Analyzing the HR360WB Antenna Analyzer

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For the Oak Forest Amateur Radio Club
11/18/17

Agenda

- What does it do?
- Original Design Proposal
- Understanding the SWR Bridge
- Understanding Diode Characteristics
- Simulations with Different Diodes
- Reverse Engineering – Specs
- Alternative Designs
- Future Plans

Objective

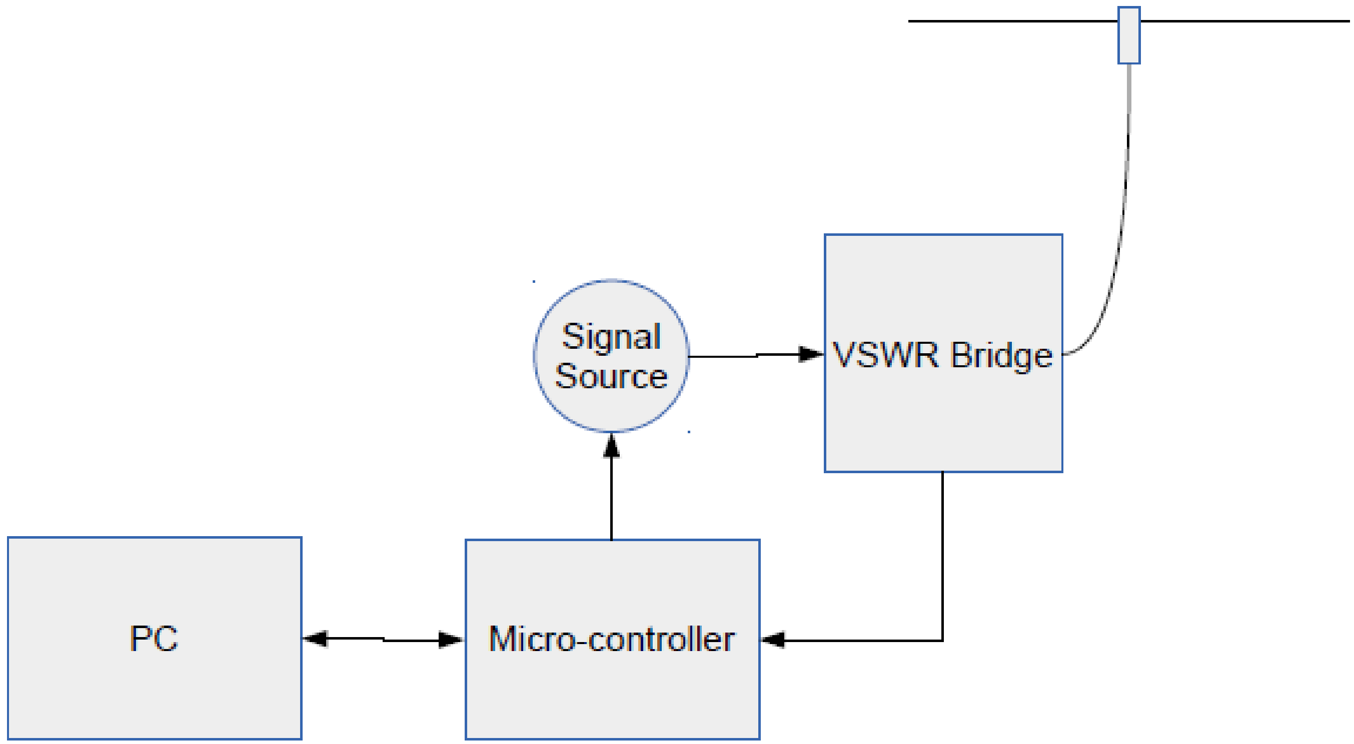
- Measure antenna system SWR and adjust system to achieve SWR near "1"
- Best for transmitter health
- Best efficiency (highest radiation)

Instrument Comparisons

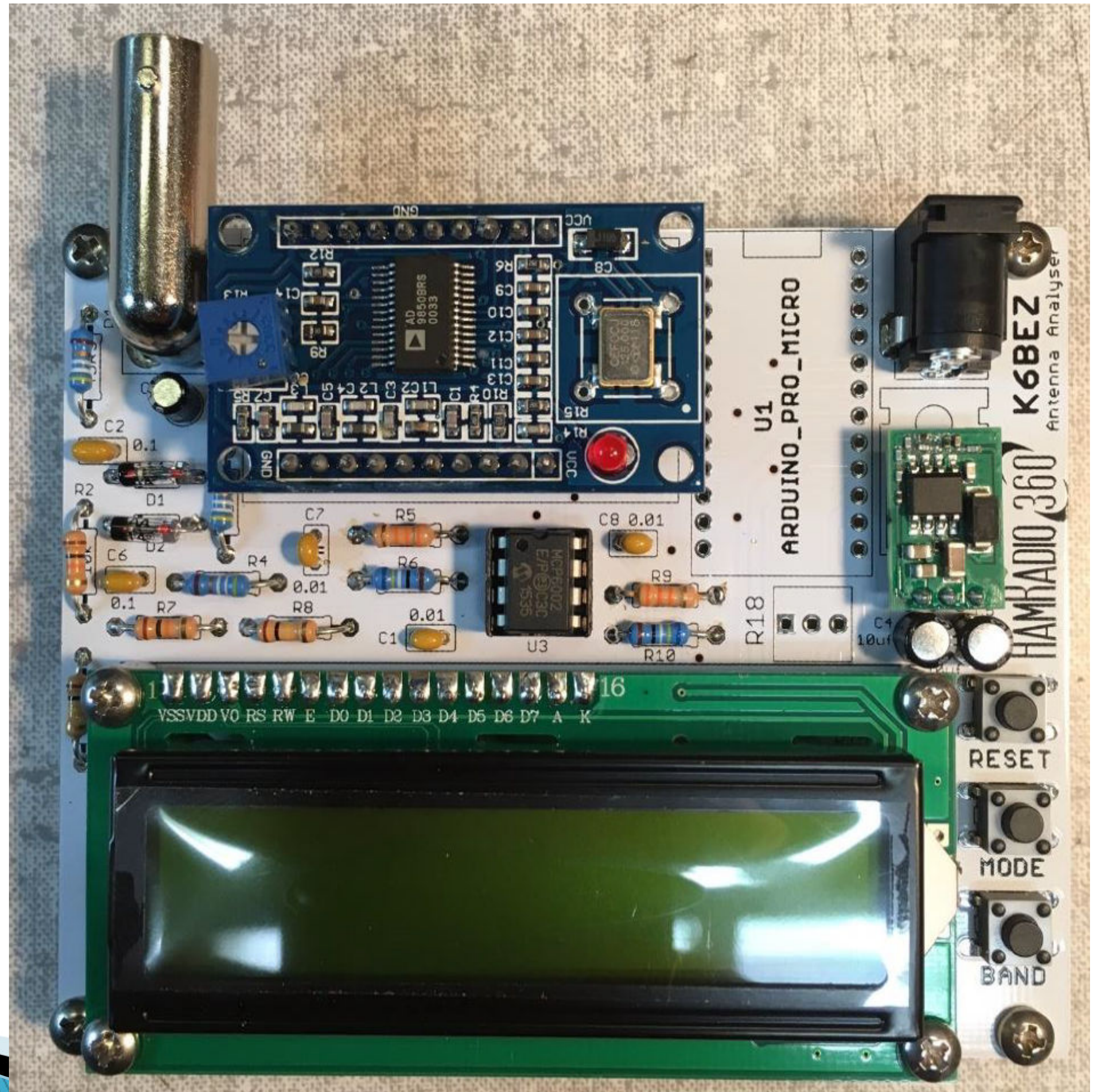
- Objective: Measure Antenna System SWR

Instrument	Has Generator?	Frequency Sweep?	Measures Complex Impedance?	S Parameters
SWR Meter	No	No	No	No
Antenna Analyzer	Yes	Yes	No	No
Vector Network Analyzer (VNA)	Yes	Yes	Yes	Yes

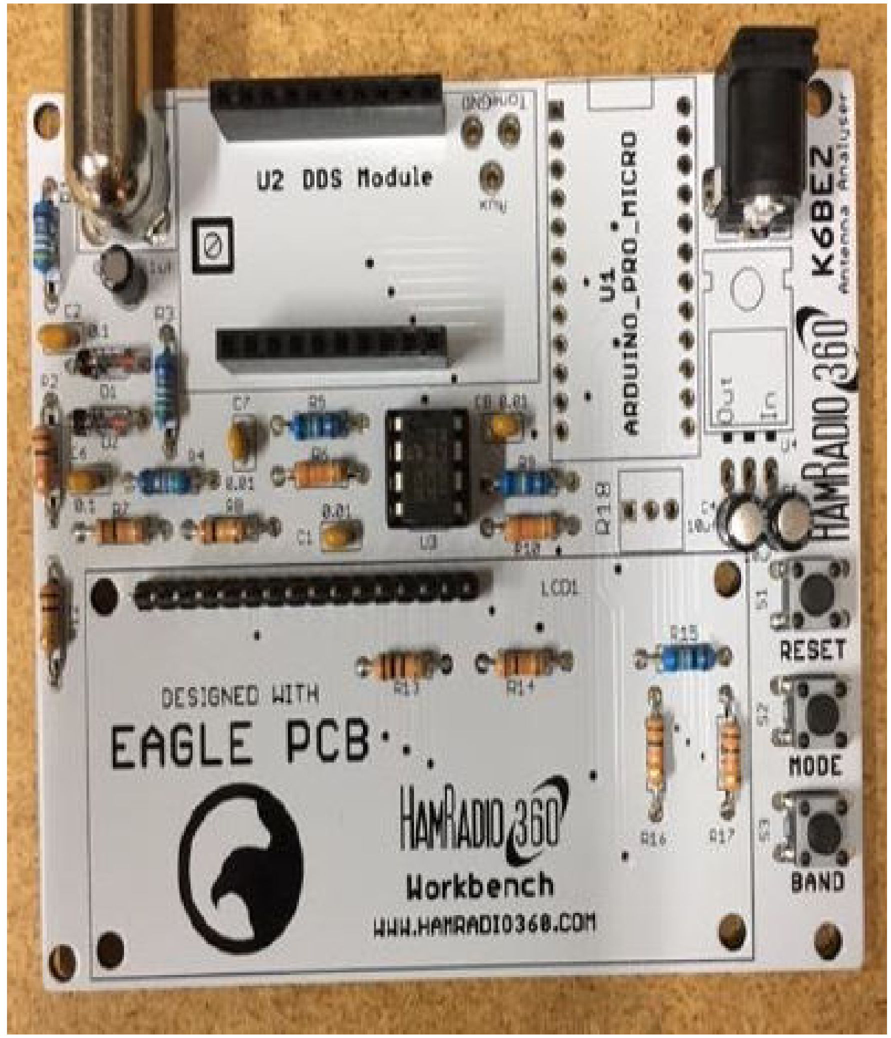
Analyzer Block Diagram



Finished Product



Mother Board



VSWR Theory

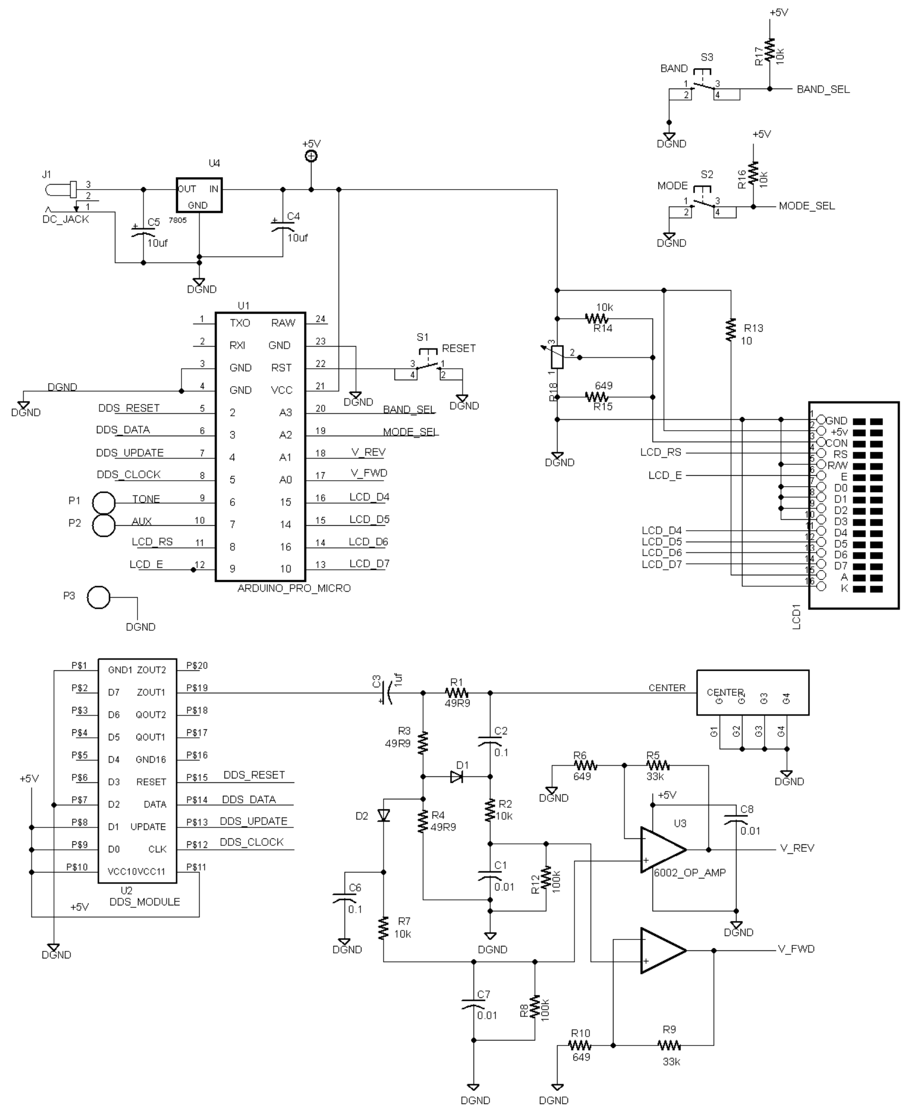
- VSWR is the ratio of maximum to minimum voltage seen along a length of antenna feedline.
- VSWR can be predicted if the characteristic impedance (Z_0) and the impedance of the (antenna) load are known.
- VSWR is defined by these equations:

$$\Gamma = (Z_L - Z_0) / (Z_L + Z_0)$$

$$\rho = | \Gamma |$$

$$VSWR = (1+ \rho) / (1- \rho)$$

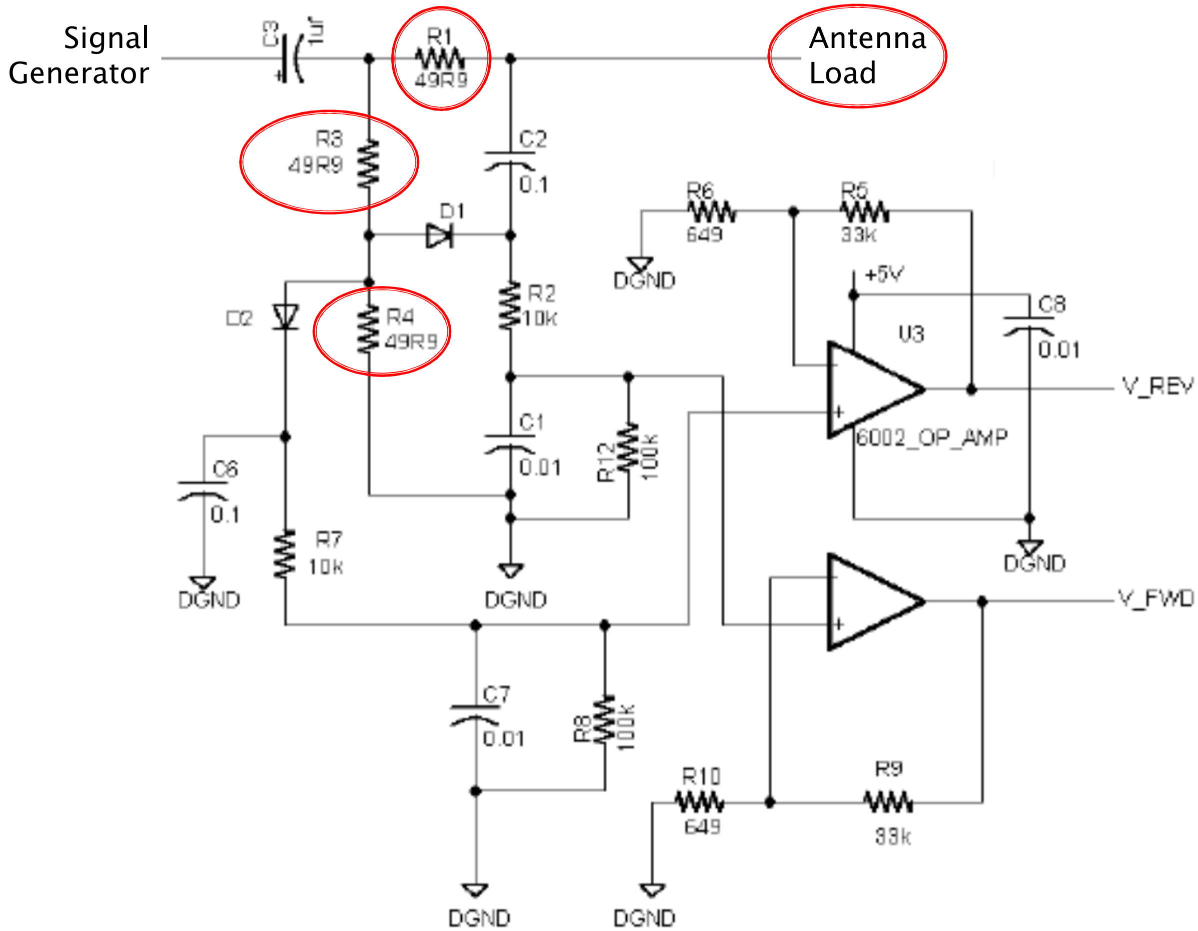
Complete Schematic



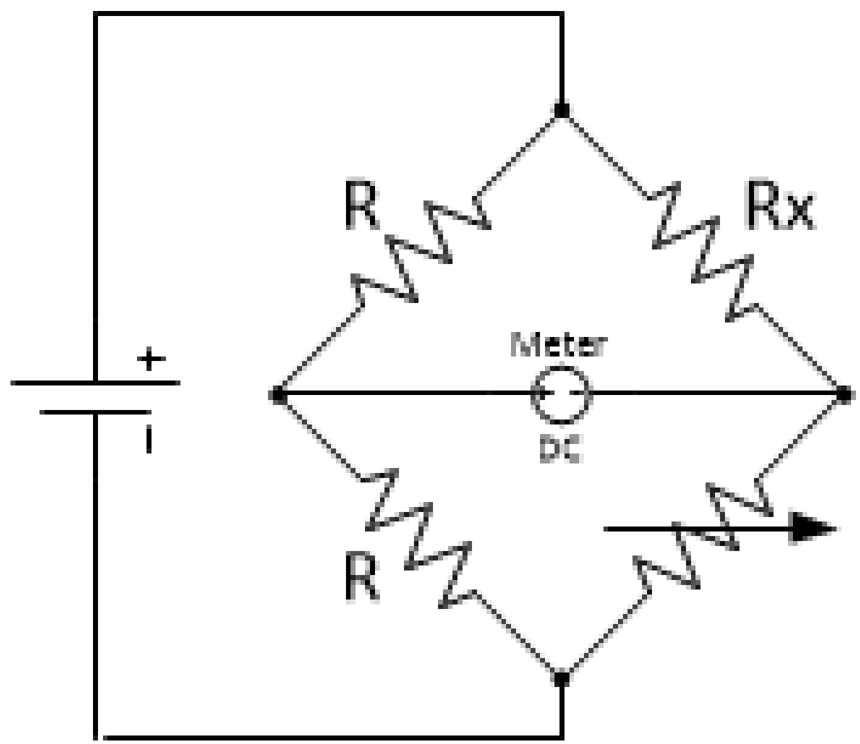
Analysis Tools / Resources

- Ham Radio 360 Work Bench web page
- Other web resources
- Project description from Beric Dunn K6BEZ
- TI SPICE analysis program (TINA)
- Microsoft Excel

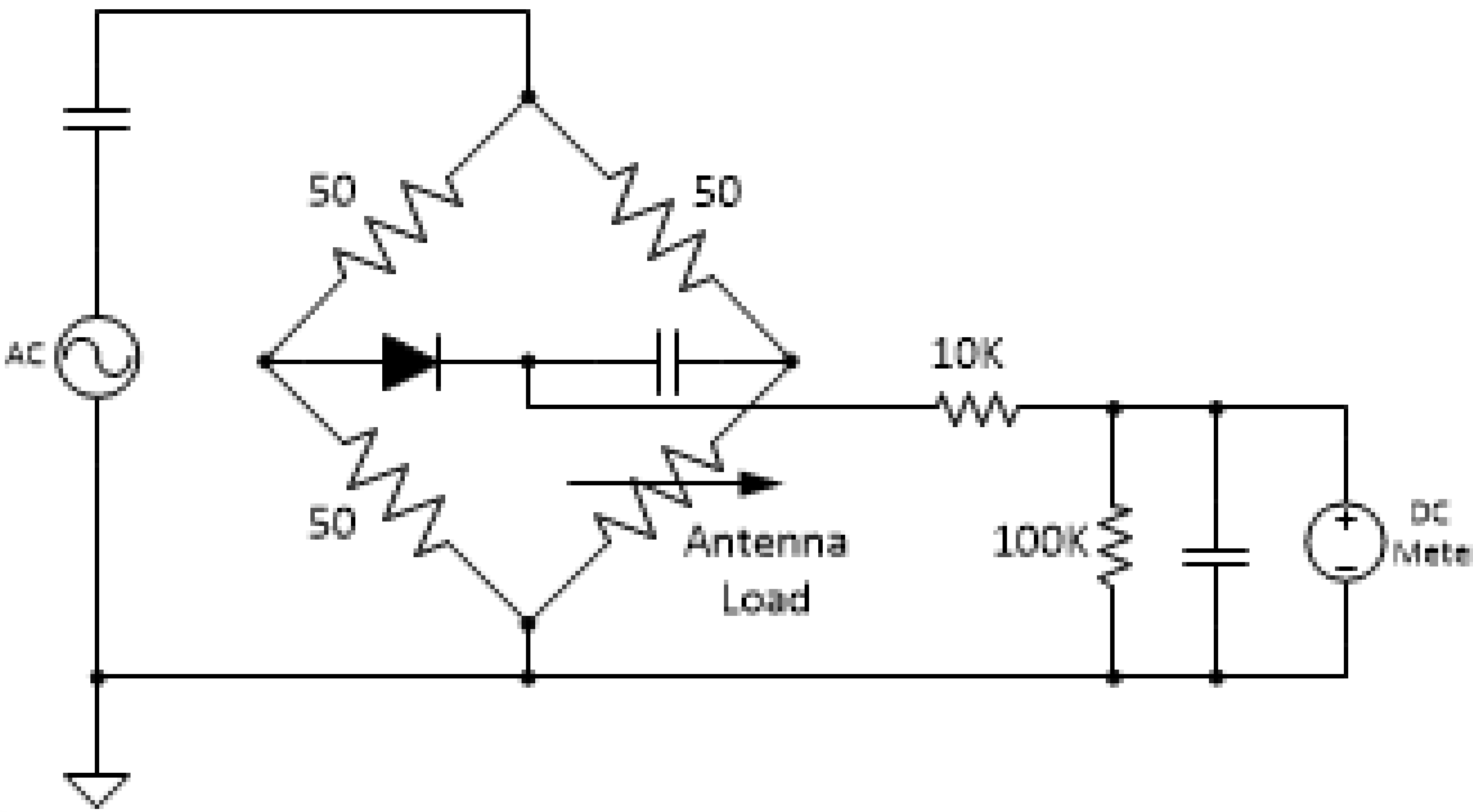
VSWR Bridge Schematic



The Wheatstone Bridge



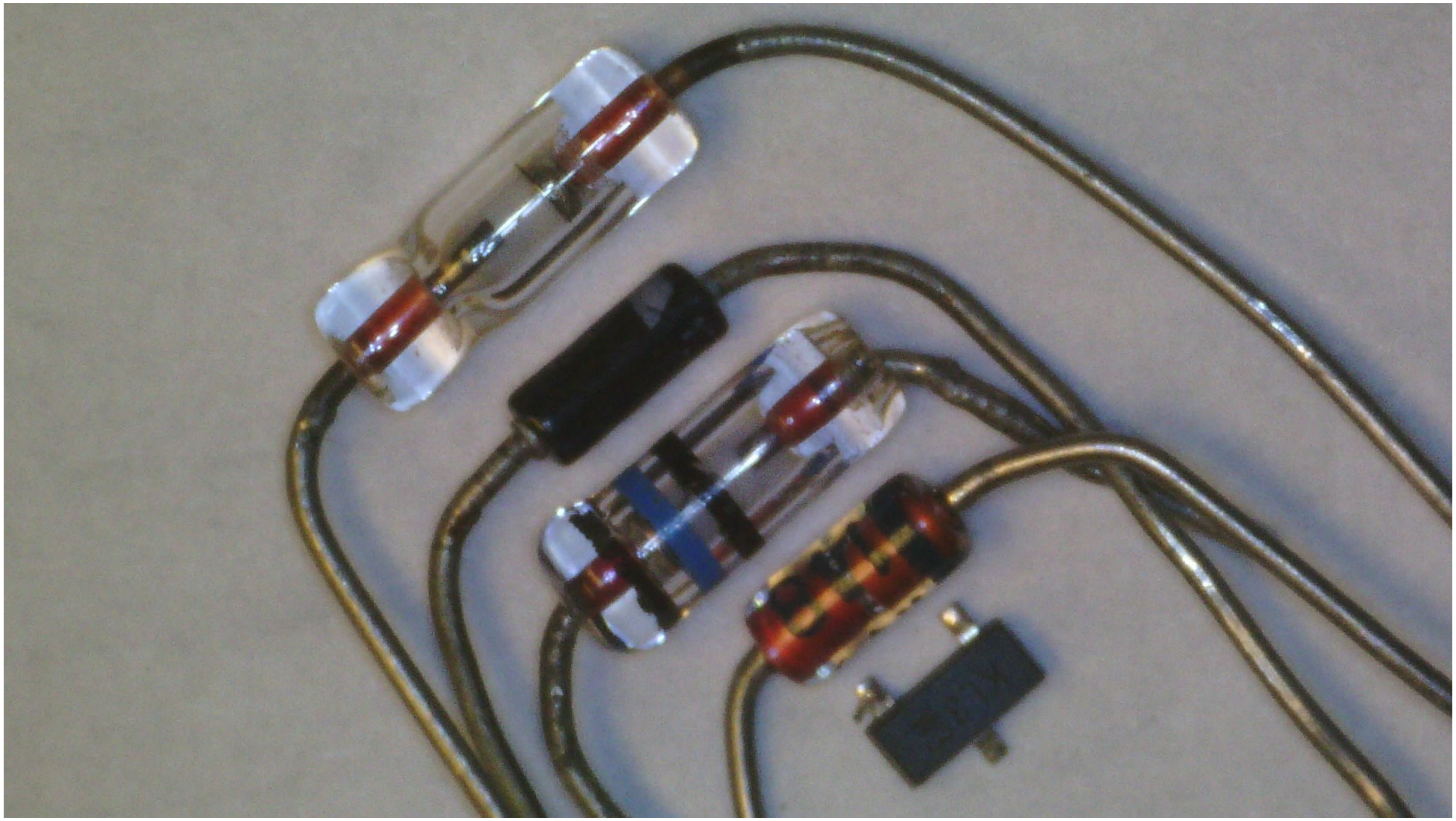
The VSWR Bridge



Magic Sauce – Detector Diode

- AA143 – no longer in production
- Is nearly unobtainium
- What makes it special?
  - Low forward voltage drop
  - Low conduction current
  - Low capacitance
  - Fast transfer time (high frequency)

Diodes – various packages



Diode Comparisons

Type	Example P/N	V_F @1 ma	I_R @ 20V	T_{RR}	C_J	Junction
Silicon	1N914	0.62 V	0.025 uA	4 ns	4 pf	P-N
Germanium	1N34A AA143	0.3 V	25 uA	70 ns	0.5 pf	P-N
Schottky Barrier	1N5819 BAT17	0.5 V	0.1 uA	50 ns	1.5 pf	N-Metal
Ideal		0 V	0 uA	0 ns	0 pf	

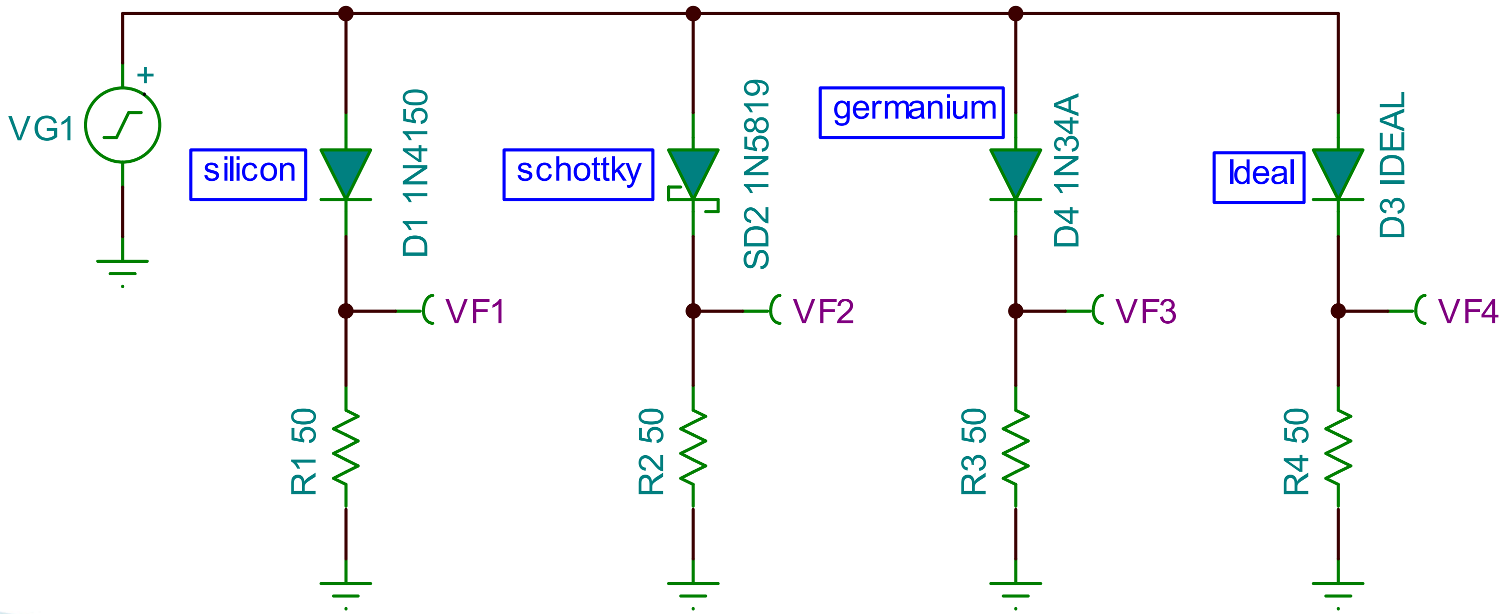
SPICE
Diode Model Parameters

Silicon	Germanium	Schottky	Ideal	Parameter
1N914	!N34A	1N5819		Part Number
1E-9	1E-06	2E-07	1E-07	IS – controls forward and reverse current against voltage.
1.7	0.537	0.850	1E-07	N – controls forward current against voltage.
100	40	75	100	BV, IBV – control reverse breakdown characteristics.
4E-12	1.36E-10	5E-13	1E-14	CJO, M , VJ – control variation of capacitance with voltage.
1.11	1.11	0.670	1E-01	EG – controls barrier height.
0.002	0.0556	7	1E-03	RS – series resistance controls forward voltage at high current.
25.9E-9	1.67E-09	1E-10	1E-13	TT – controls switching reverse recovery characteristics.
10		10		RZ – zener Resistance

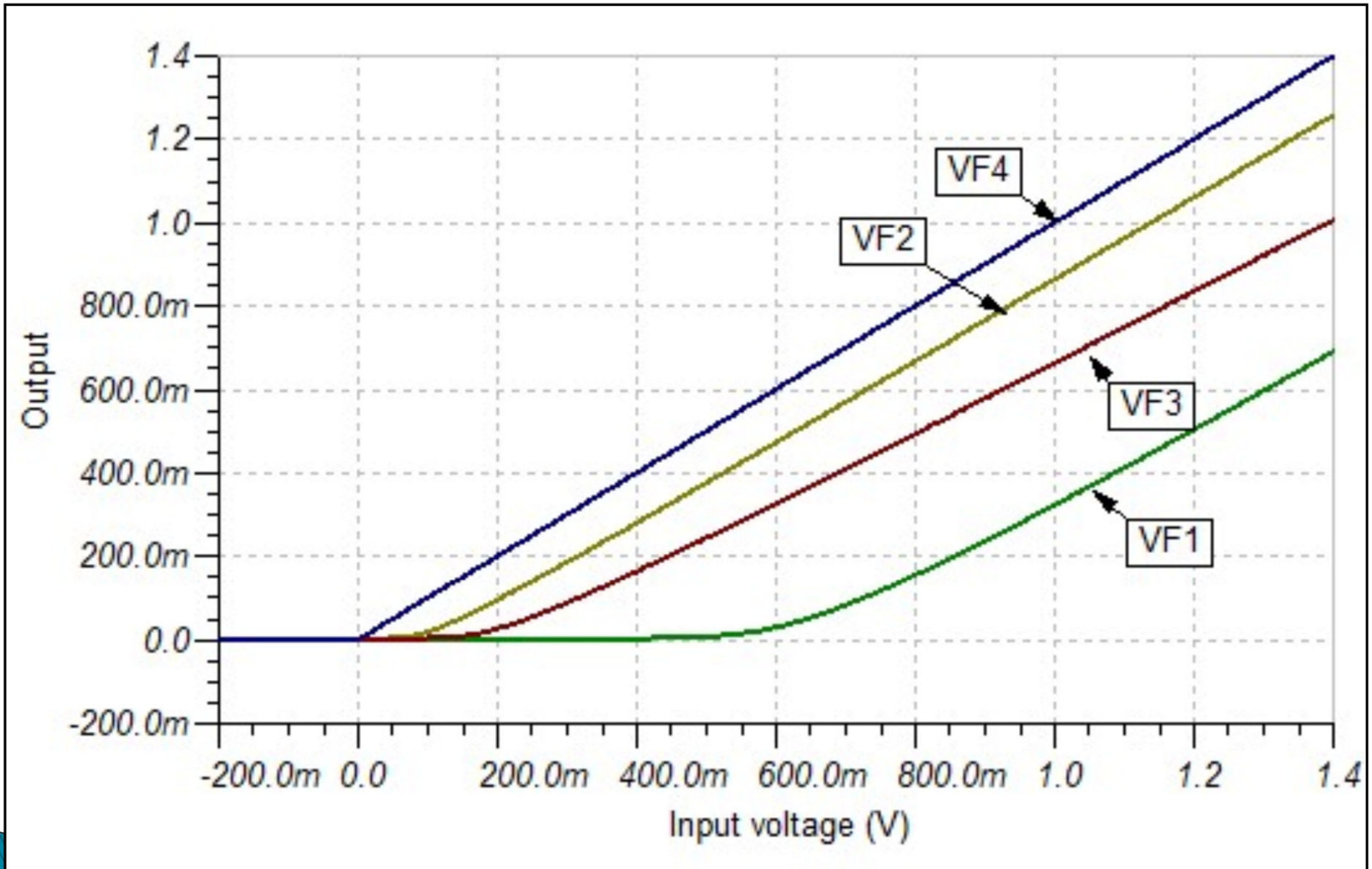
Diode Simulations –50Ω Load

Barry Basile, 11/04/17
Diode DC Transfer Characteristics

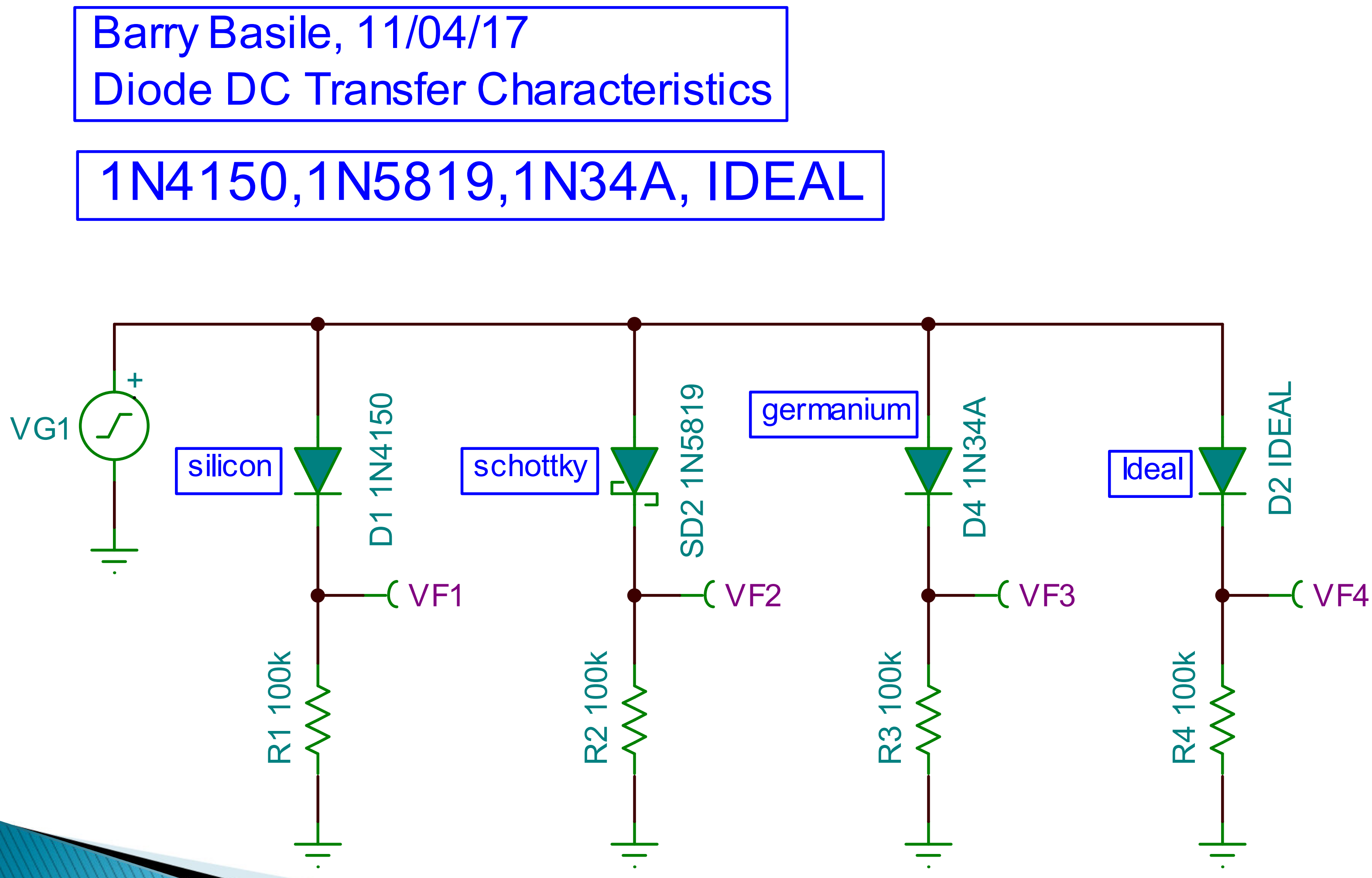
1N4150,1N5819,1N34A, IDEAL



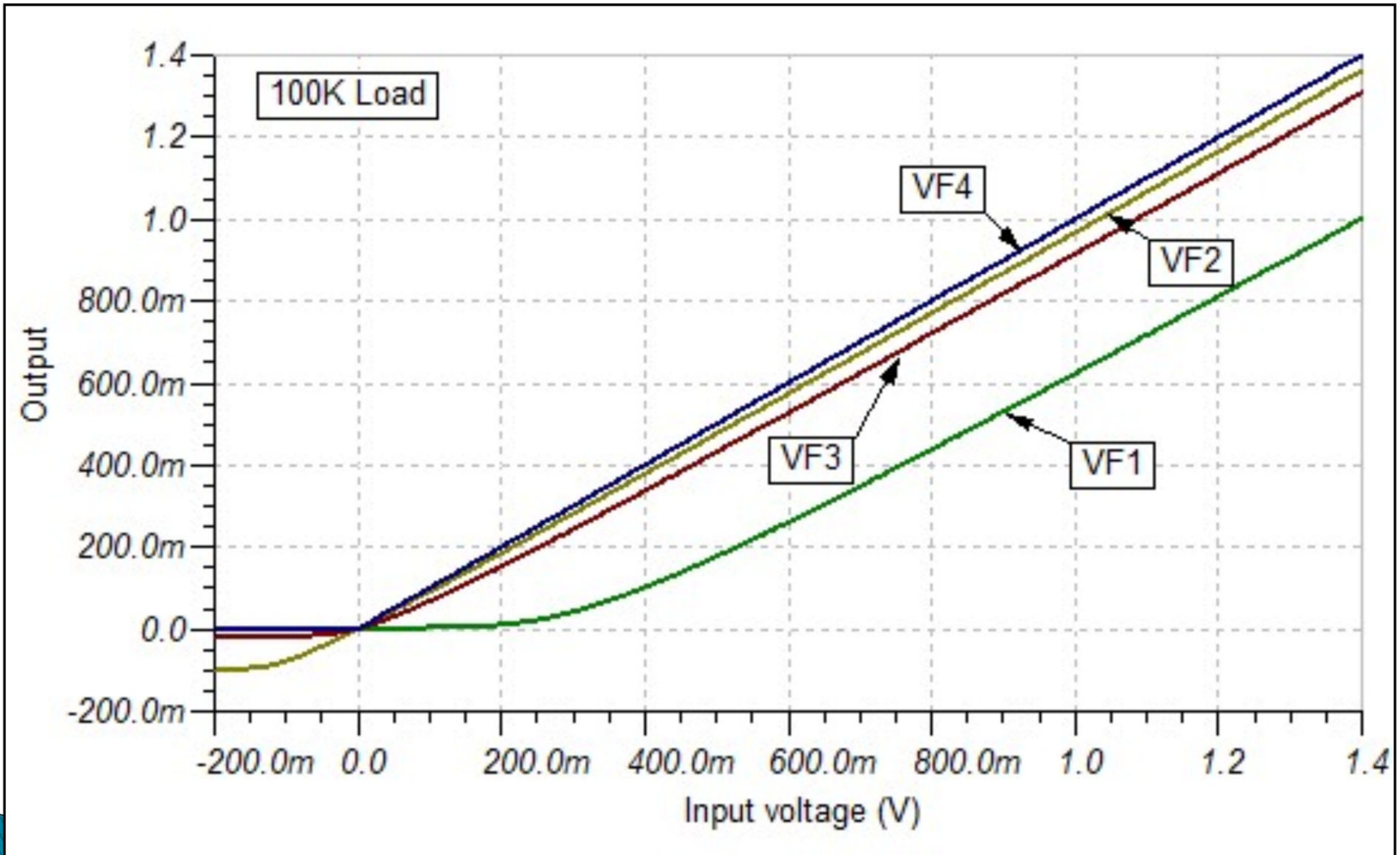
Voltage Transfer, 50Ω Load



Diode Simulations –100k Load



Voltage Transfer, RL = 100k



Reverse Engineering

ADC Voltage Range	0 – 5V	Assume 0-4V
Op amp Gain	1 + RF/RI	1 + (33k/649) ~ 52
VSWR Gain	0.5 – diode VF	Assume 0.4
DDS Output (sine)	(4/52) /.4	Assume about 200mv peak

MCU Code – Frequency Sweep

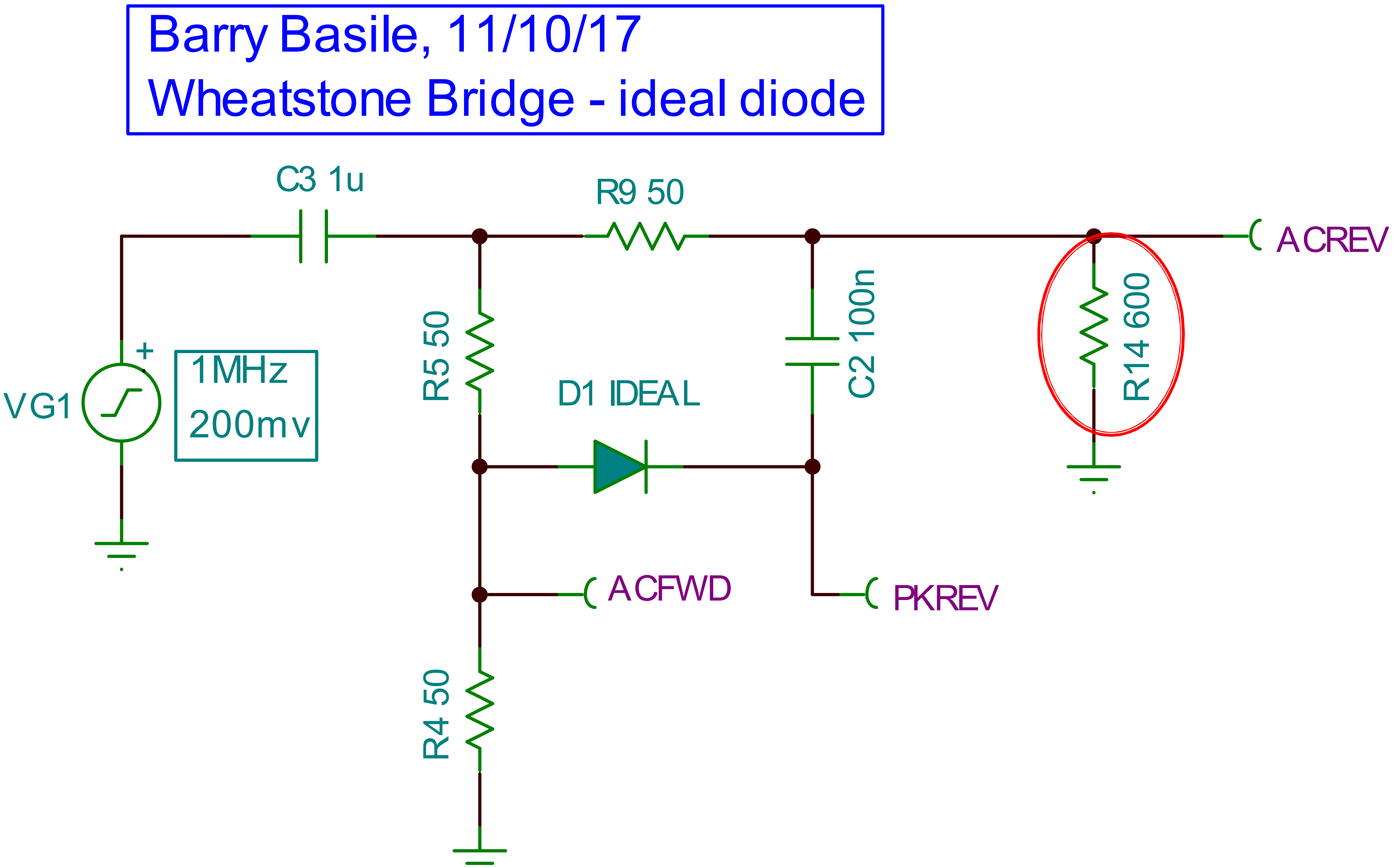
```
// Start loop
 for(long i=0;i<=num_steps;i++){
   // Calculate current frequency
   current_freq = Fstart + i*Fstep;

   // Set DDS to current frequency
   SetDDSFreq(current_freq);
   // Wait a little for settling
  if(digitalRead(BAND) == LOW){mode_pressed=1;}
   delay(10); // 10 msec
   // Read the forawrd and reverse voltages
   REV = analogRead(A0);
   FWD = analogRead(A1);
```

MCU Code – VSWR Calculation

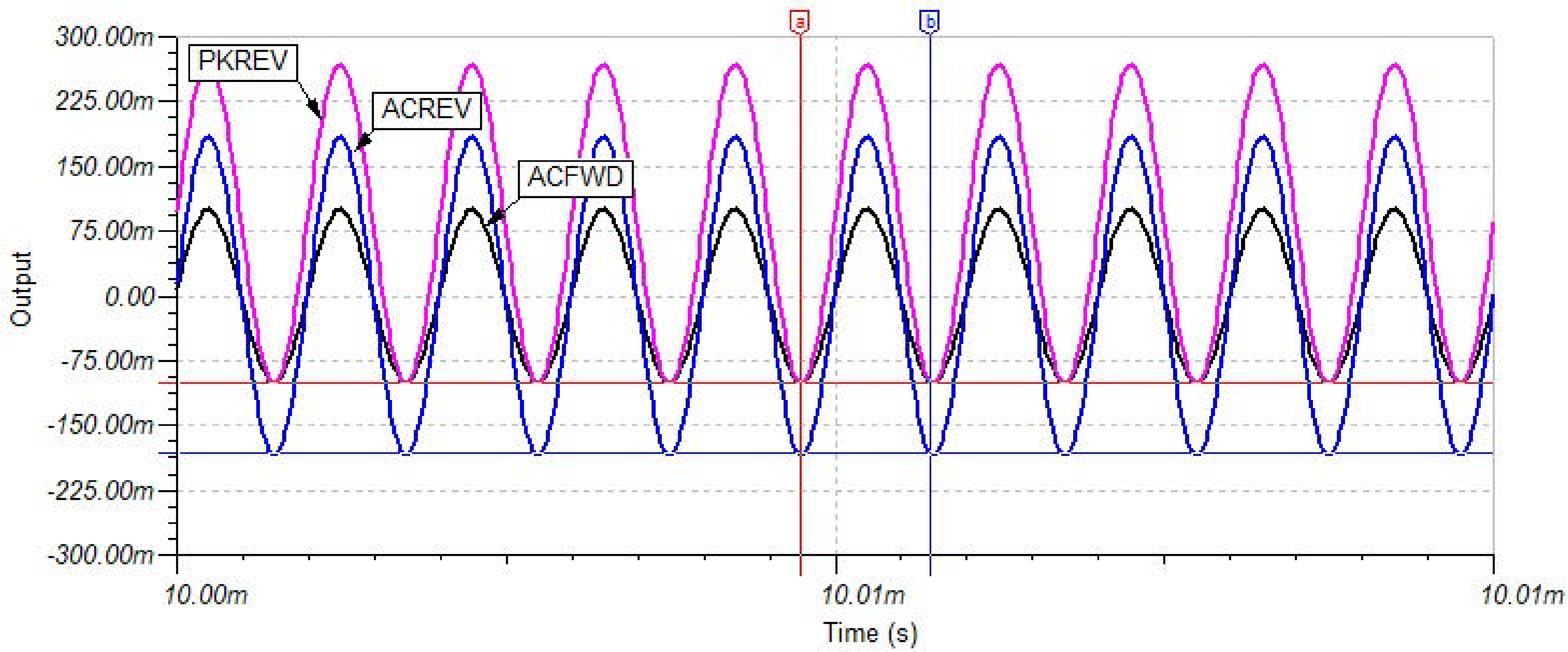
```
if(REV>=FWD){
      // To avoid a divide by zero or negative VSWR then set to max 999
      VSWR = 999;
    }else{
      // Calculate VSWR
      VSWR = ((double)FWD+(double)REV)/((double)FWD-(double)REV);
    }
```

```
// That is: VSWR = (FWD+REV)/(FWD-REV);
```

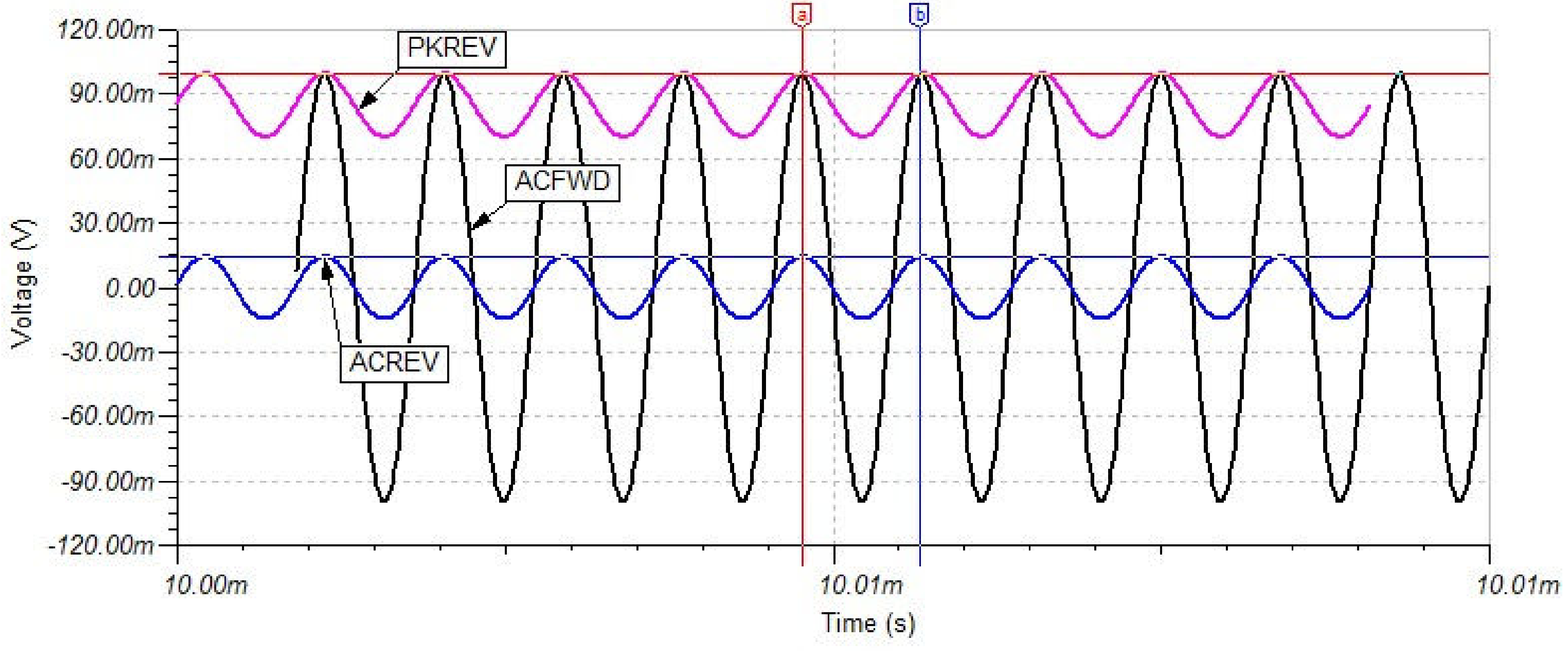
Bridge Simulation – Ideal Diode



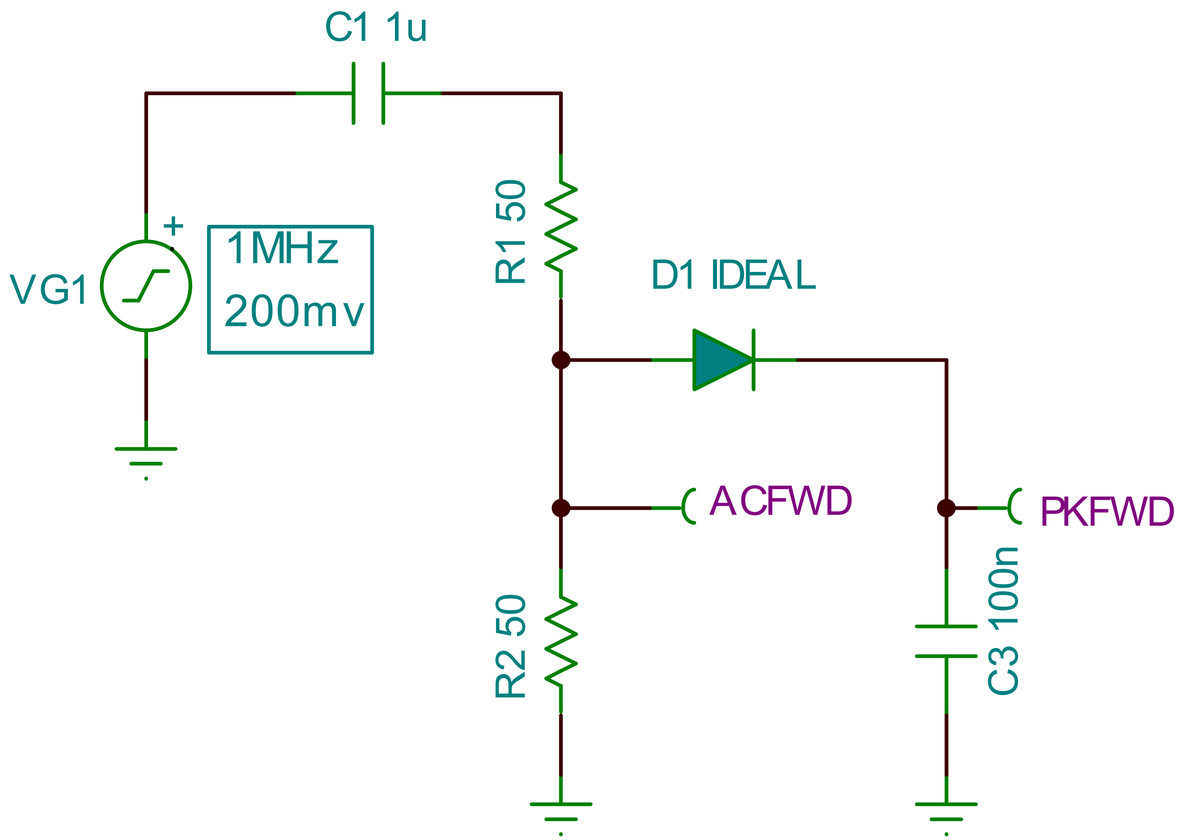
Simulation at RL = 600Ω



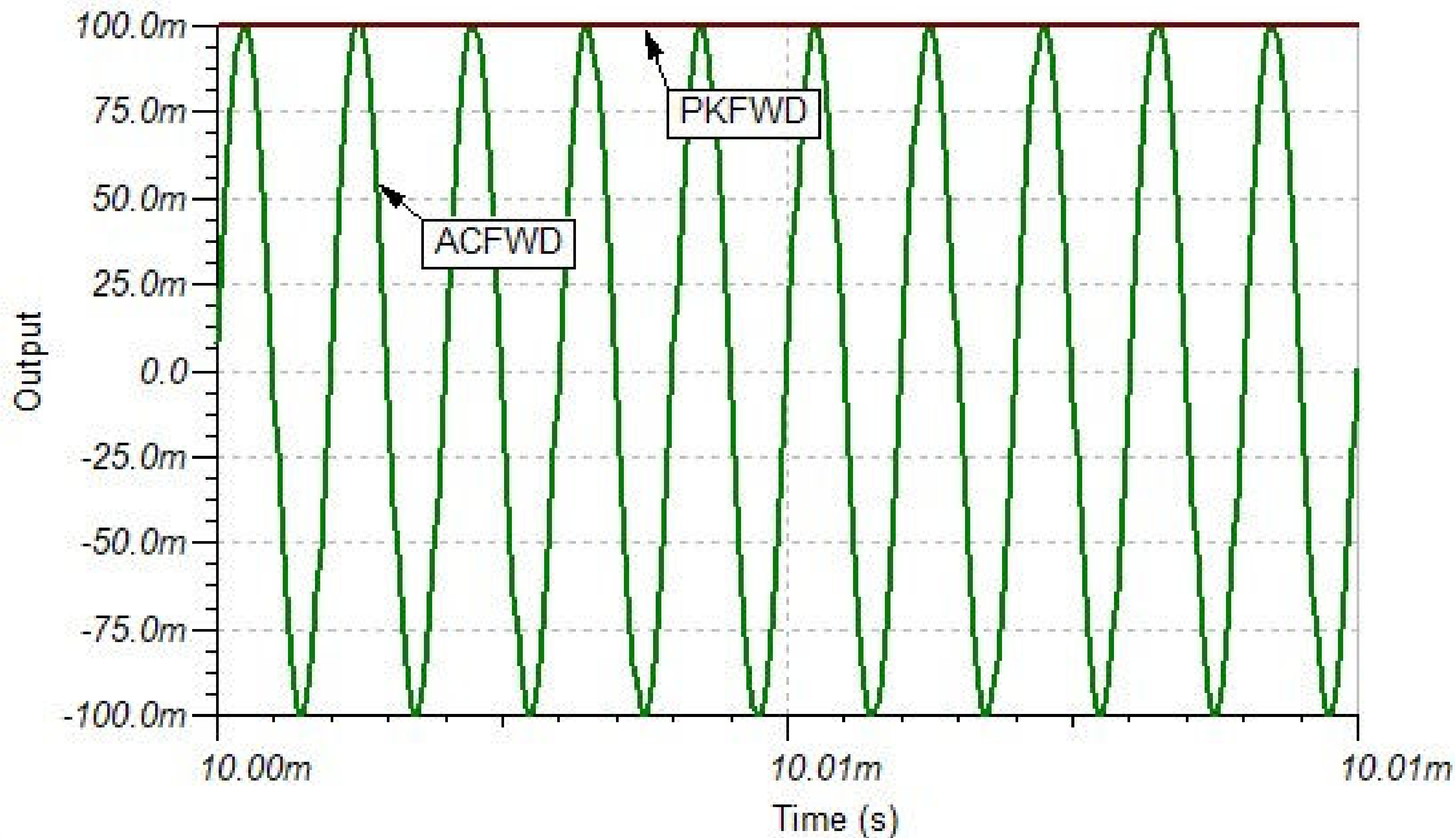
Simulation at RL = 4Ω



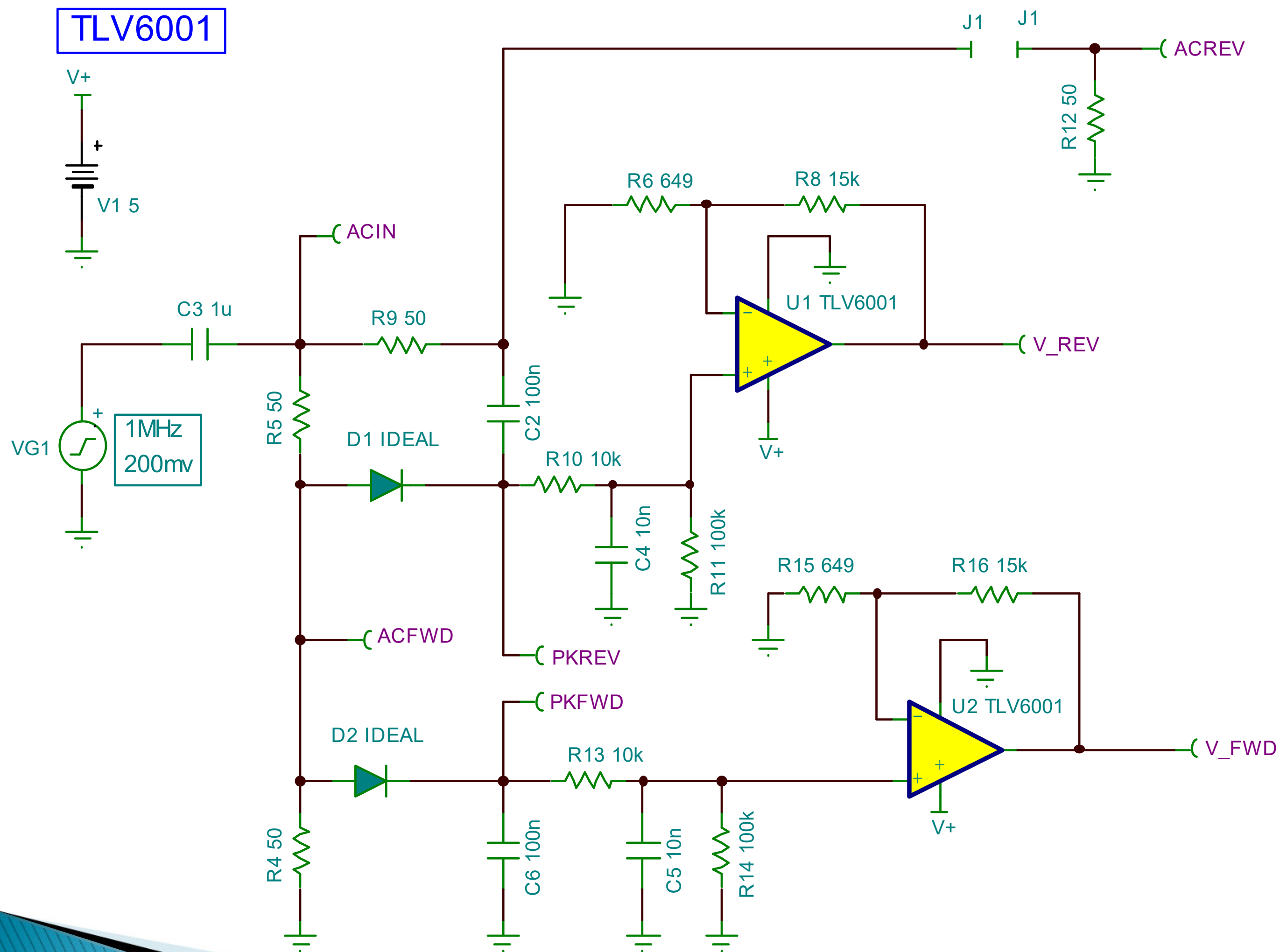
Forward Voltage – Reference



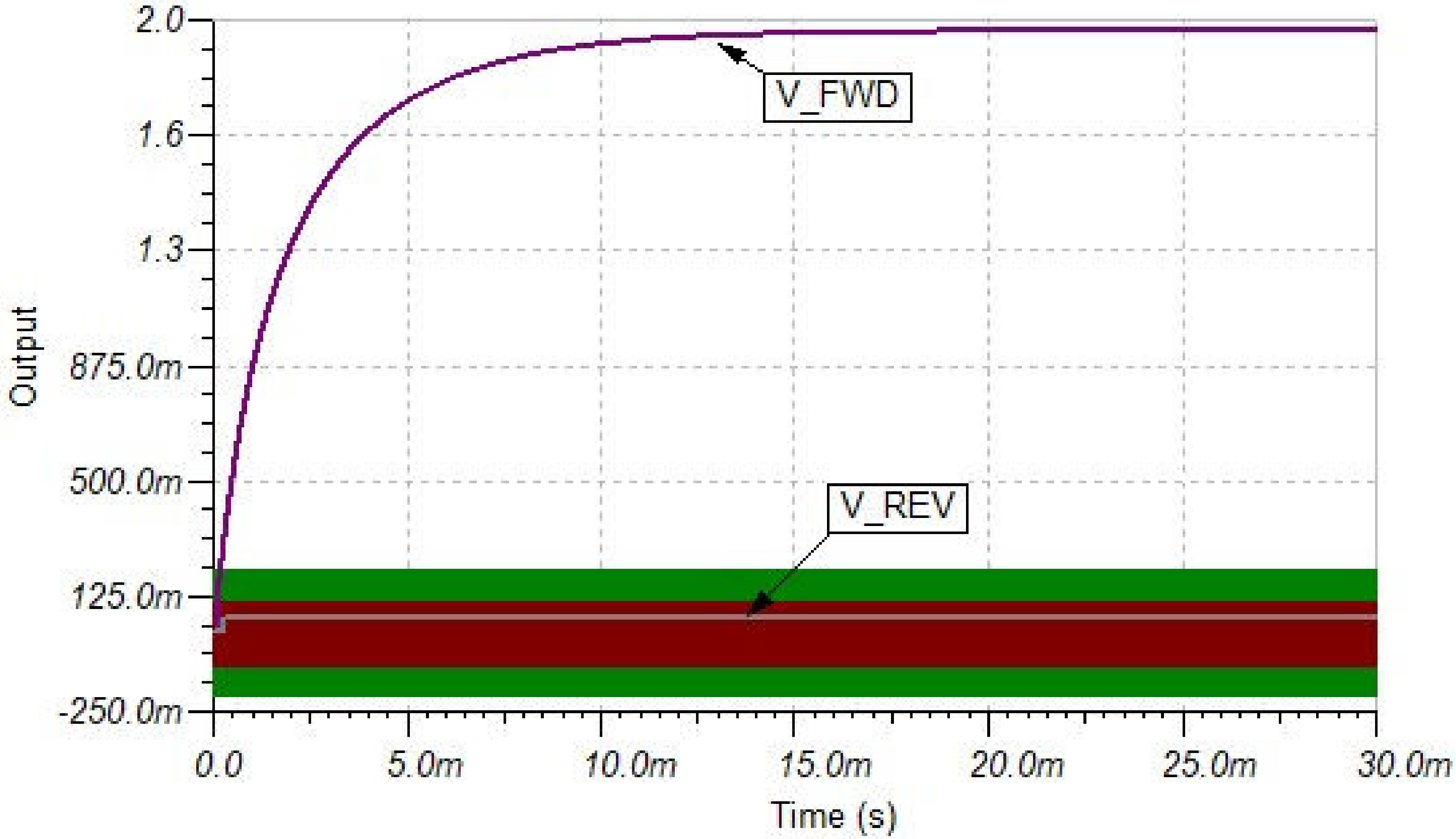
Forward Voltage Peak Detector



Simulation Circuit

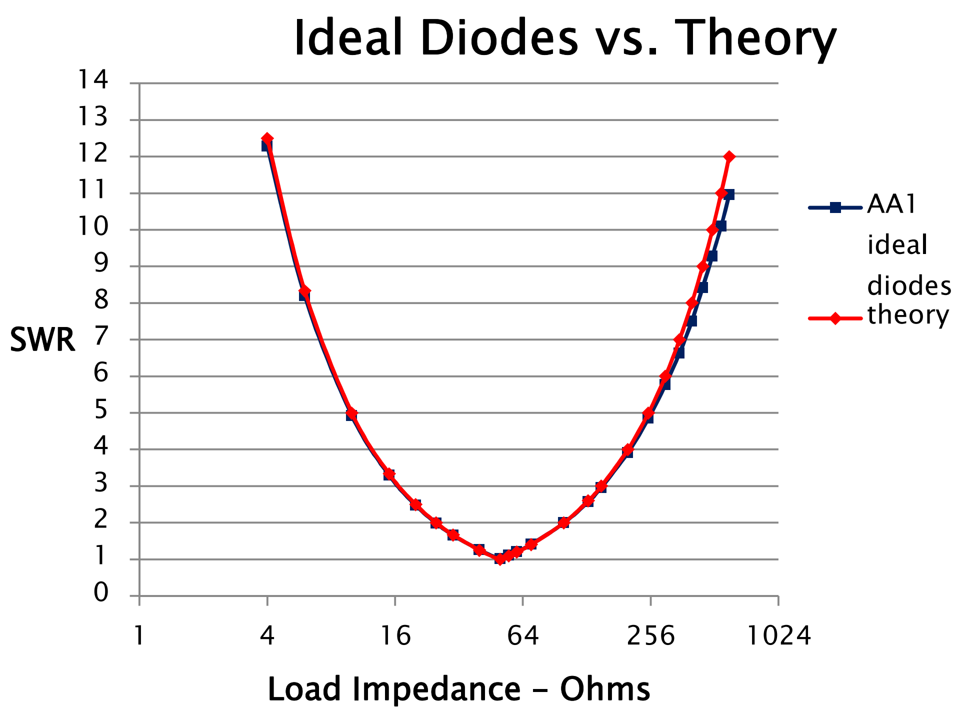


Settling Time – 1N34A

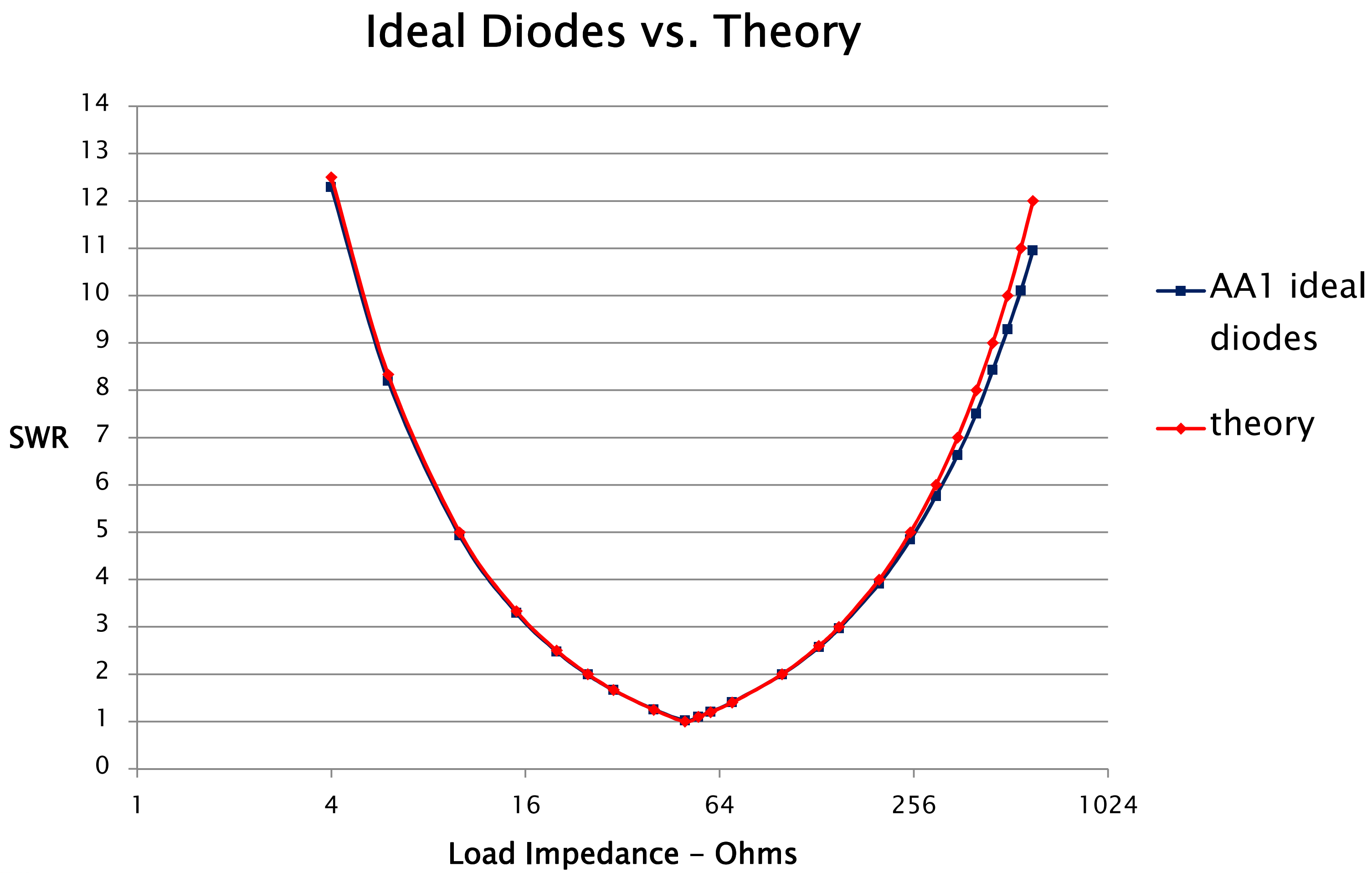


Ideal Diodes vs. Theory

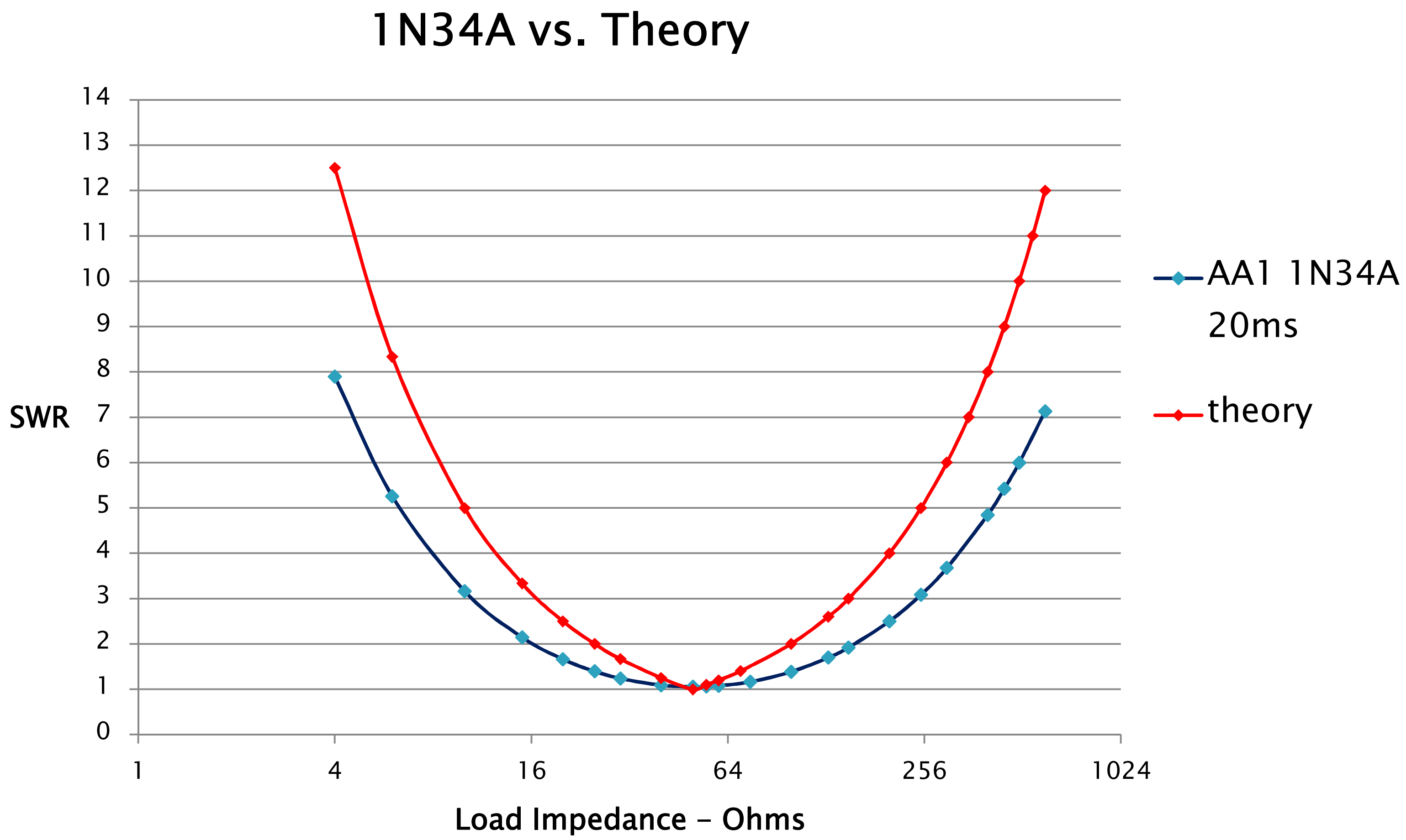
Case: Reference Design Simulated with ideal diodes					
Zo =	50 ohms				
Load	Vrev	Vfwd	AA1 ideal diodes	lamda	theory
4	1.840	2.166	12.289	-0.852	12.50
6	1.696	2.168	8.199	-0.786	8.33
10	1.438	2.170	4.930	-0.667	5.00
15	1.161	2.173	3.294	-0.538	3.33
20	0.924	2.176	2.478	-0.429	2.50
25	0.720	2.178	1.987	-0.333	2.00
30	0.540	2.179	1.660	-0.250	1.67
40	0.247	2.177	1.256	-0.111	1.25
50	0.023	2.191	1.021	0.000	1.00
55	0.107	2.184	1.103	0.048	1.10
60	0.206	2.191	1.208	0.091	1.20
70	0.370	2.192	1.406	0.167	1.40
100	0.727	2.189	1.995	0.333	2.00
130	0.965	2.192	2.573	0.444	2.60
150	1.084	2.187	2.964	0.500	3.00
200	1.297	2.187	3.915	0.600	4.00
250	1.439	2.188	4.846	0.667	5.00
300	1.541	2.188	5.764	0.714	6.00
350	1.617	2.191	6.628	0.750	7.00
400	1.676	2.191	7.504	0.778	8.00
450	1.724	2.188	8.425	0.800	9.00
500	1.762	2.188	9.282	0.818	10.00
550	1.794	2.189	10.101	0.833	11.00
600	1.822	2.188	10.956	0.846	12.00



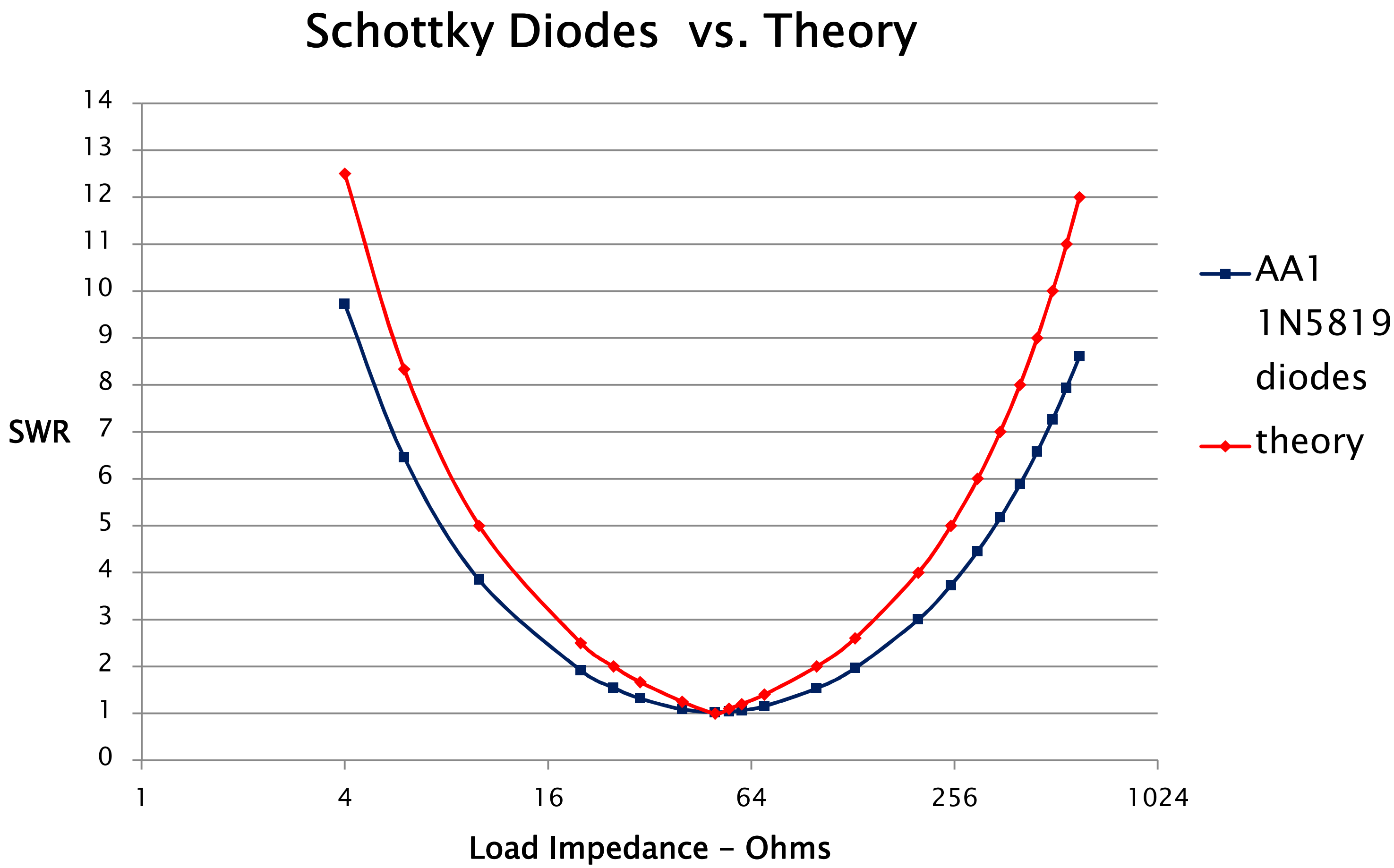
Ideal Diodes vs. Theory



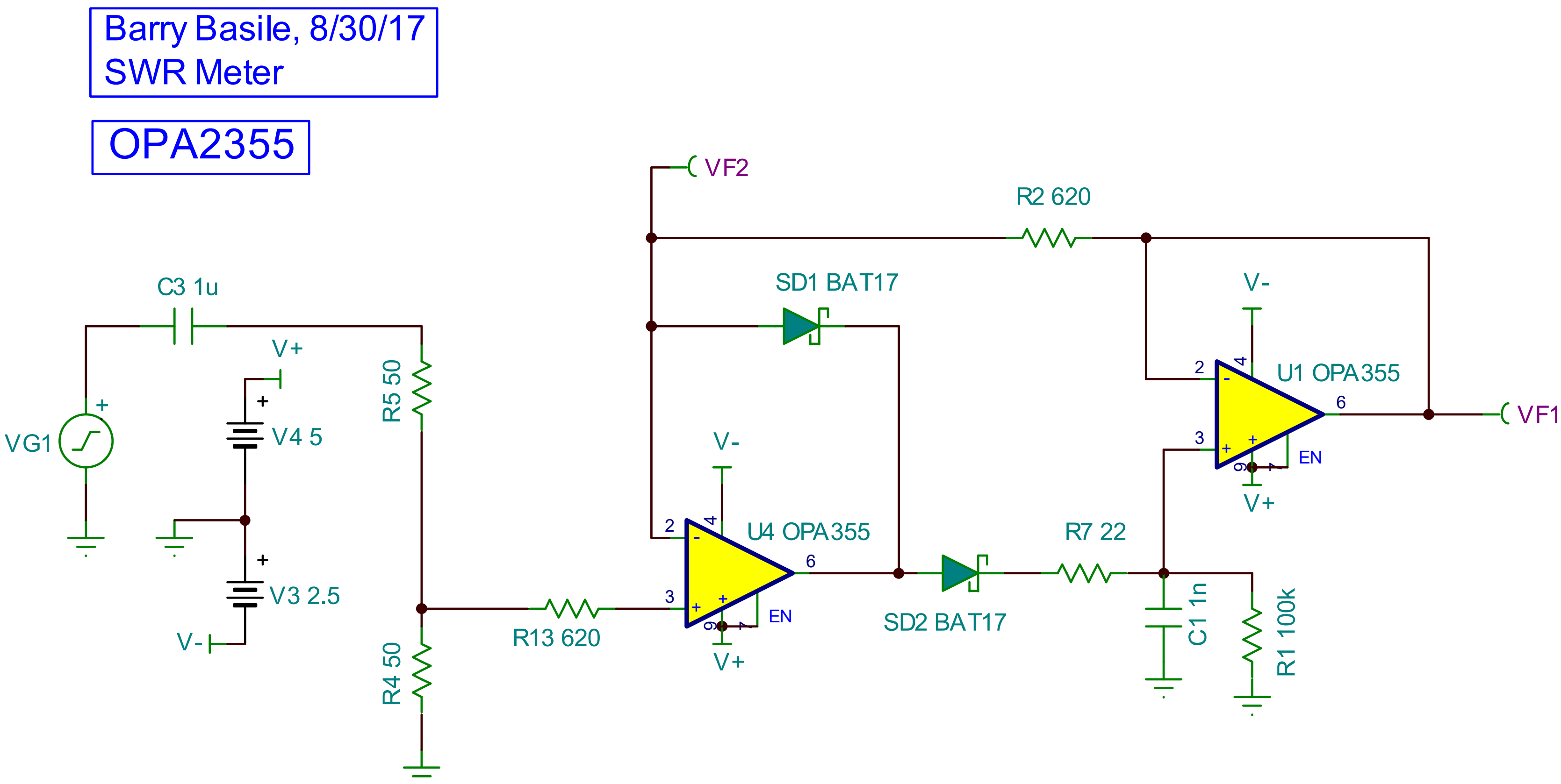
Germanium Diodes vs. Theory



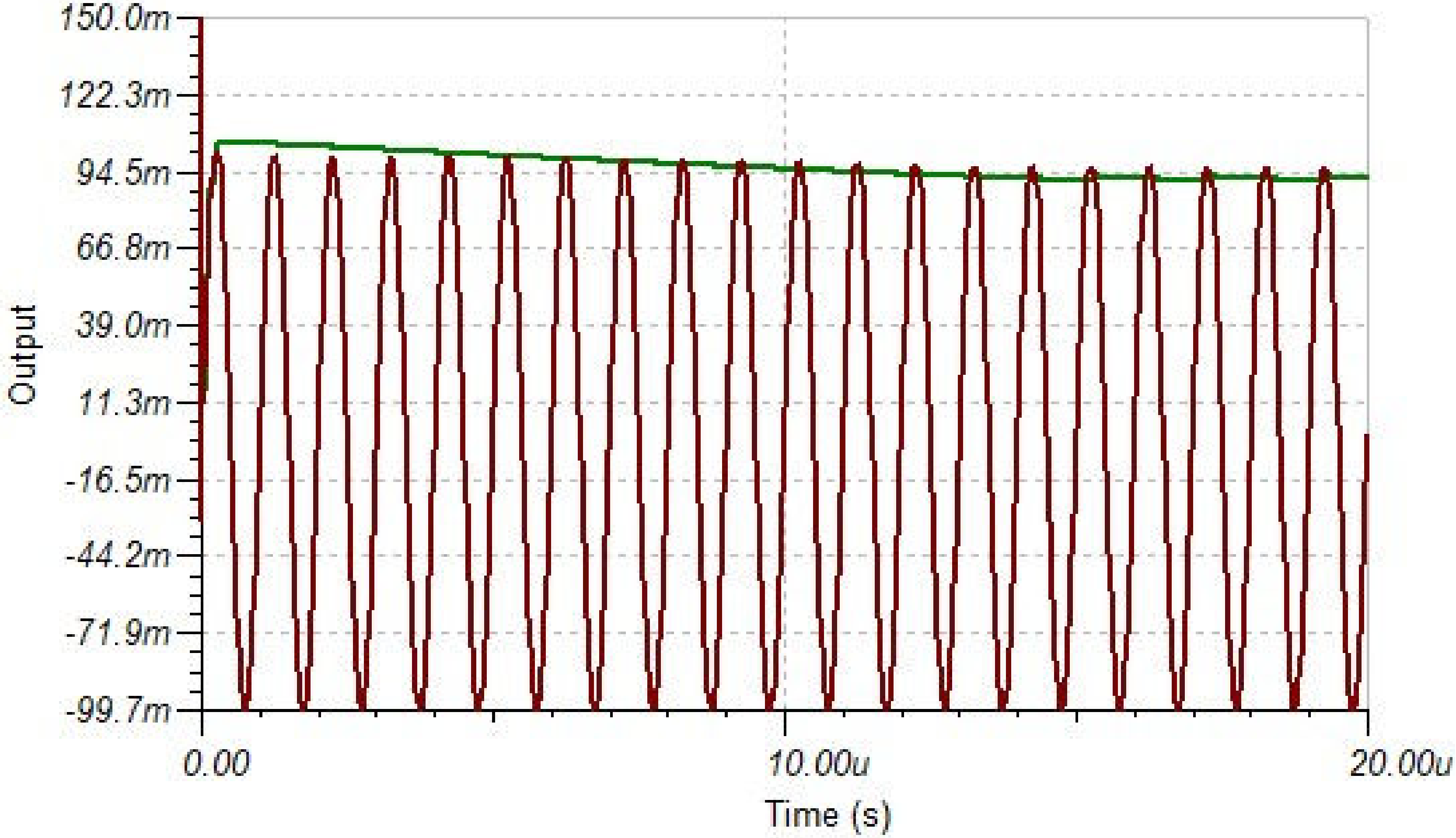
Schottky Diodes vs. Theory



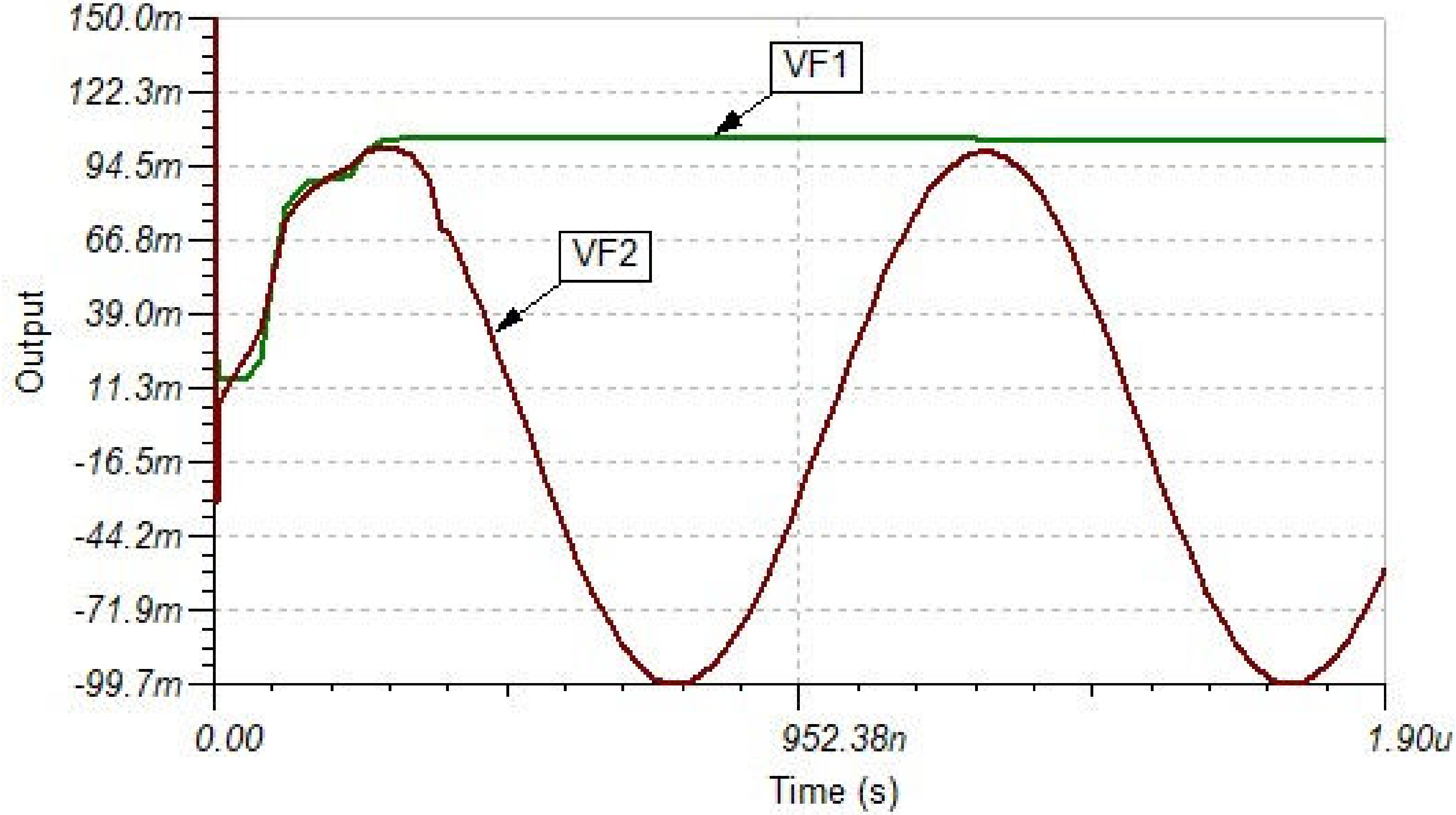
Op Amp Peak Detector



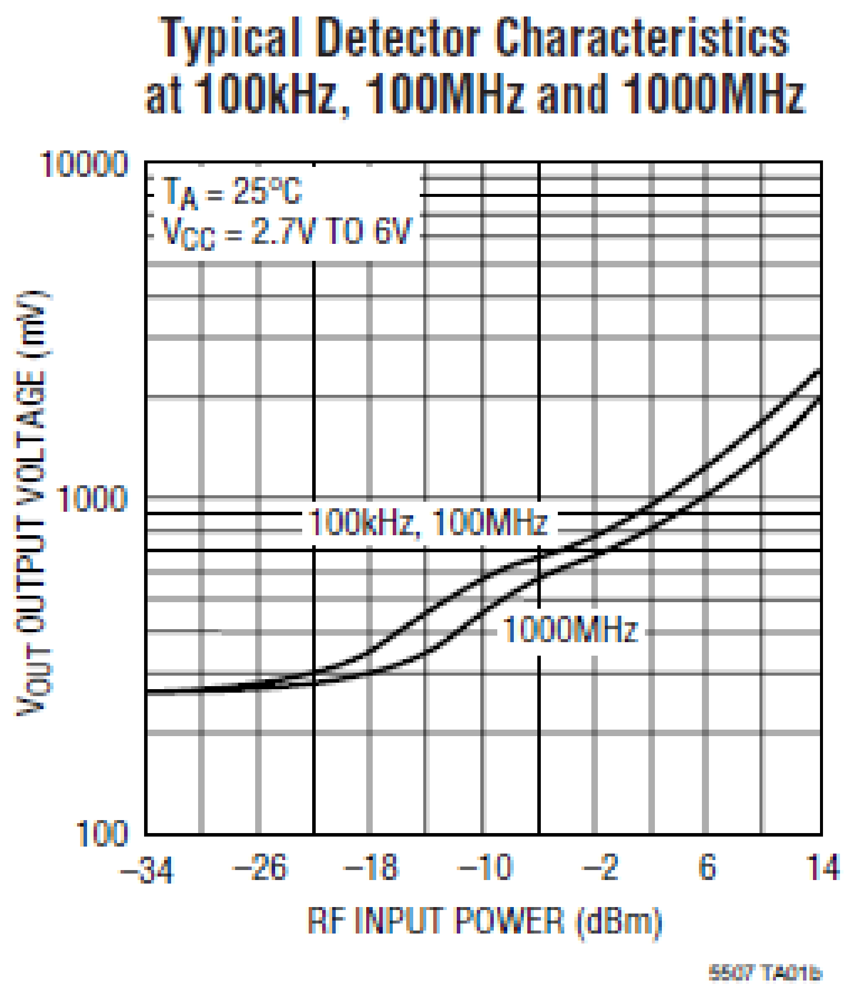
Op Amp Peak Detector



Op Amp Peak Detector



Best Solution – Use LTC5507



Future Plans

- Build and test original design with various diodes and measure accuracy against fixed dummy loads
- Develop an enhanced version using LTC5507 in place of diodes
- Report results to the club!

References

Original Description by K6BEZ:
www.hamstack.com/hs_projects/k6bez_antenna_analyzer.pdf

Wheatstone Bridge:
http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html

VI Curves:
http://www.electronics-tutorials.ws/blog/i-v-characteristic-curves.html

Maximum Power Transfer:
https://en.wikipedia.org/wiki/Maximum_power_transfer_theorem

SPICE:
https://en.wikipedia.org/wiki/SPICE
TINA:
https://e2e.ti.com/support/development_tools/webench_design_center/b/elabblog/archive/2011/05/03/download-tina-ti-version-9-1

Diode SPICE models:
http://www.keysight.com/upload/cmc_upload/All/Diode.pdf