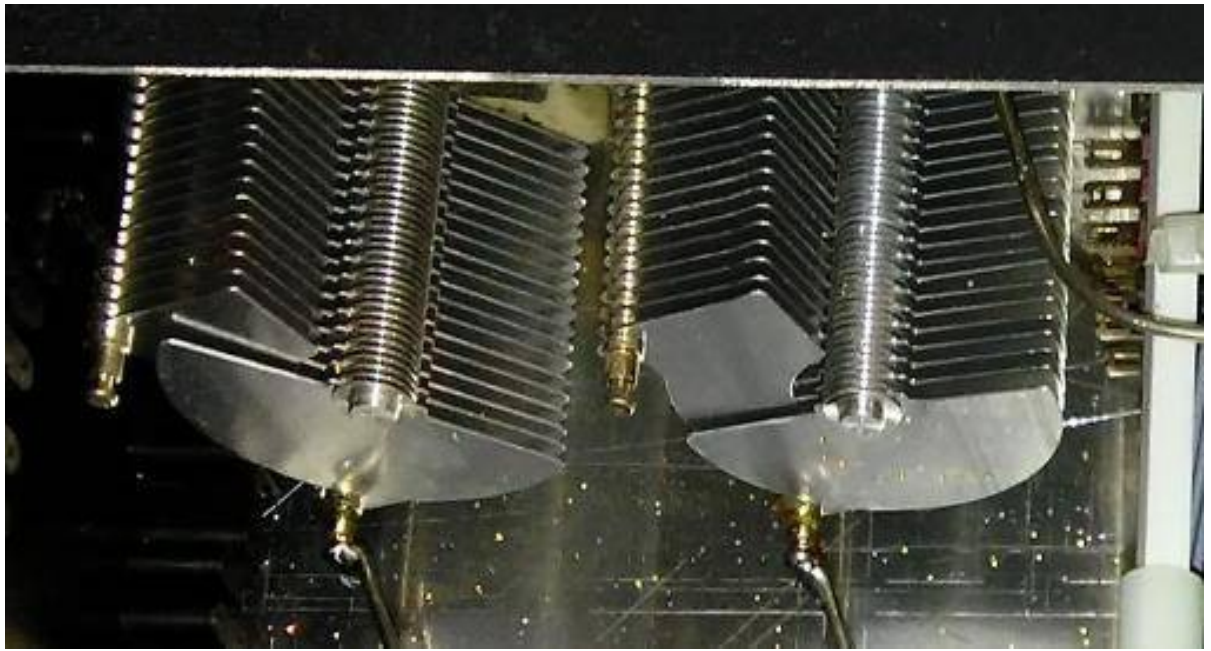
Resistors

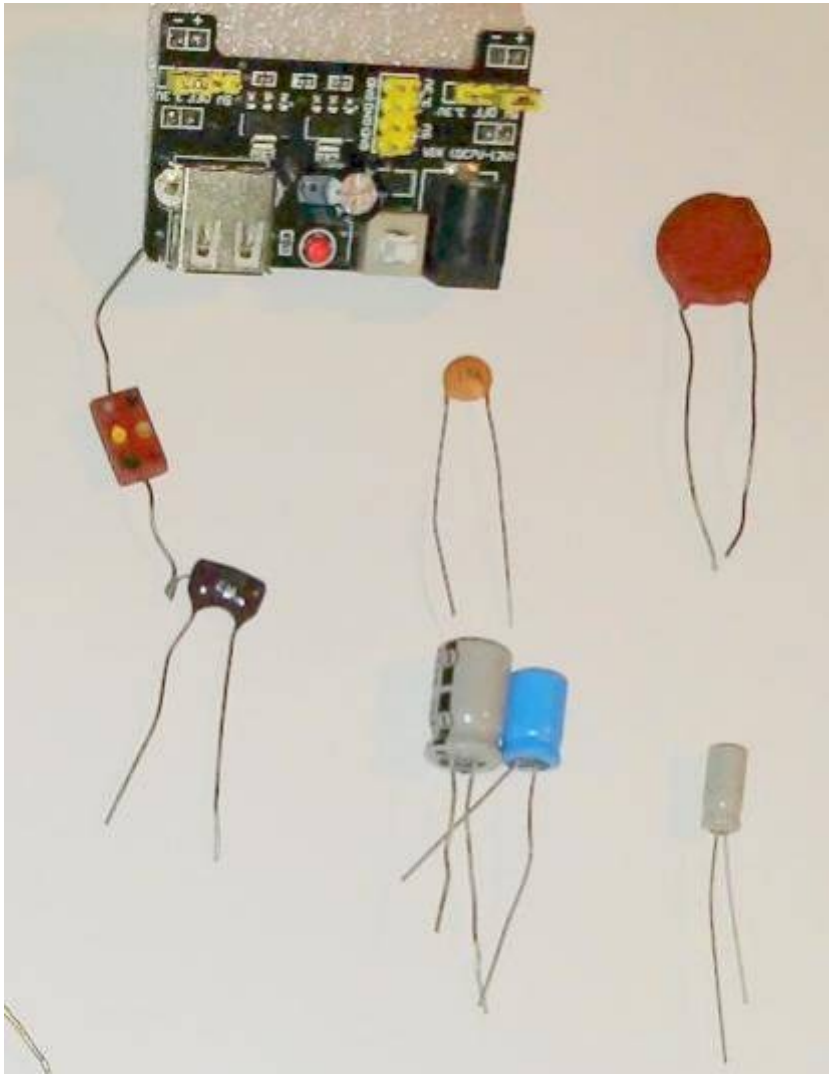


Capacitors

- Ideally blocks DC, no leakage, no energy loss
- Tolerance and temperature coefficient
- Voltage rating and breakdown
- Frequency, resistance, leakage, inductance considerations
- Ceramic, plastic film, mica, electrolytic, air-variable, vacuum
- Electrolytics are high capacity and polarized - low frequency filtering

Capacitors

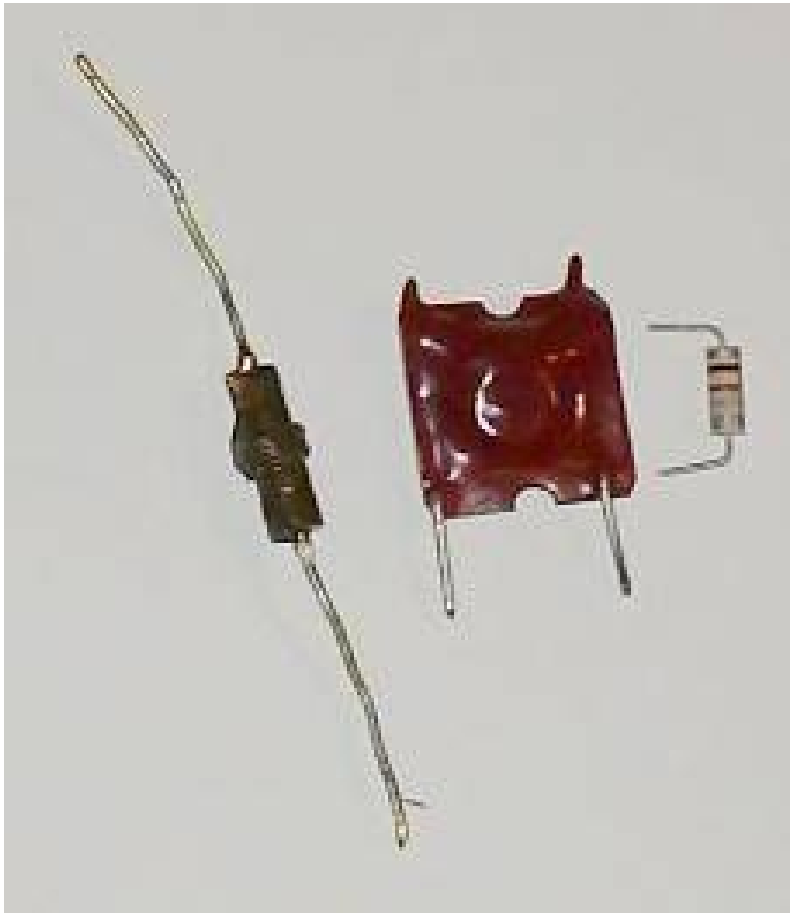


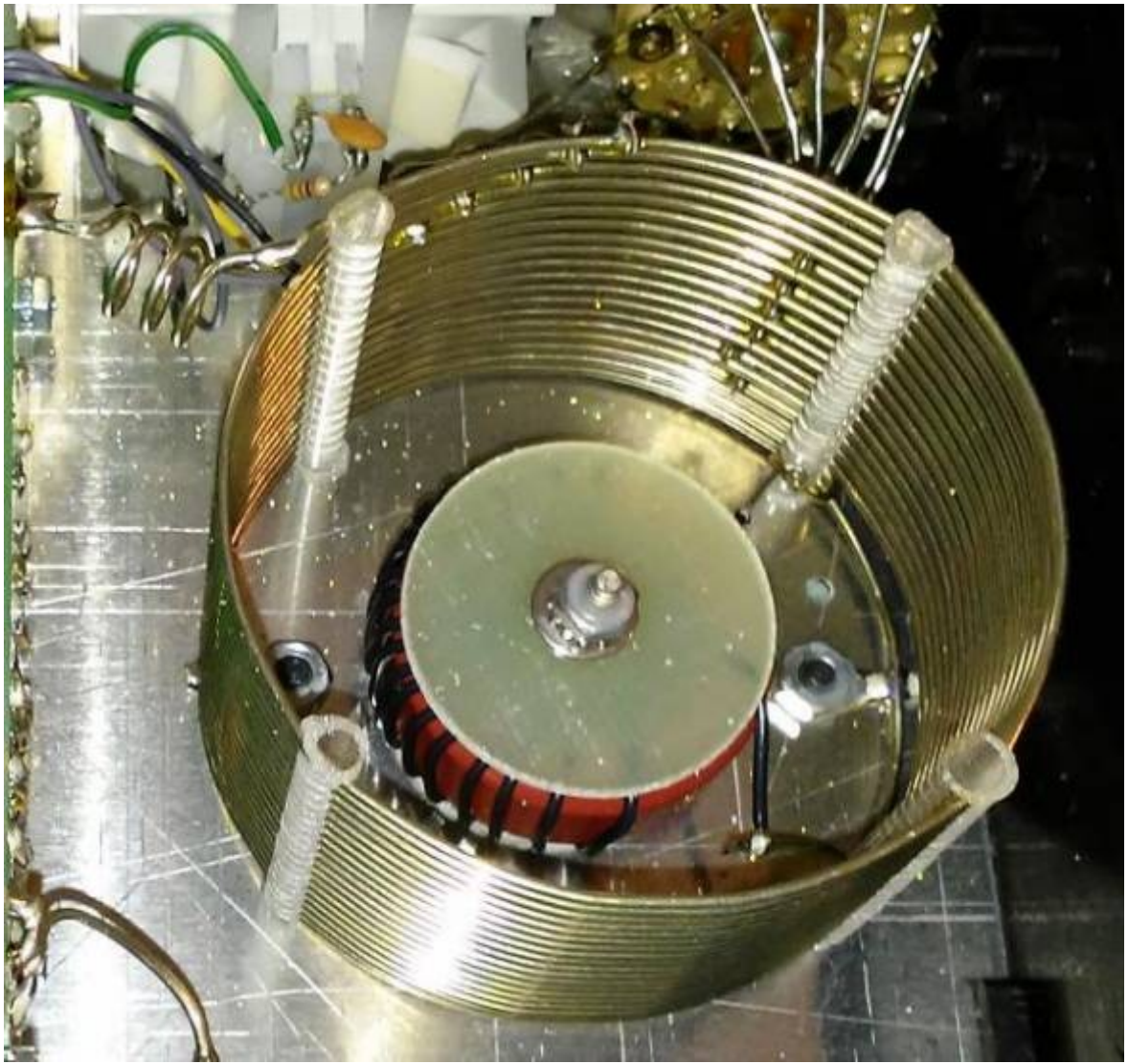


Inductors

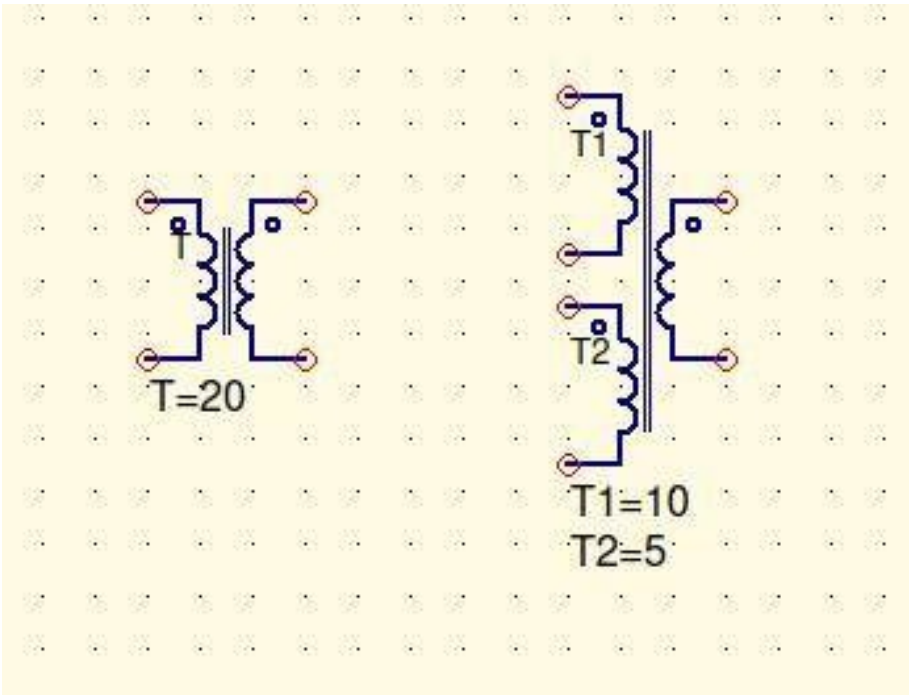
- Air-core or iron-core
- Encapsulated (looks like resistor)
- Slug tuned (variable)
  - magnetic or non-magnetic core inside coiled inductor
  - Adjust with screw-driver

Inductors



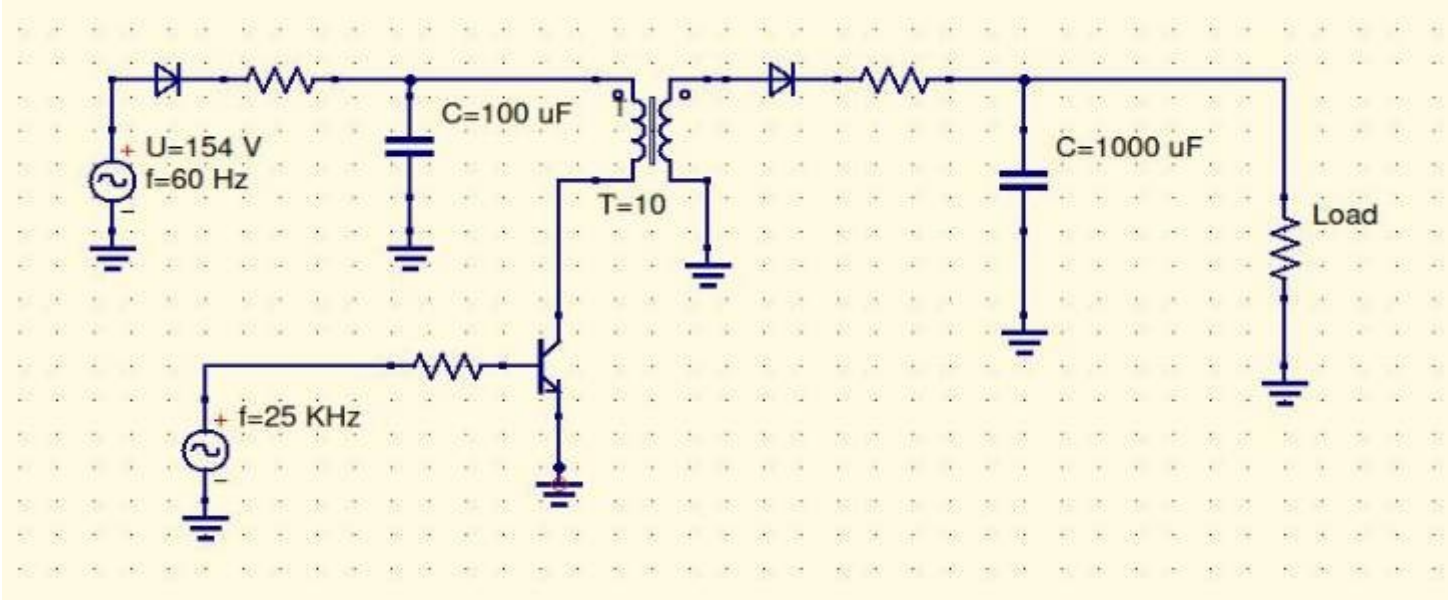


Transformers



Switching Power Supply (Conceptual)

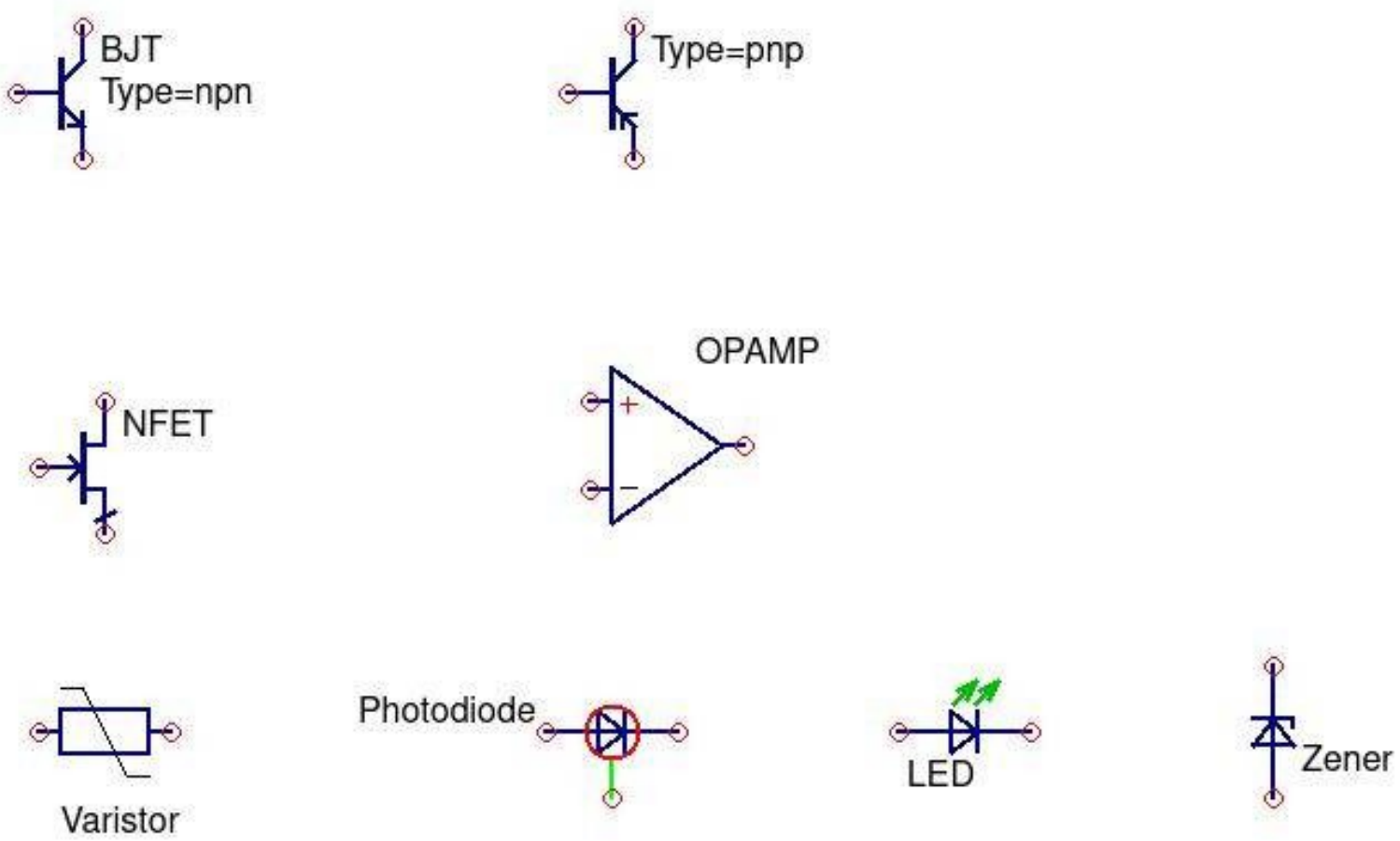
- Use high frequency to minimize transformer size/weight
- Needs careful design/shielding to avoid HF interference



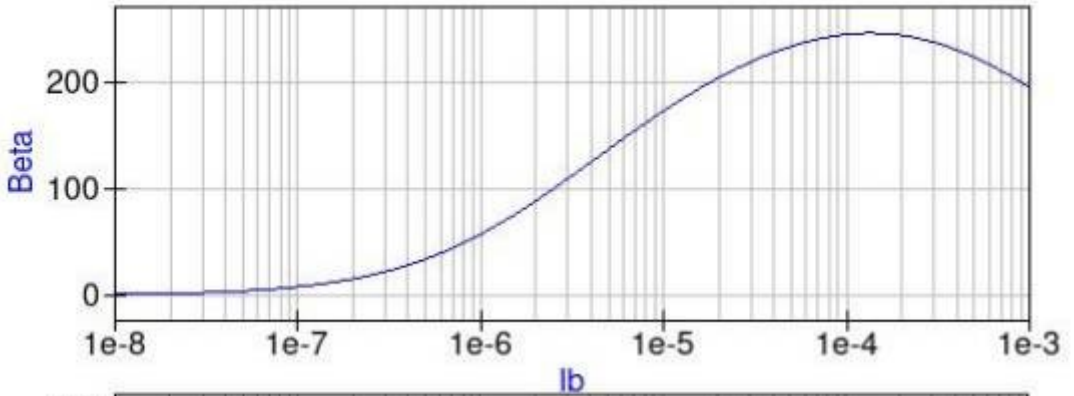
Semiconductors

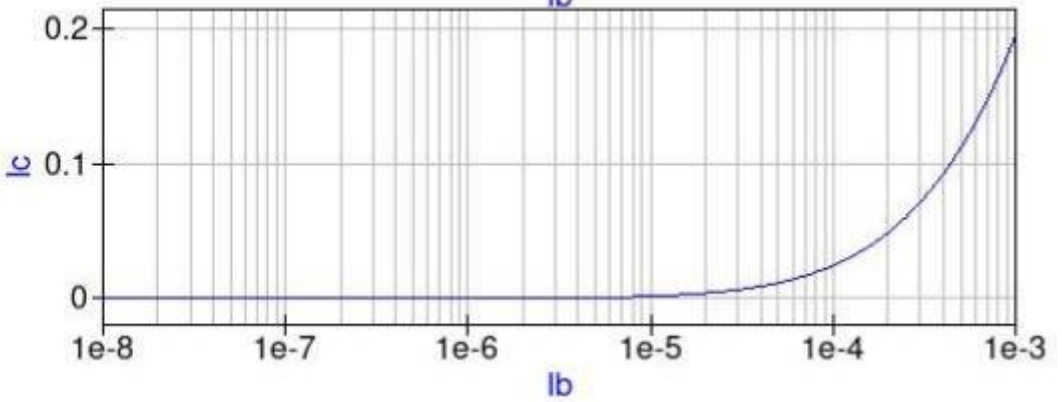
- Diodes – Point Contact, Pin, Schottky, Varactor, Zener
  - Current, PIV, Speed, Reverse Current
- Transistors – BJT, JFET, MOSFET
  - Gain, Operating Regions and Parameters
- Optical – Photo, LED, Laser, Optoisolators
- Fiber Optics

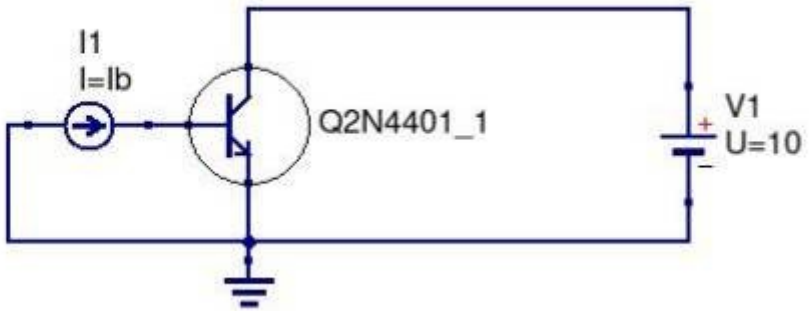
Some Semiconductor Symbols



NPN Amplifier







Equation

Eqn1
Ic=-V1.I
Beta=Ic/Ib

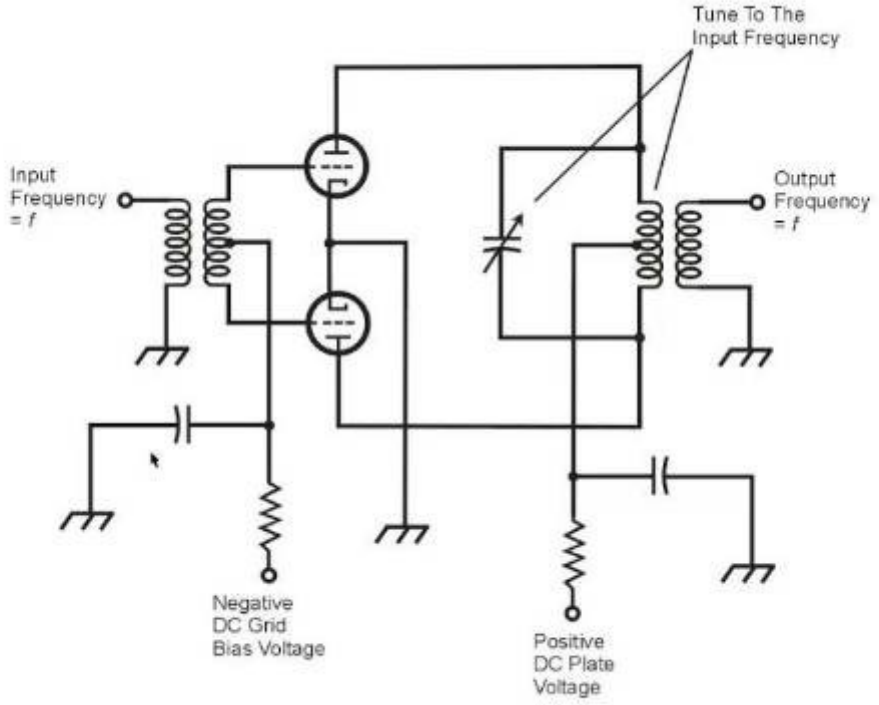
dc simulation

DC1

Parameter sweep

SW1
Sim=DC1
Type=log
Param=Ib
Start=10n
Stop=1 m

811A Vacuum Tube Push-Pull Final

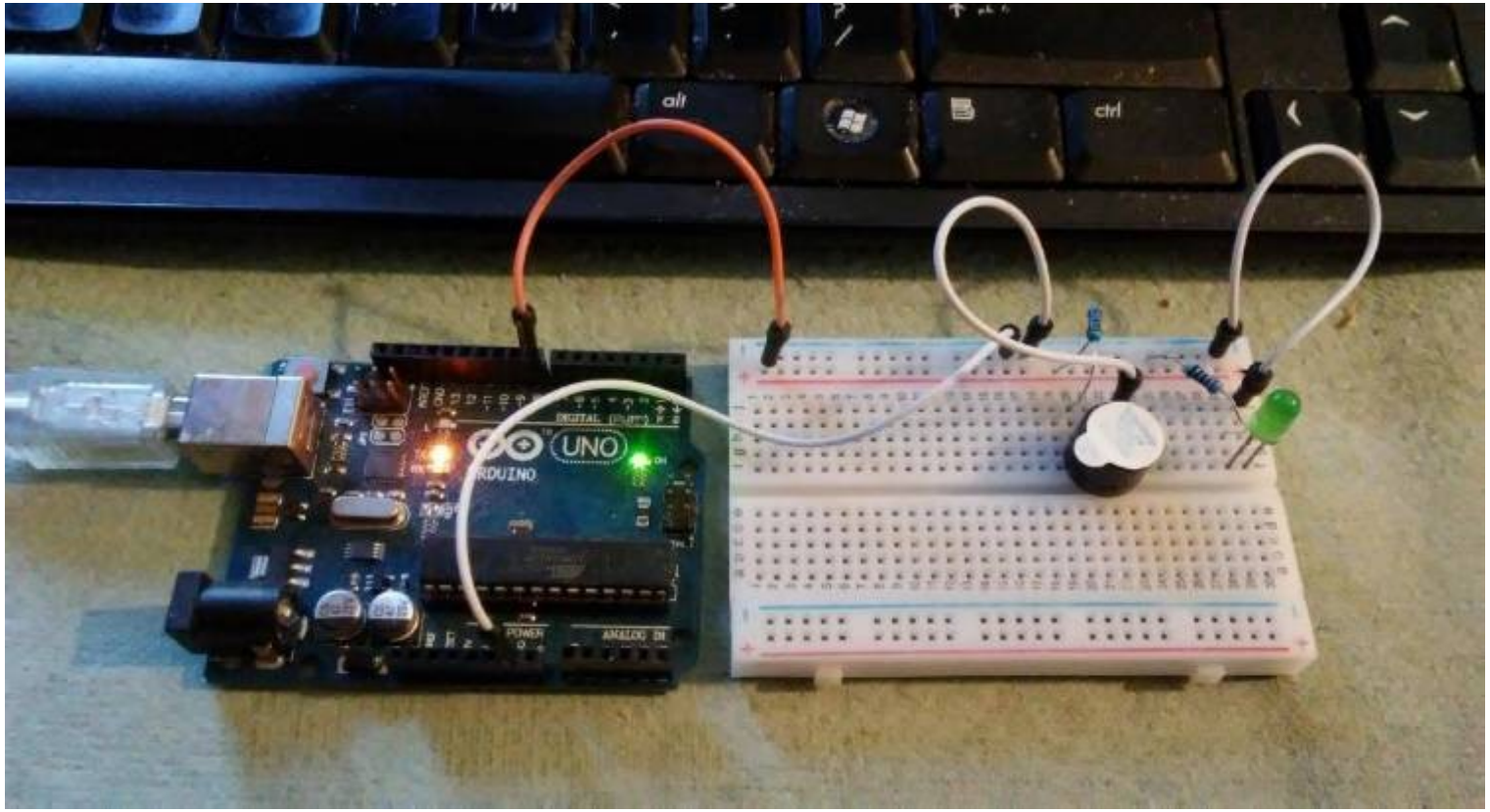


TOOLS

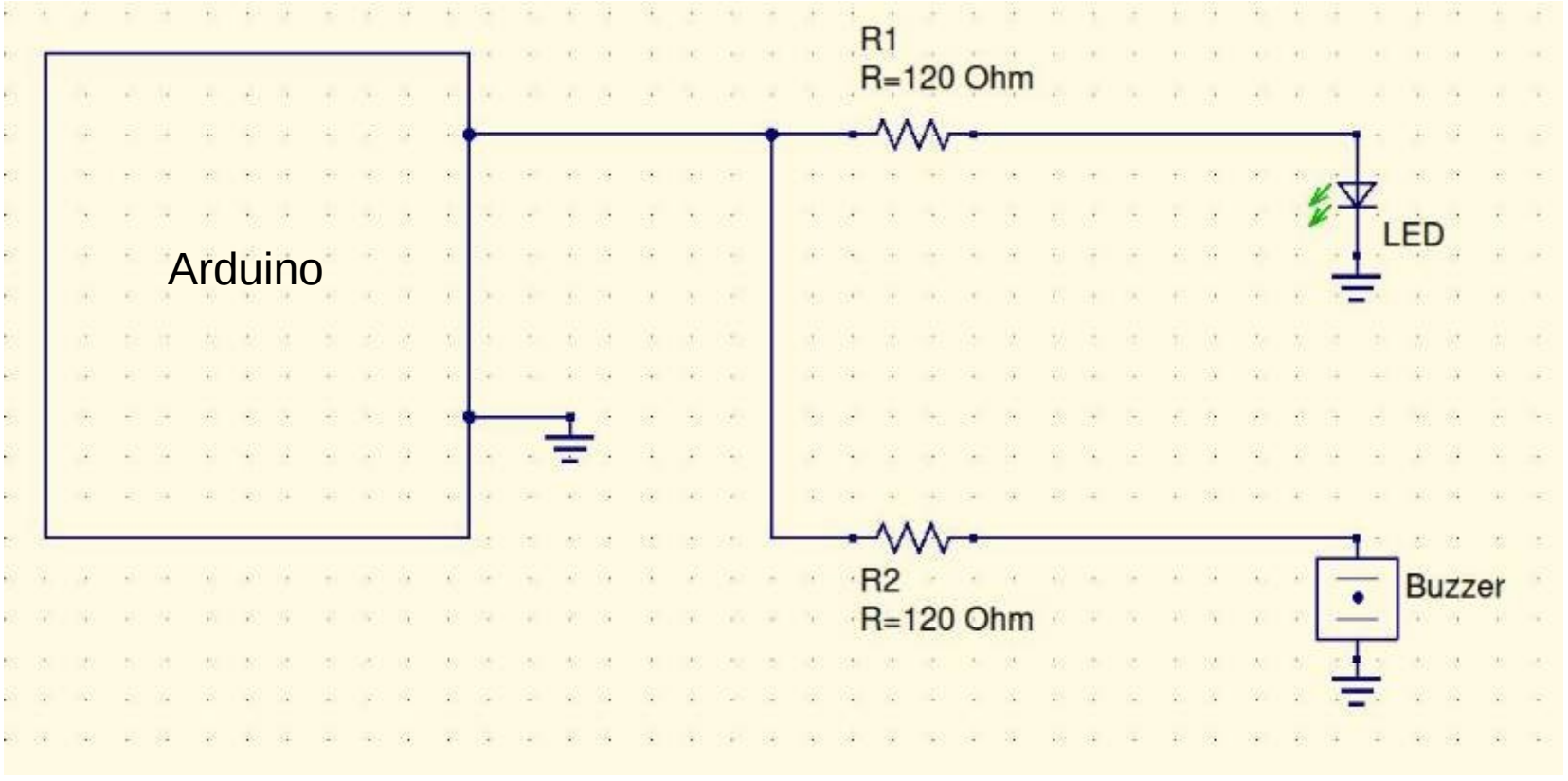
- Arduino UNO + Breadboard
- QUES – Quite Universal Circuit Simulator (Free)
  - https://sourceforge.net/projects/qucs/files/latest/download
- Circuit Calculations with Complex Numbers and Spreadsheets (Excel or LibreOffice CALC)
  - Free LibreOffice Download: https://www.libreoffice.org/
- Software Modems
- Software Defined Radios

Arduino and Breadboard

CQ CQ DE AE7OH K

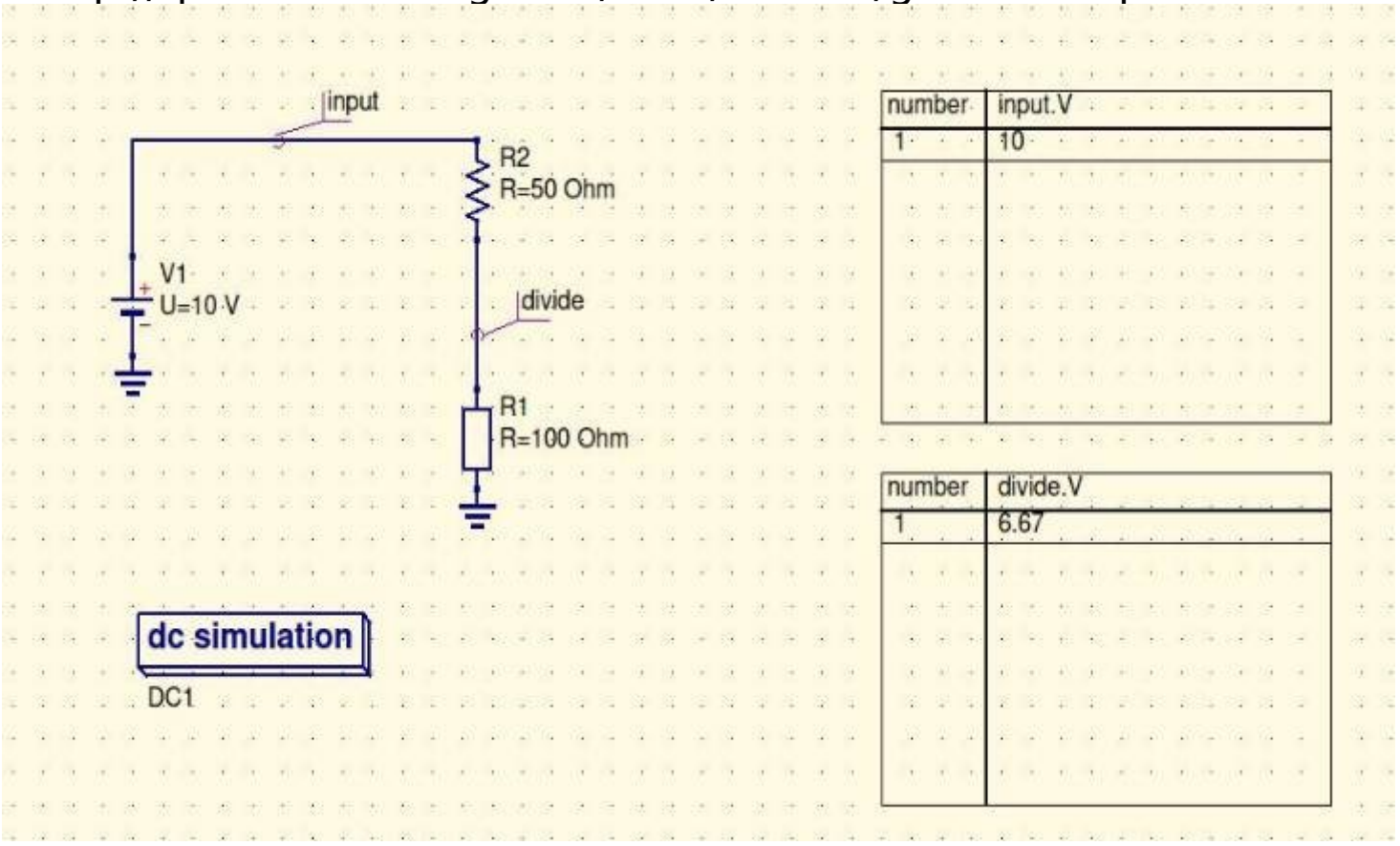


Arduino+Breadboard Schematic



QuiteUniversalCircuitSimulator

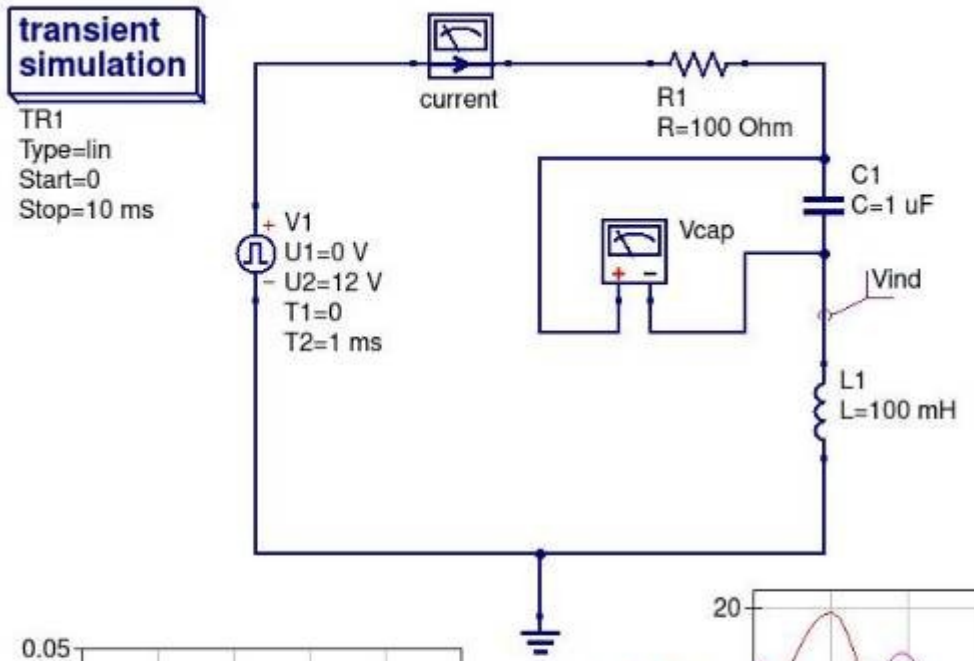
https://sourceforge.net/projects/qucs/files/latest/download
Manual: http://qucs.sourceforge.net/docs/tutorial/getstarted.pdf



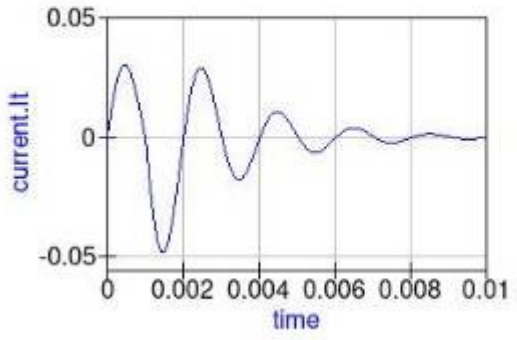
number	input.V
1	10

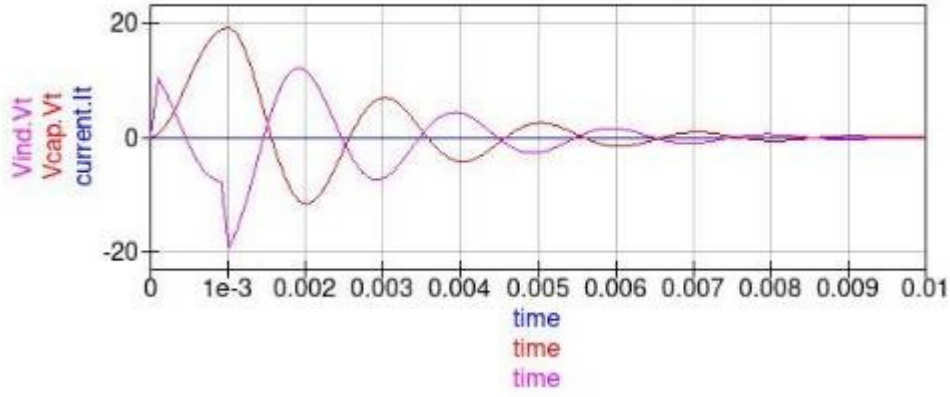
number	divide.V
1	6.67

RLC Transient Simulation

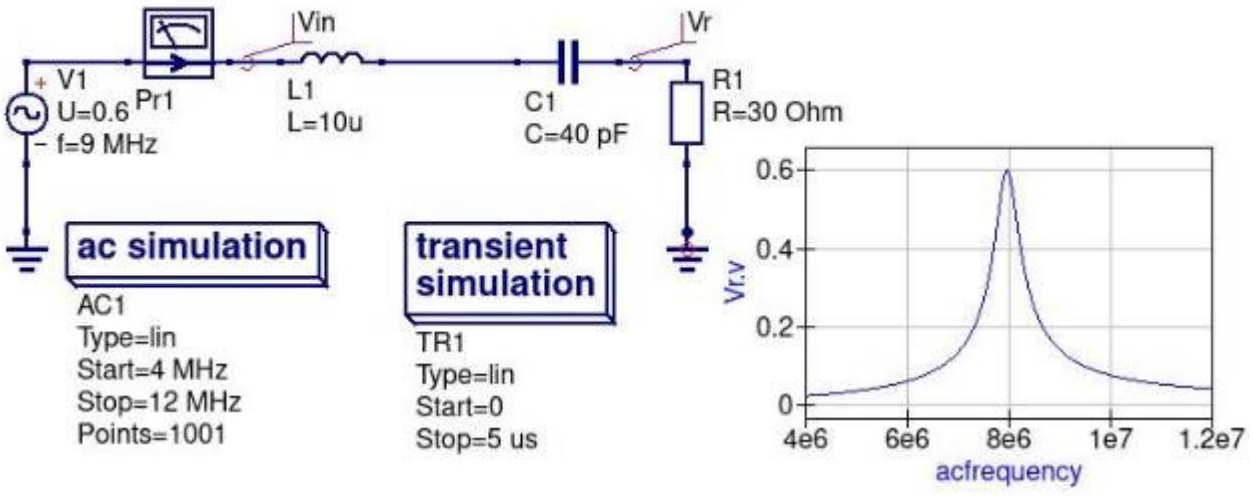


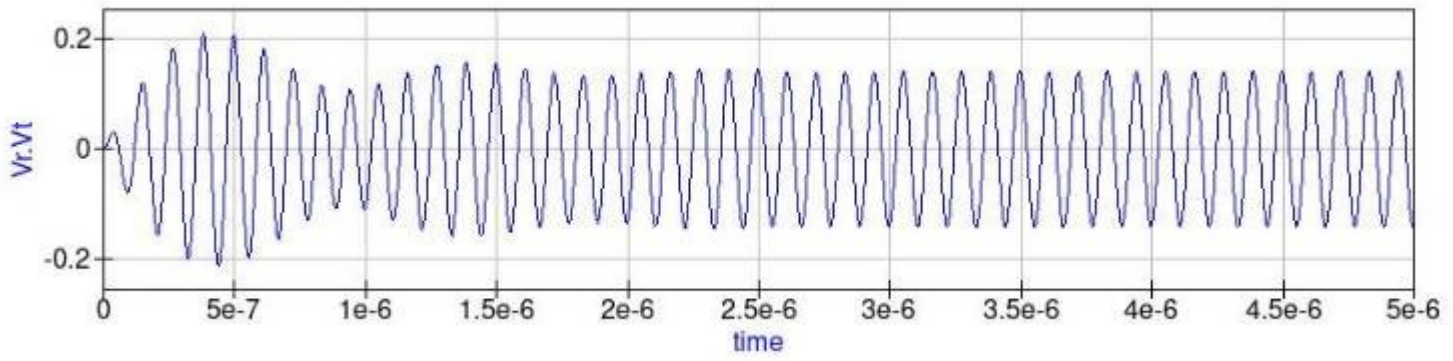
time	current.It	Vcap.Vt	Vind.Vt
0	0	0	0
0.000101	0.0113	0.587	10.3
0.000202	0.0205	2.21	7.74
0.000303	0.0268	4.63	4.69
0.000404	0.0299	7.52	1.49
0.000505	0.0299	10.6	-1.55
0.000606	0.0269	13.5	-4.15
0.000707	0.0217	15.9	-6.1
0.000808	0.0149	17.8	-7.27
0.000909	0.00729	18.9	-7.64
0.00101	-0.000903	19.3	-19.2
0.00111	-0.019	18.2	-16.3
0.00121	-0.0335	15.5	-12.2
0.00131	-0.0433	11.6	-7.29
0.00141	-0.0481	6.97	-2.16
0.00152	-0.0478	2.09	2.69
0.00162	-0.0429	-2.53	6.82



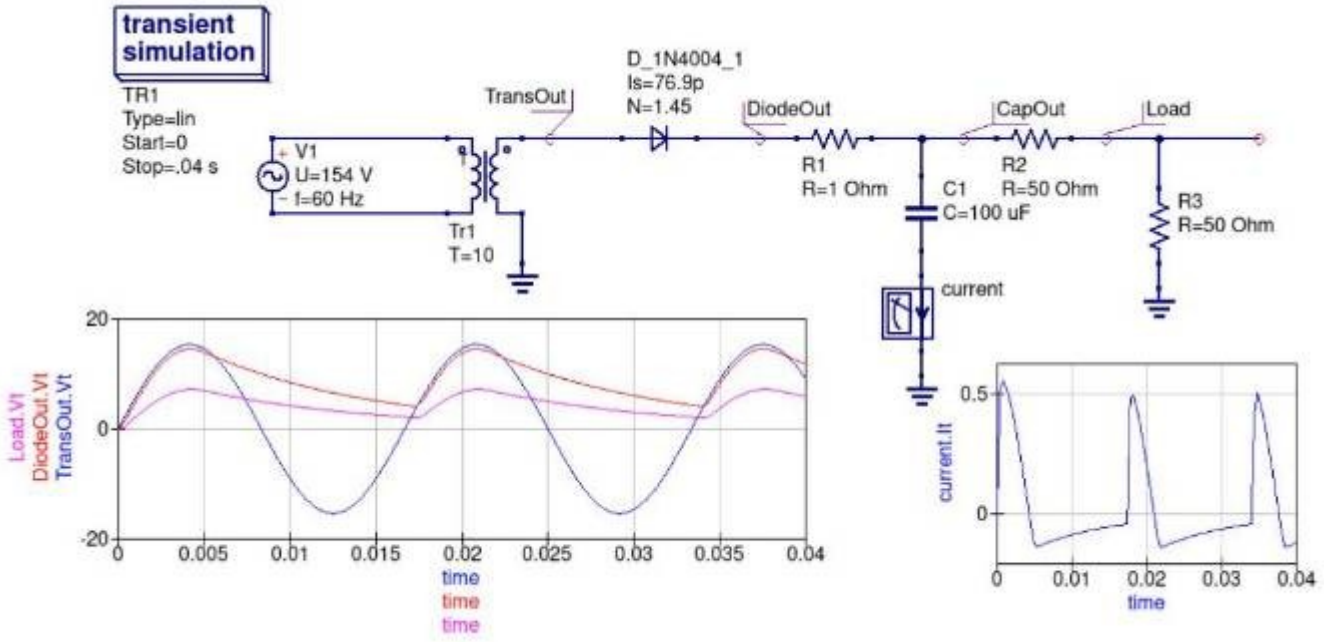


RLC Frequency And Transient Simulations

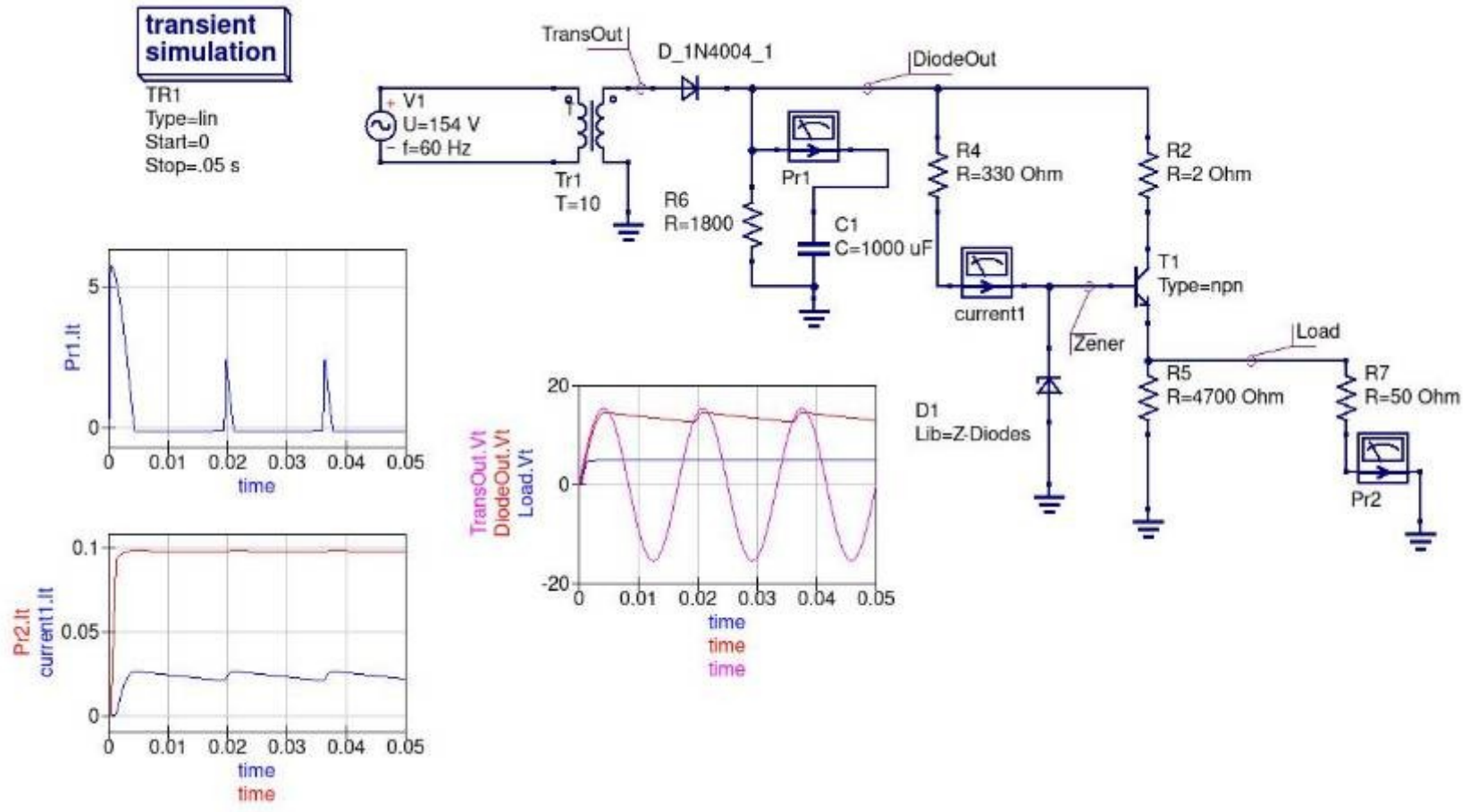




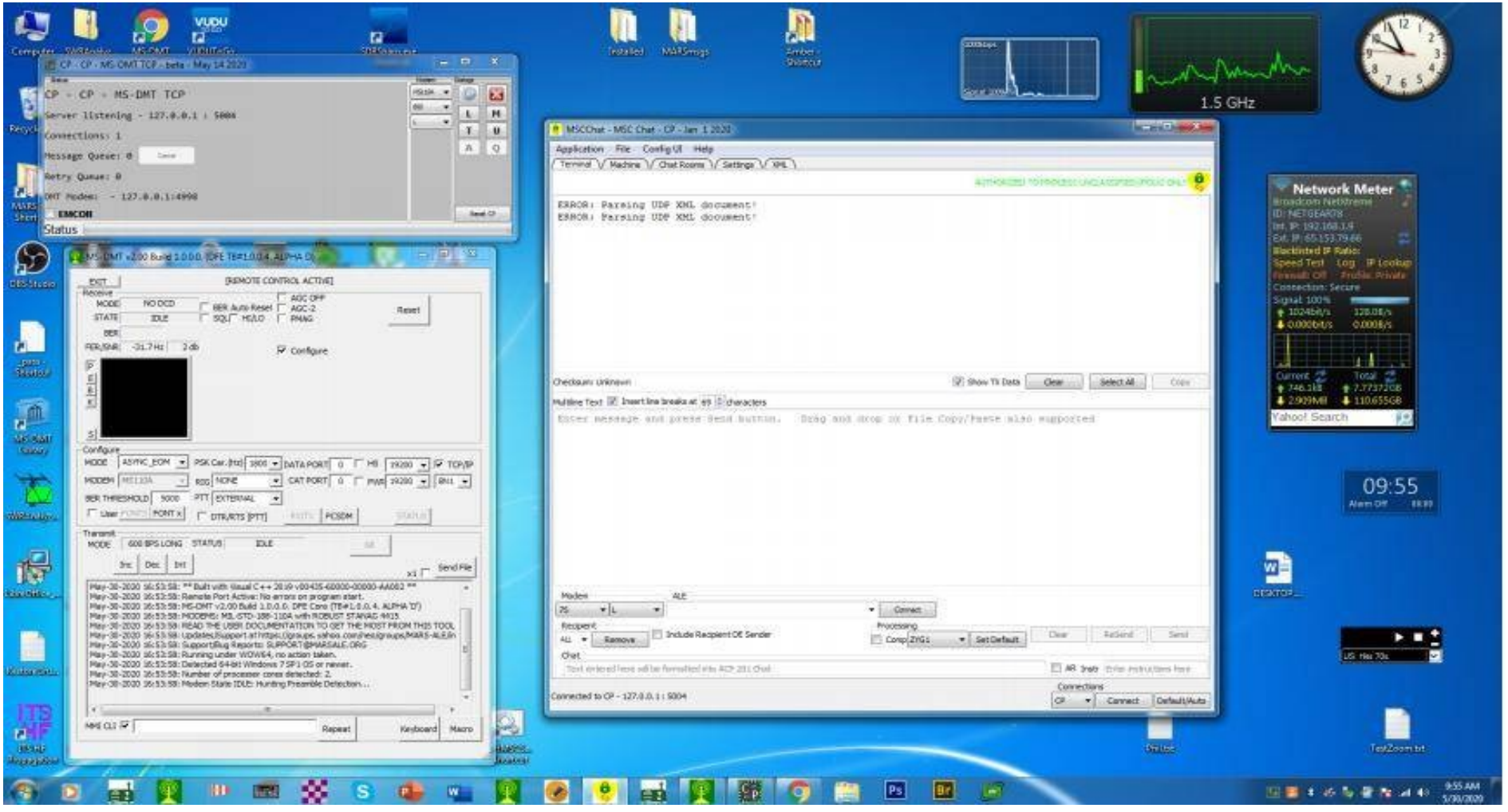
Simple Power Supply

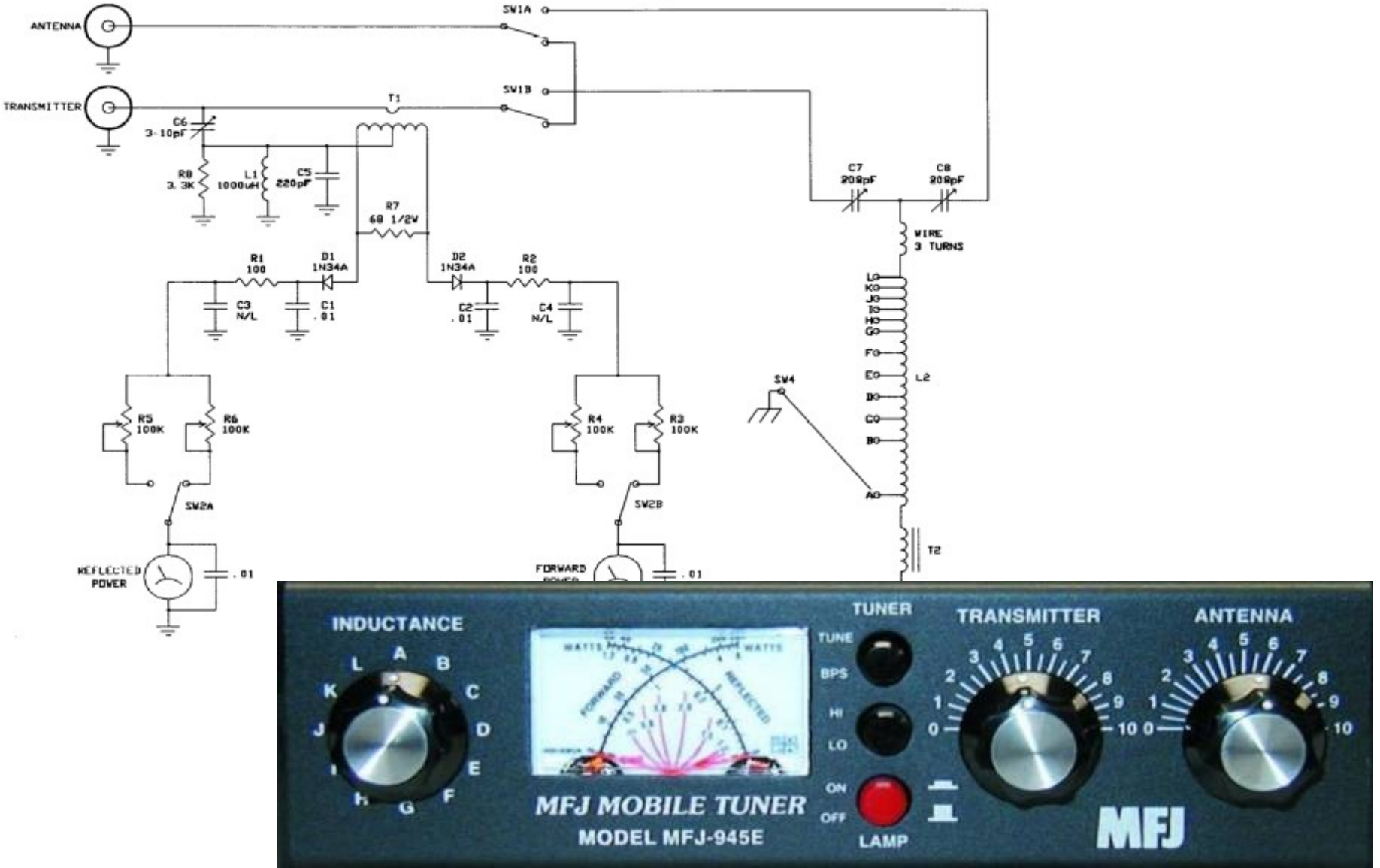


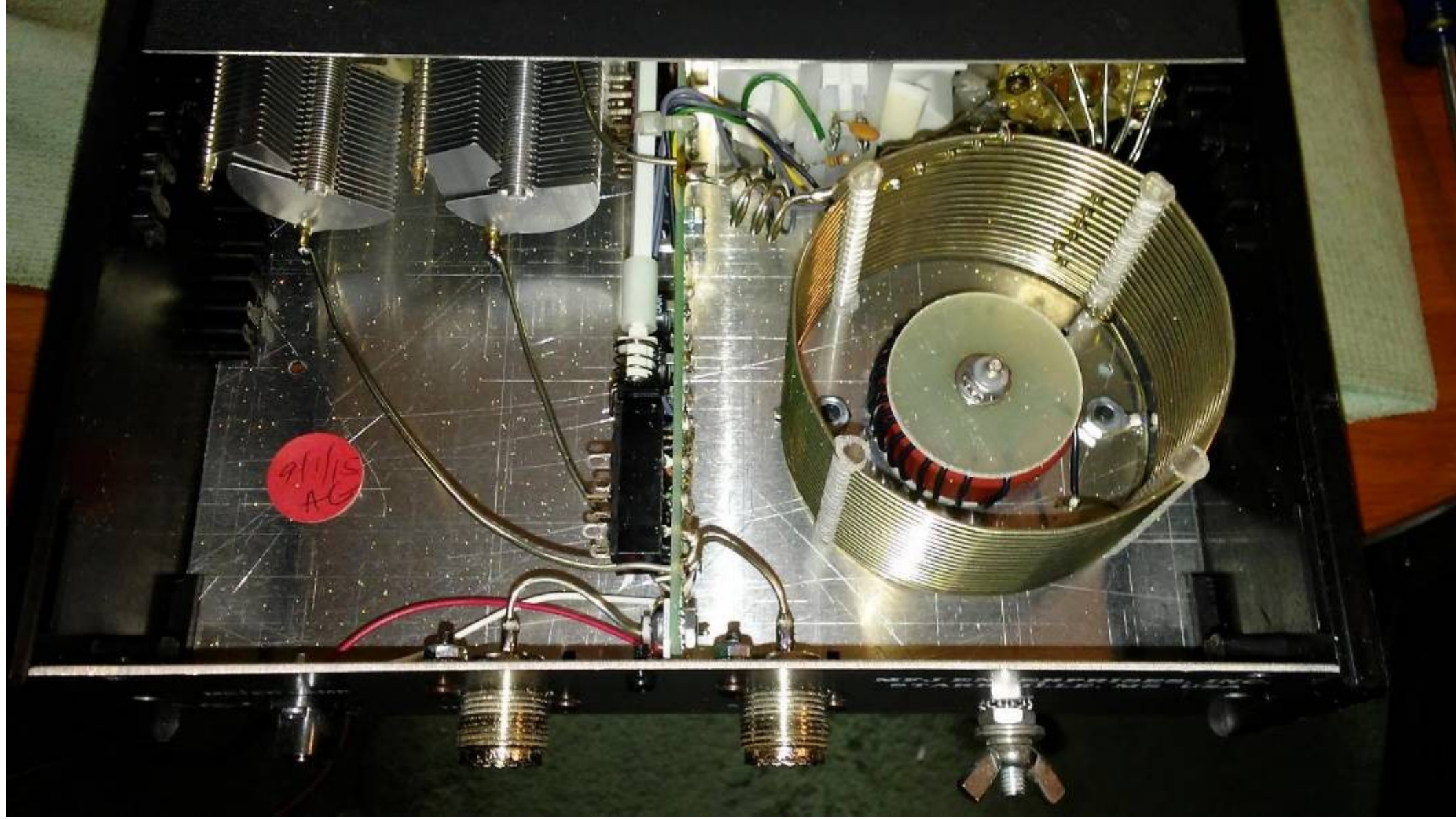
Regulated Power Supply



MODEM IS ENTIRELY SOFTWARE




ANTENNA
TRANSMITTER
SW1A
SW1B
T1
C6
3-10pF
R8
3.3K
L1
1000uH
C5
220pF
R7
68 1/2W
C7
209pF
C8
209pF
WIRE
3 TURNS
L2
T2
R1
100
D1
1N34A
D2
1N34A
R2
100
C3
N/L
C1
.01
C2
.01
C4
N/L
R5
100K
R6
100K
R4
100K
R3
100K
SW4
SW2A
SW2B
REFLECTED
POWER
FORWARD
.01
INDUCTANCE
TUNER
TUNE
BPS
HI
LO
ON
OFF
LAMP
TRANSMITTER
ANTENNA
MFJ MOBILE TUNER
MODEL MFJ-945E
MFJ


9/1/15
AC

Alternating Current Sinusoids

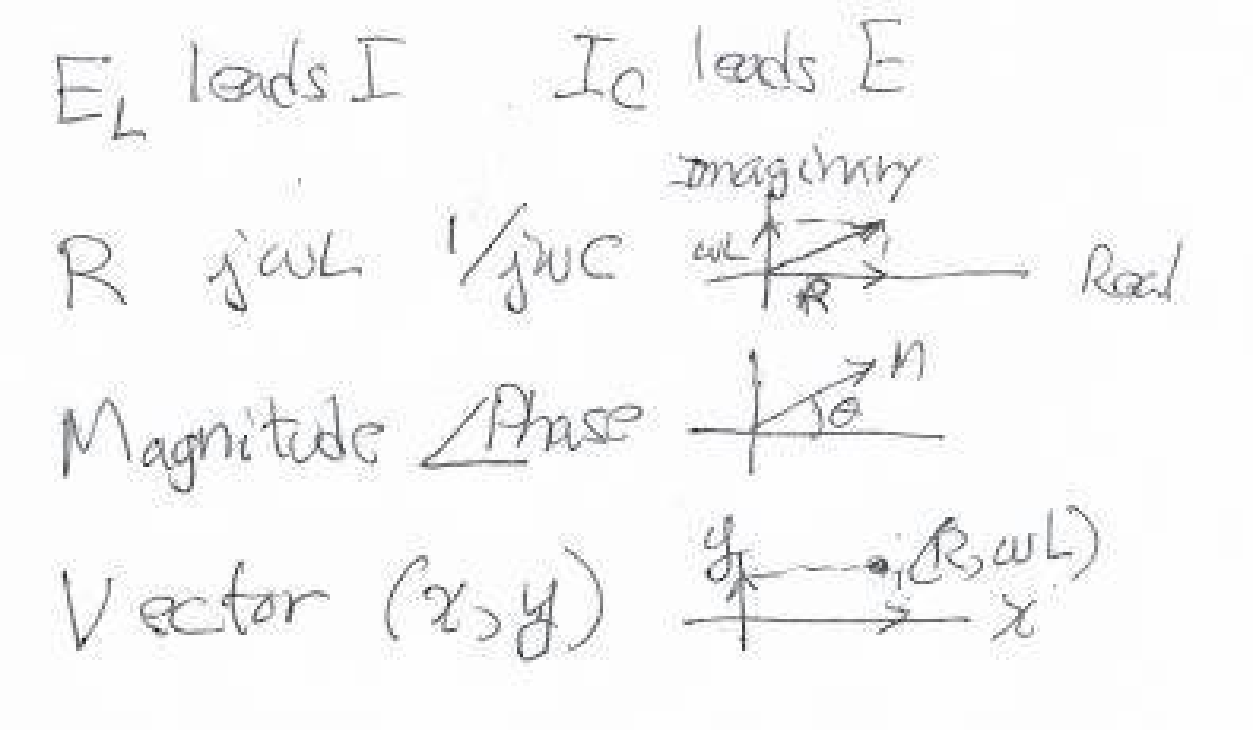
imaginary

Radius rotates at f cycles per second to create sinusoid

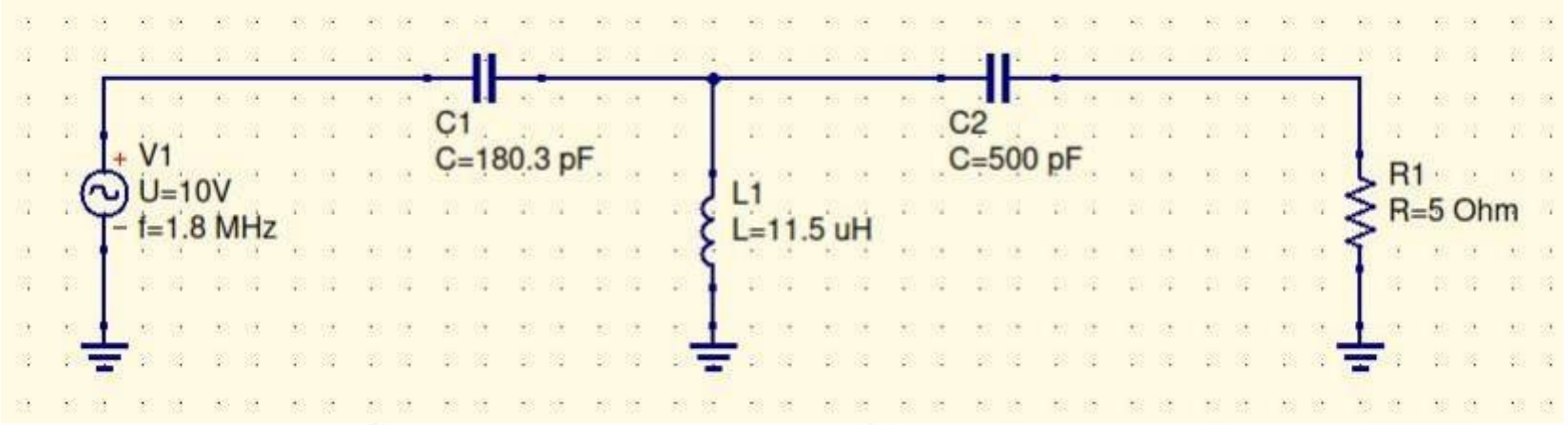
real

AC Representation Choice for Calculations

- Eli the Ice man
- Complex Numbers
  (easy calcs)
- Polar form
- Vectors



Calculate Tuned Antenna Impedance



$$50\,\Omega = \frac{1}{j\omega C_1} + \frac{1}{\frac{1}{j\omega L_1} + \frac{1}{R_1 + \frac{1}{j\omega C_2}}}$$

(IMPEDANCE)

(ADMITTANCE)

(IMPEDANCE)

Tuner Calc Spreadsheet

(See Figure 24.4 in Antenna Book)

	A	B	C	D	E	F	G	H
1				T NETWORK			ANTENNA	
2	component		C-xmtr		C-antenna		x	y
3				L				
4								
5								
6	value		1.80E-10	1.15E-05	5.00E-10		5	0
7			(180.3 pf)	(11.5 uhenry)	(500 pf)			
8								
9	reactance		-490.402038344852i	130.061826i	-176.838975027154i		5	
10								
11					38.2180330964639-2.79408640923299i			
12		freq	1.80E+06		answer			
13	radian_freq	rad. Freq.	11309724					
14	(1.8 Mhz)							
15								
16		Q	1000	200	1000			
17			0.490402038344852-490.402038344852i	0.65030913+130.061826i	0.176838975027154-176.838975027154i		5	
18								
19				per Figure 24.4 Antenna Book	49.0615676552388-4.68763200560596i			
20					answer			

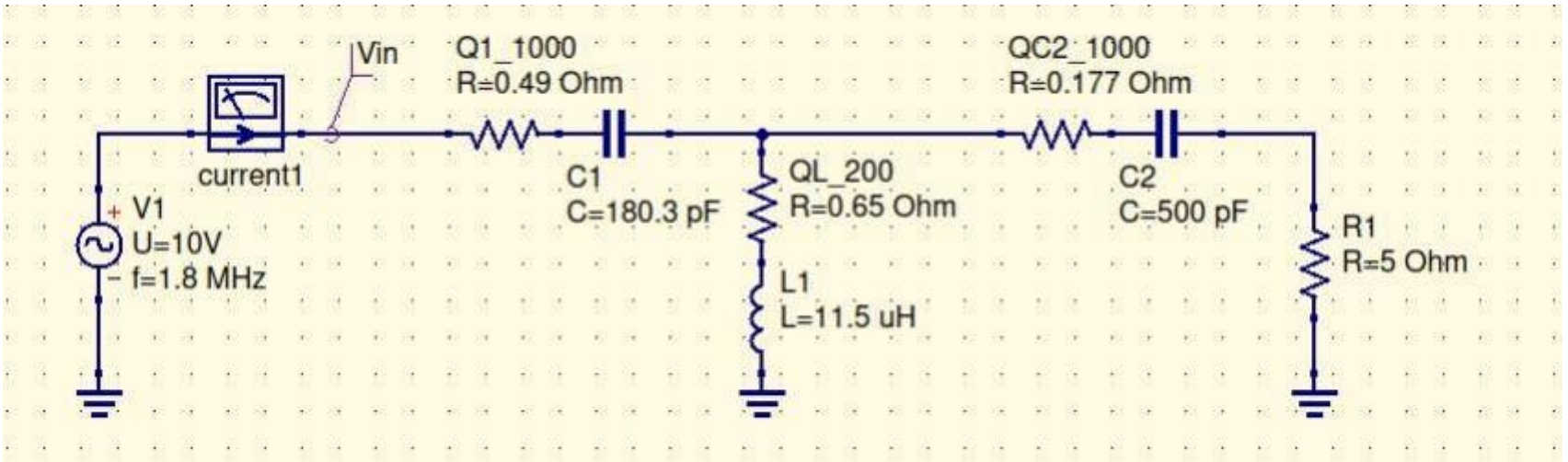
=IMSUM(C9,IMDIV(1,IMSUM(IMDIV(1,D9),IMDIV(1,IMSUM(E9,G9)))))

Excel or CALC Complex Functions

COMPLEX	Returns a complex number, given real and imaginary parts as numbers.	IMLOG10	Returns the base-10 logarithm of a complex number.
IMABS	Returns the absolute value of a complex number.	IMLOG2	Returns the base-2 logarithm of a complex number.
IMAGINARY	Returns the imaginary part of a complex number.	IMPOWER	Returns a complex number raised to a power.
IMARGUMENT	Returns the argument of a complex number.	IMPRODUCT	Returns the product of complex numbers.
IMCONJUGATE	Returns the complex conjugate of a complex number.	IMREAL	Returns the real part of a complex number.
IMCOS	Returns the cosine of a complex number.	IMSEC	Returns the secant of a complex number.
IMCOSH	Returns the hyperbolic cosine of a complex number.	IMSECH	Returns the hyperbolic secant of a complex number.
IMCSC	Returns the cosecant of a complex number.	IMSIN	Return the sine of a complex number.
IMCSCH	Returns the hyperbolic cosecant of a complex number.	IMSINH	Returns the hyperbolic sine of a complex number.
IMCOT	Returns the cotangent of a complex number.	IMSQRT	Returns the square root of a complex number.
IMDIV	Returns the result of dividing one complex number by another.	IMSUB	Returns the difference between 2 complex numbers.
IMEXP	Returns e to the power of a complex number.	IMSUM	Returns the sum of complex numbers.
IMLN	Returns the natural logarithm of a complex number.	IMTAN	Returns the tangent of a complex number.

Tuner Adjustments

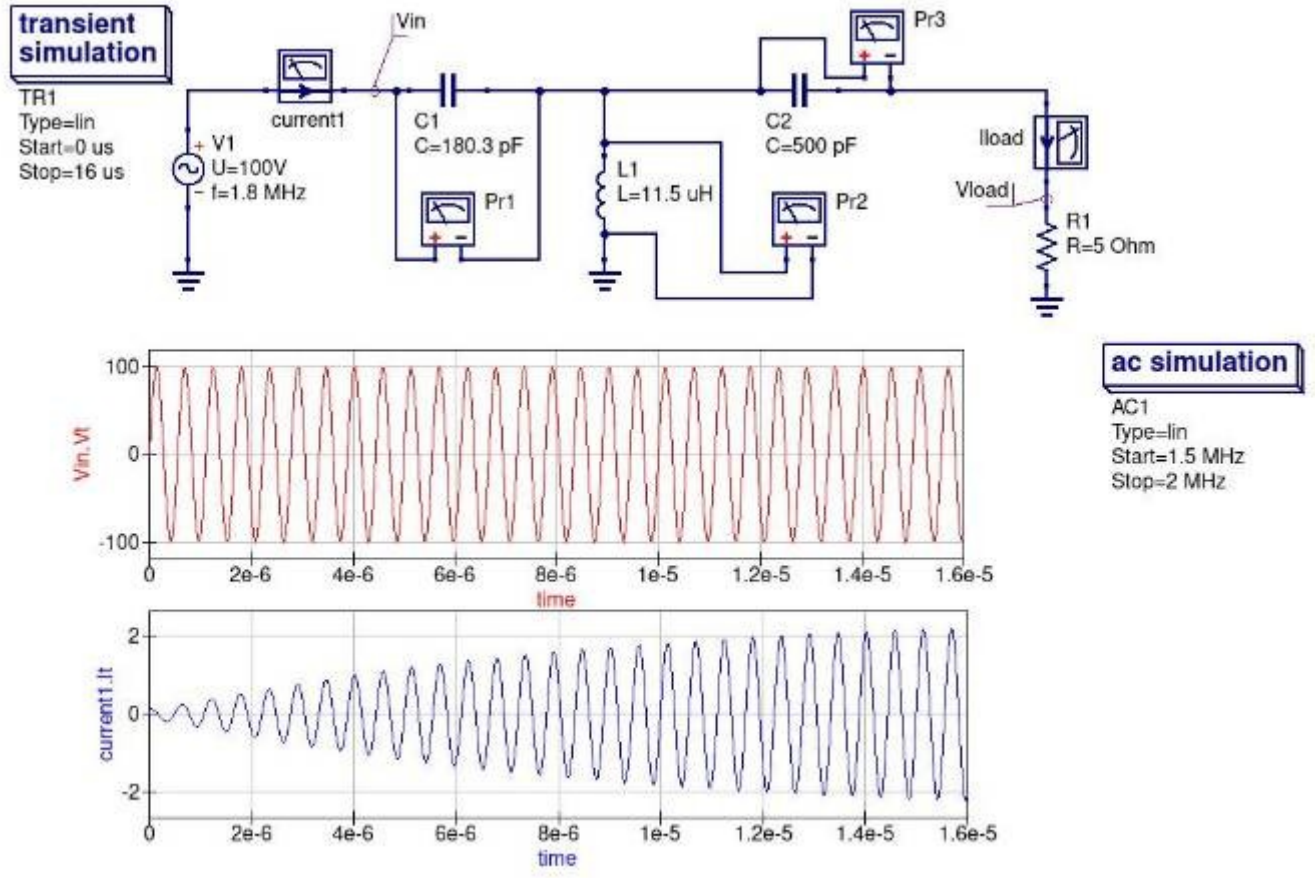
- Tuner adjusted 5-Ohm Antenna to 38 ohms
- Ant. Book assumed Q-values for components
- Added Q-Resistors yield 50 ohms



Tuner Reactance Tweaks

- Minor phase error in answer can be removed by changing C1 to zero the reactance error
- C2 can be adjusted to compensate for a reactive component in the Antenna:
  - Decrease C2 to compensate for inductive antenna
  - Increase C2 to compensate for capacitive antenna
- Antenna design would probably try to make antenna nearer to the ideal 50-ohm, 0-reactance impedance at the desired frequency(s)
- Stay tuned!

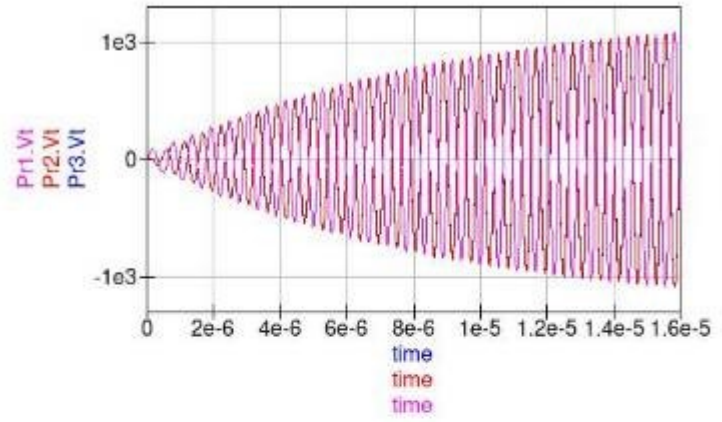
Match1

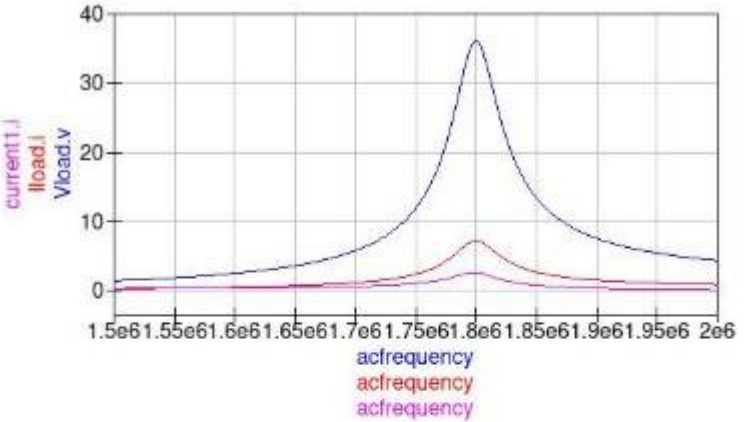

transient simulation
TR1
Type=lin
Start=0 us
Stop=16 us
V1
U=100V
f=1.8 MHz
current1
Vin
C1
C=180.3 pF
Pr1
L1
L=11.5 uH
C2
C=500 pF
Pr3
Pr2
Iload
Vload
R1
R=5 Ohm
ac simulation
AC1
Type=lin
Start=1.5 MHz
Stop=2 MHz
Vin.Vt
100
0
-100
0
2e-6
4e-6
6e-6
8e-6
1e-5
1.2e-5
1.4e-5
1.6e-5
time
current1.It
2
0
-2
time

Match2

Input voltage: 100V

But peak voltages across tuner elements are 1000V





time	Vin.Vt	Pr1.Vt	Pr2.Vt	Pr3.Vt	Vload.Vt
1.57e-5	98.7	-100	199	229	-29.6
1.57e-5	100	94.2	5.79	36.1	-30.3
1.57e-5	98	286	-188	-158	-30.1
1.57e-5	92.9	468	-375	-346	-28.8
1.57e-5	84.7	635	-550	-524	-26.6
1.58e-5	73.8	782	-708	-684	-23.5
1.58e-5	60.4	903	-842	-823	-19.6
1.58e-5	45.1	994	-949	-934	-15.1
1.58e-5	28.3	1.05e+03	-1.03e+03	-1.02e+03	-10.2
1.58e-5	10.5	1.08e+03	-1.07e+03	-1.06e+03	-4.83
1.58e-5	-7.53	1.07e+03	-1.08e+03	-1.08e+03	0.659
1.59e-5	-25.4	1.02e+03	-1.05e+03	-1.06e+03	6.13
1.59e-5	-42.4	945	-987	-999	11.4

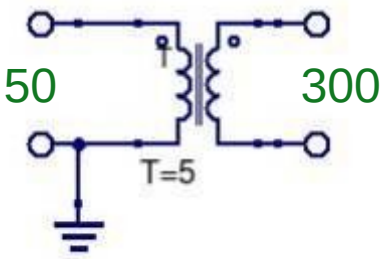
acfrequency	Iload.i	Vload.v
1.8e6	-7.07-j0.897	-35.4-j4.49
1.8e6	-7.12-j0.713	-35.6-j3.57
1.8e6	-7.16-j0.525	-35.8-j2.63
1.8e6	-7.19-j0.335	-35.9-j1.68
1.8e6	-7.21-j0.143	-36-j0.717
1.8e6	-7.21+j0.0494	-36.1+j0.247
1.8e6	-7.21+j0.242	-36.1+j1.21
1.8e6	-7.2+j0.434	-36+j2.17
1.8e6	-7.18+j0.625	-35.9+j3.13
1.8e6	-7.14+j0.813	-35.7+j4.07
1.8e6	-7.1+j0.999	-35.5+j4.99
1.8e6	-7.05+j1.18	-35.2+j5.9
1.8e6	-6.99+j1.36	-34.9+j6.79

High RF Tuner Voltages

- High Voltage in tuner elements
  - 100 volts peak source
  - 1000 volts peak across components
- Arcing and RF burns potential

- Solutions include better antenna design
  - e.g., a Balun can help match

Example: 5:1 transformer
Matches 50 ohm coax
To 300 ohm antenna



Internet Antenna

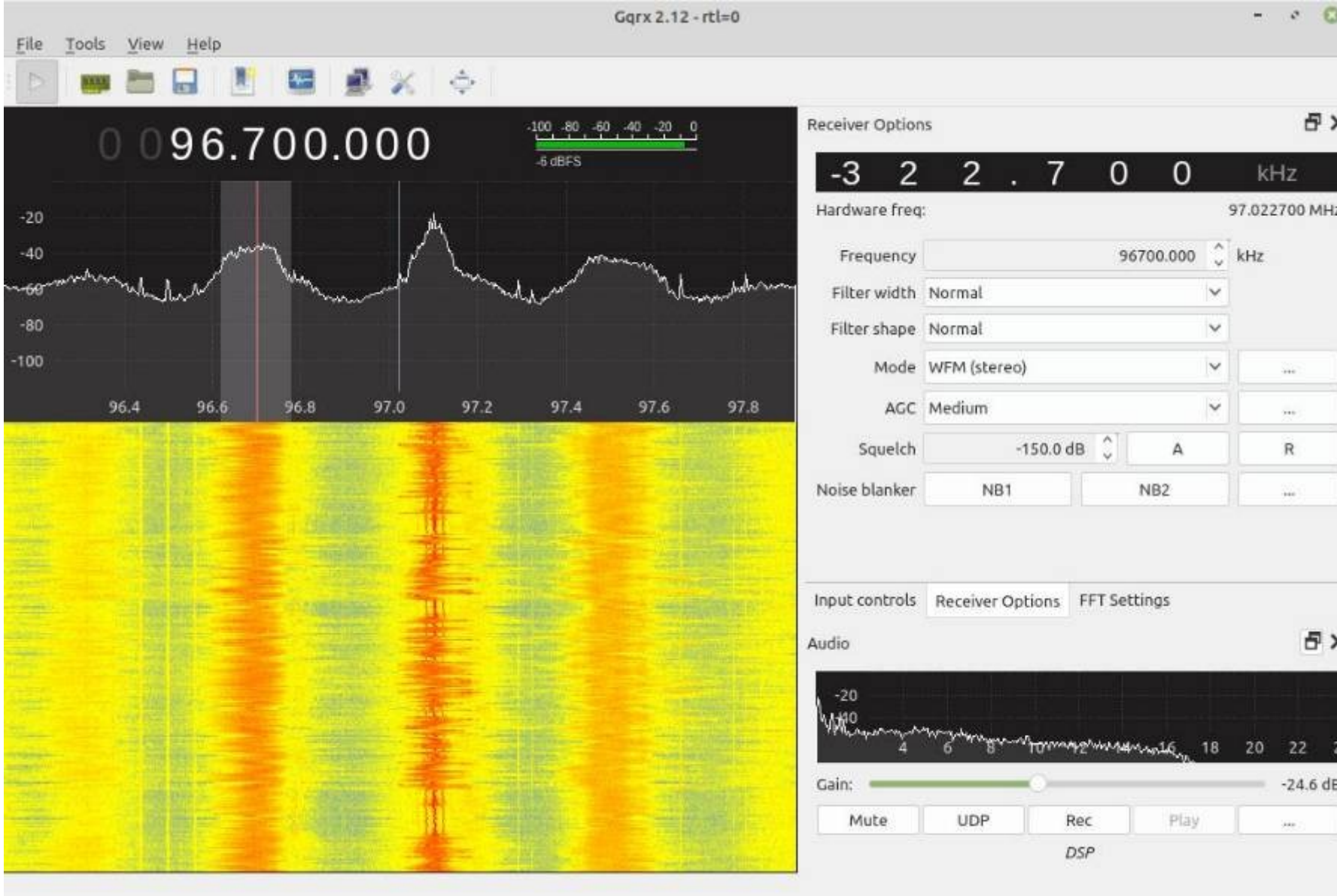
CHA TD LITE HF Antenna


RTL-SDR.COM

RTL-SDR Software Defined Radio

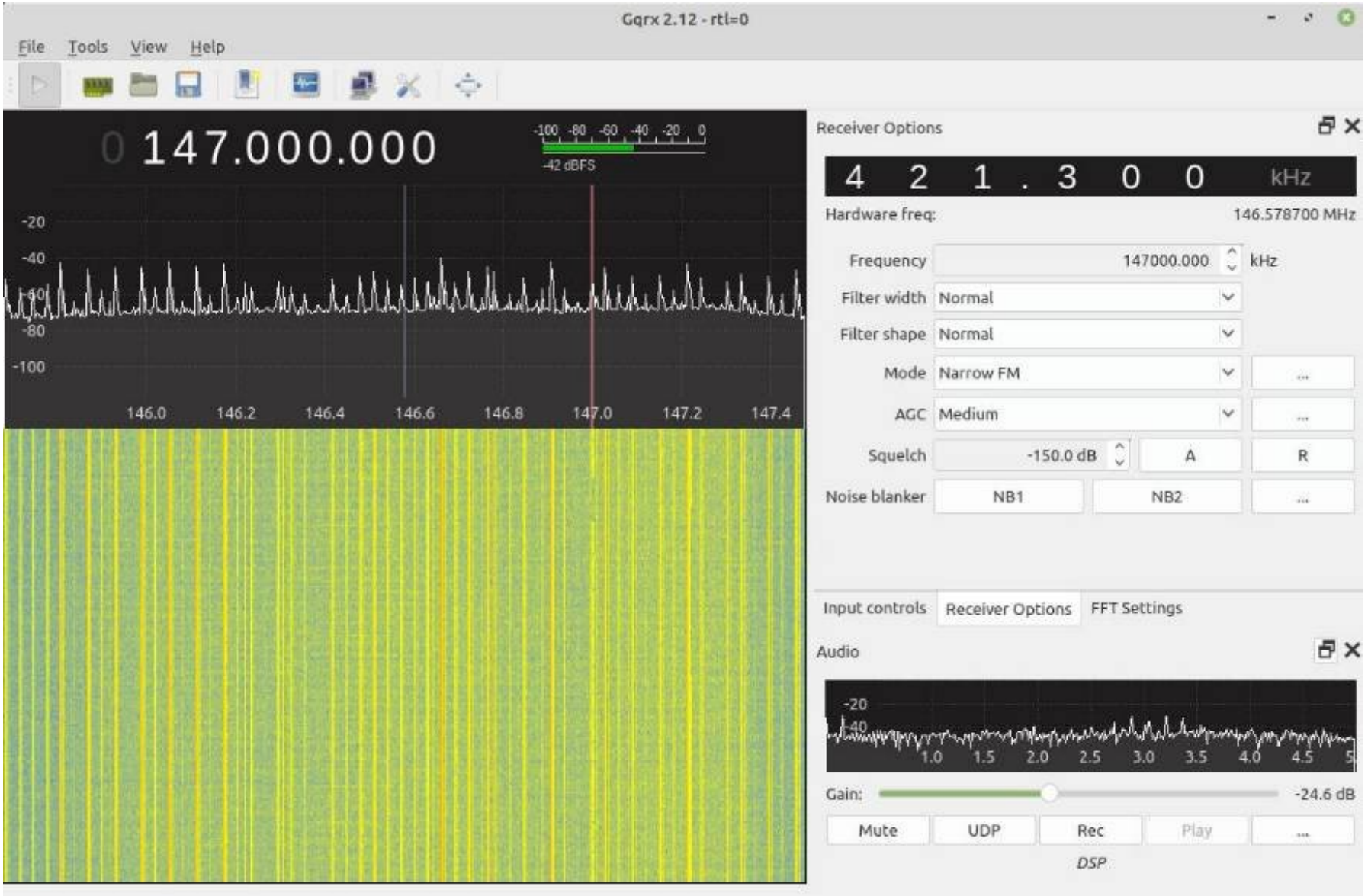
FM Radio Station

GQRX (Linux) or SDR-Sharp



SDR

VHF Station



Handhelds

20 Meter Antenna