Homebrew HF SWR/Power Meter

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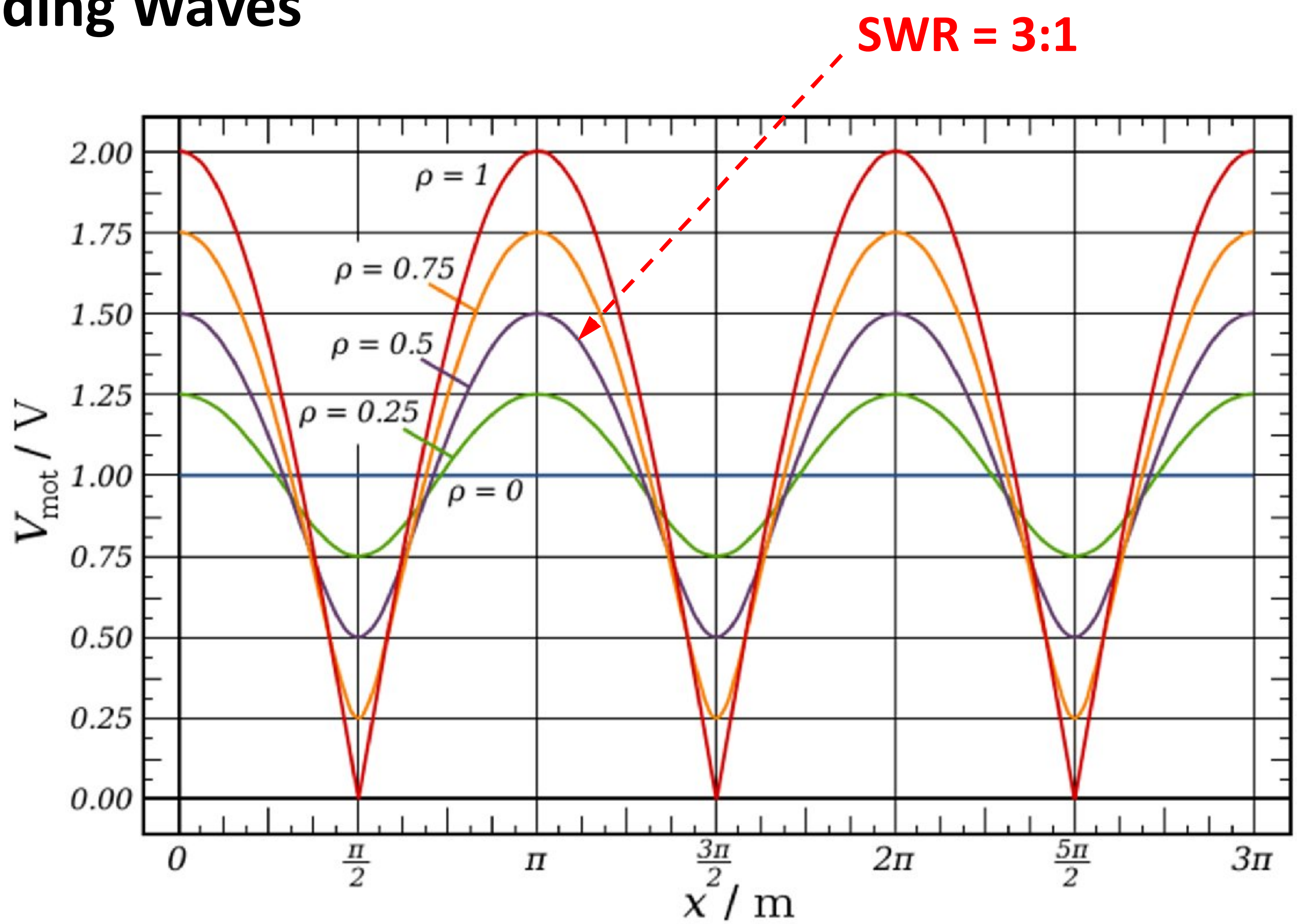
NAØTC - 285 TechConnect Radio Club
http://www.naøtc.org/

5/4/2012

Theory

- **Standing Waves**



Dynamic Demo: http://www.walter-fendt.de/ph14e/stwaverefl.htm

Theory

- **SWR Calculation**
  - ***Not a direct measurement***

$$SWR = \frac{1+\sqrt{\frac{P_R}{P_F}}}{1-\sqrt{\frac{P_R}{P_F}}} = \frac{E_F + E_R}{E_F - E_R}$$

E_F = Forward Voltage
E_R = Reverse Voltage
P_F = Forward Power
P_R = Reverse Voltage

SWR accuracy is only as good as the power measurement accuracy (both Forward & Reflected)

Theory

- **How should RF Power be measured?**
  1. **RF voltmeter connected at the output of the transmitter**

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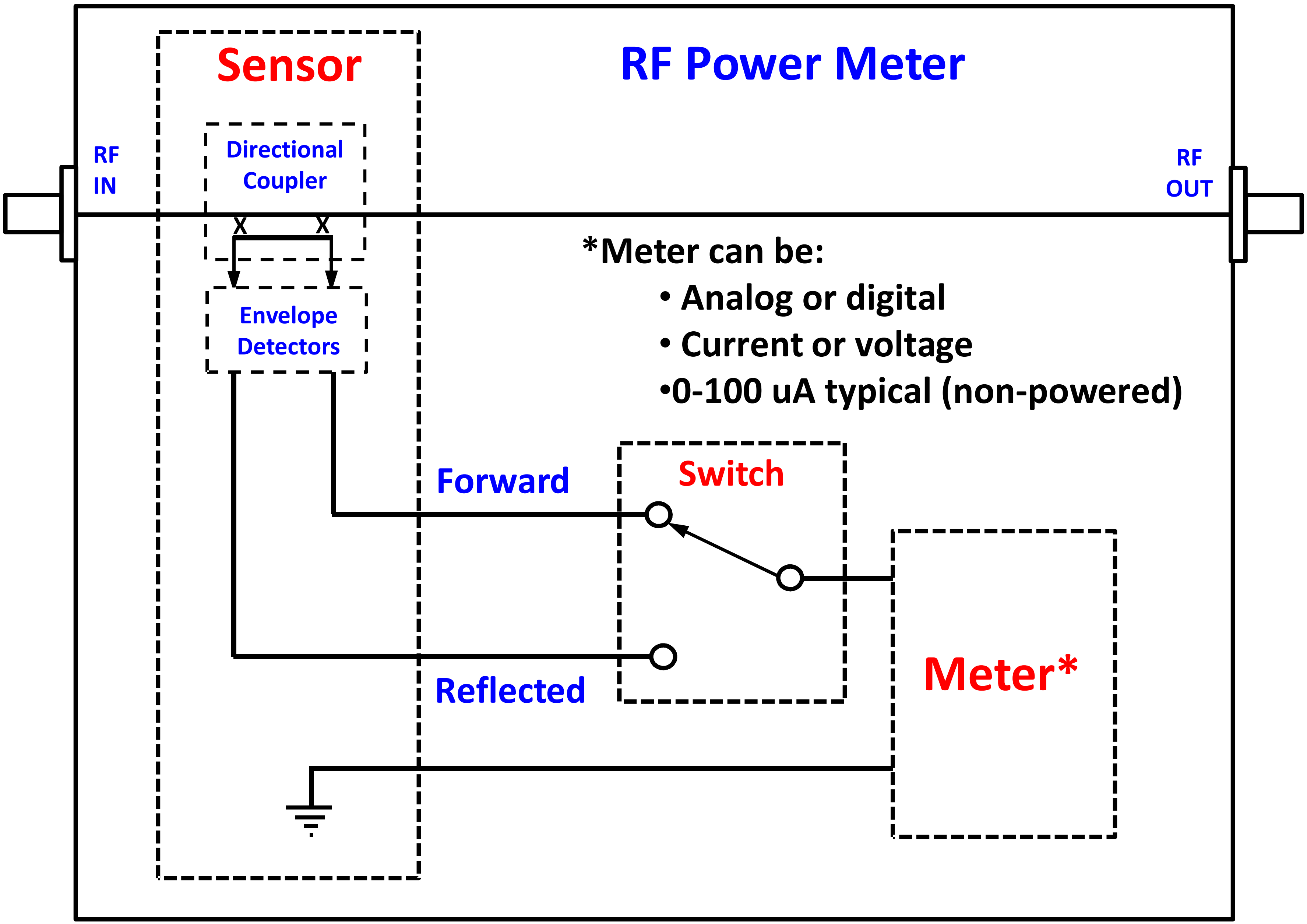
No!

1. **Voltage reading is dependent upon load impedance at the point of measurement**
   - **Power meters on Ameritron Power Amplifiers**
2. **To determine power, we need independent measurements of voltage and current**

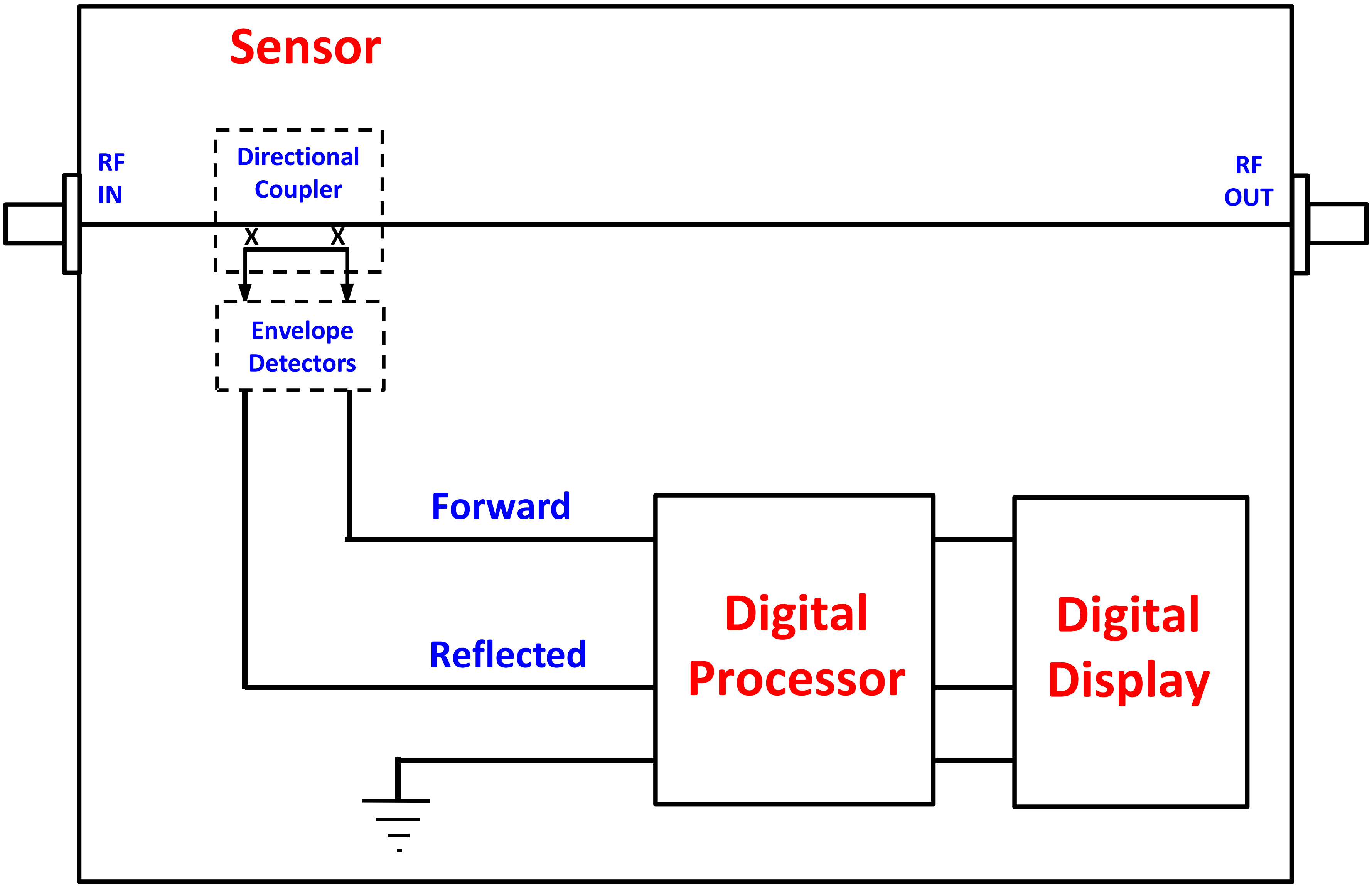
Theory

- **How should RF Power be measured?**
  1. RF voltmeter connected at the output of the transmitter
  2. **Use a TRUE POWER meter that can measure both current and voltage of both the forward and reflected waves**

RF Power Meter Components

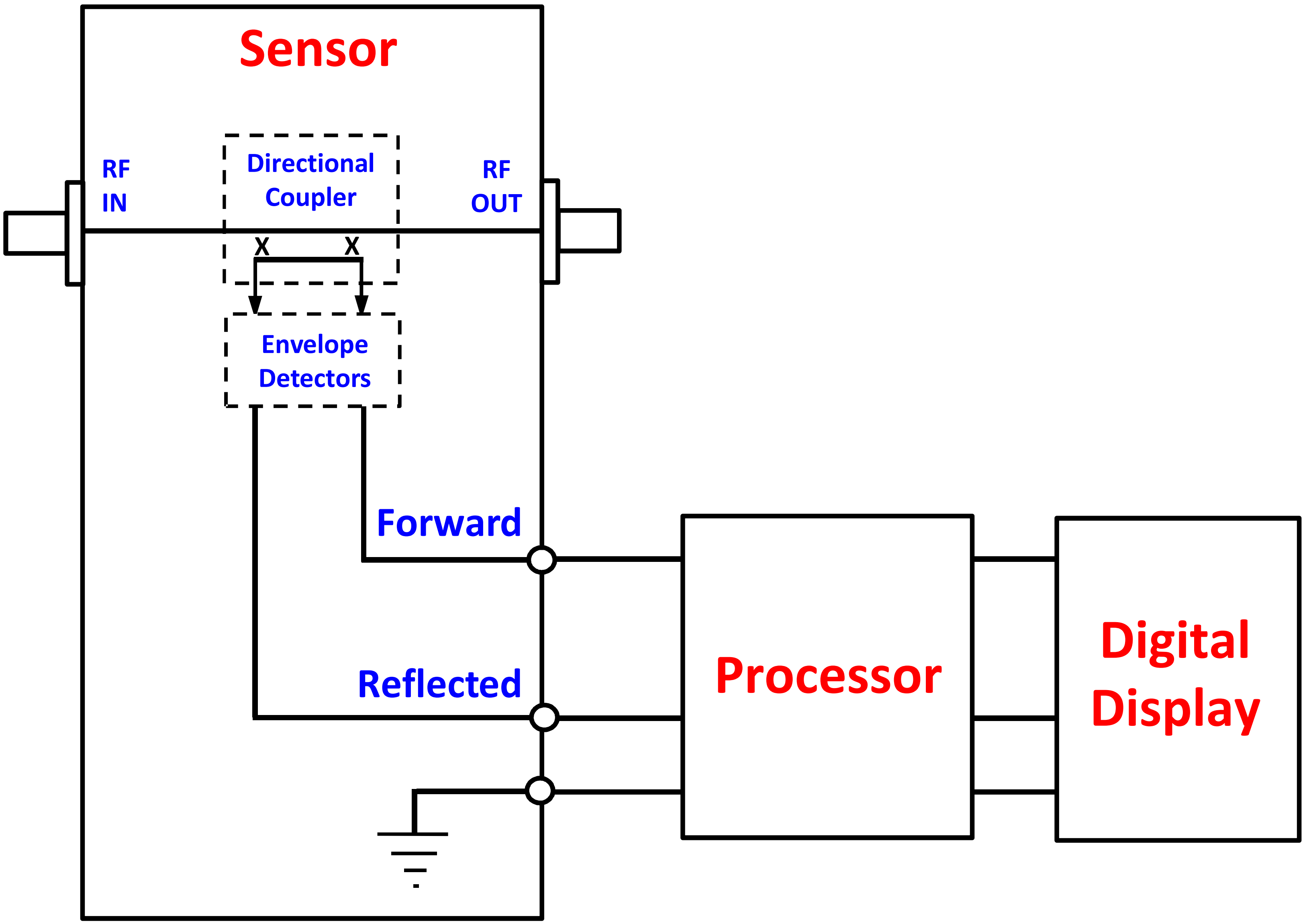


SWR/Power Meter - Digital

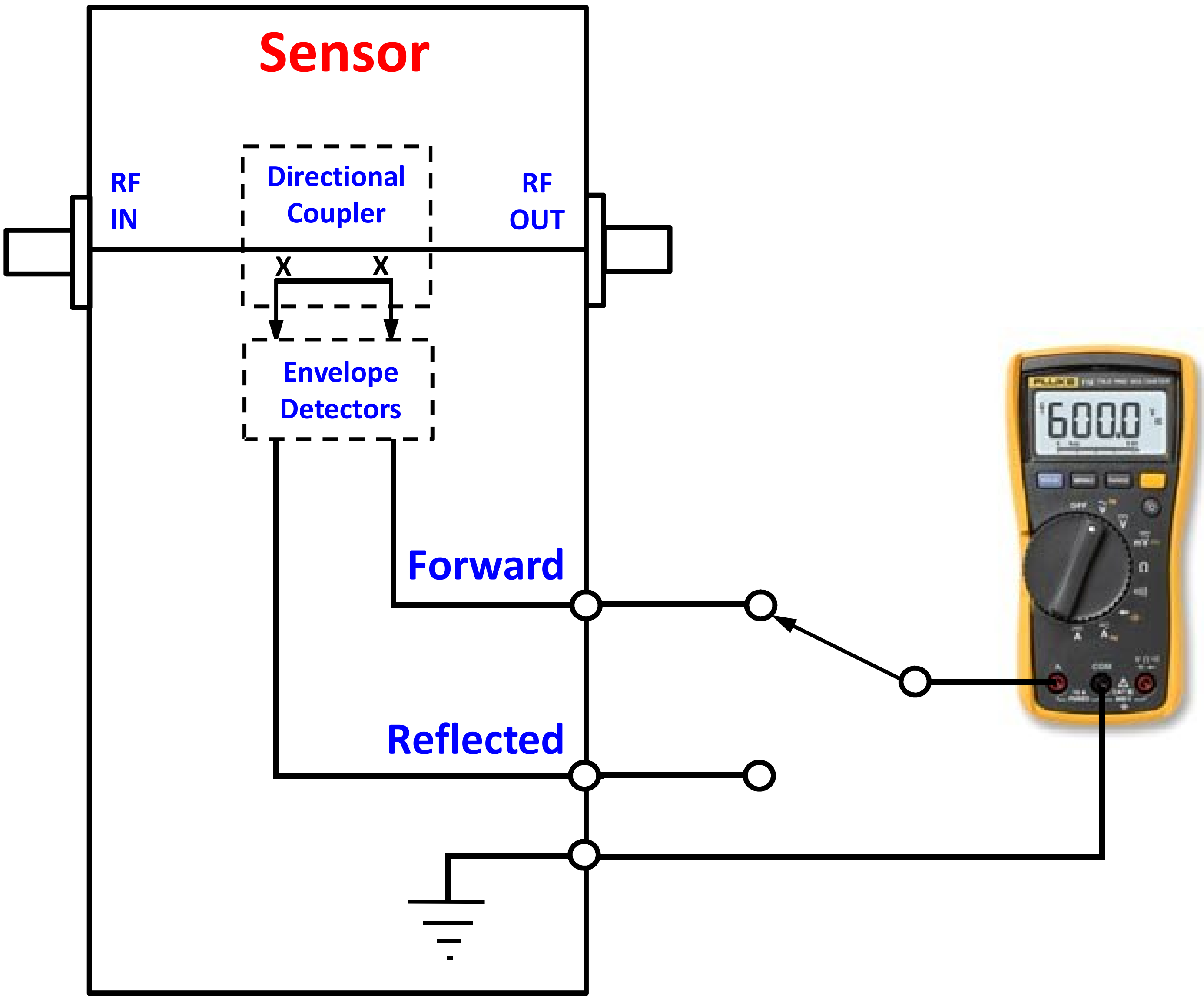


Alpha 4520 Digital Power/SWR Meter

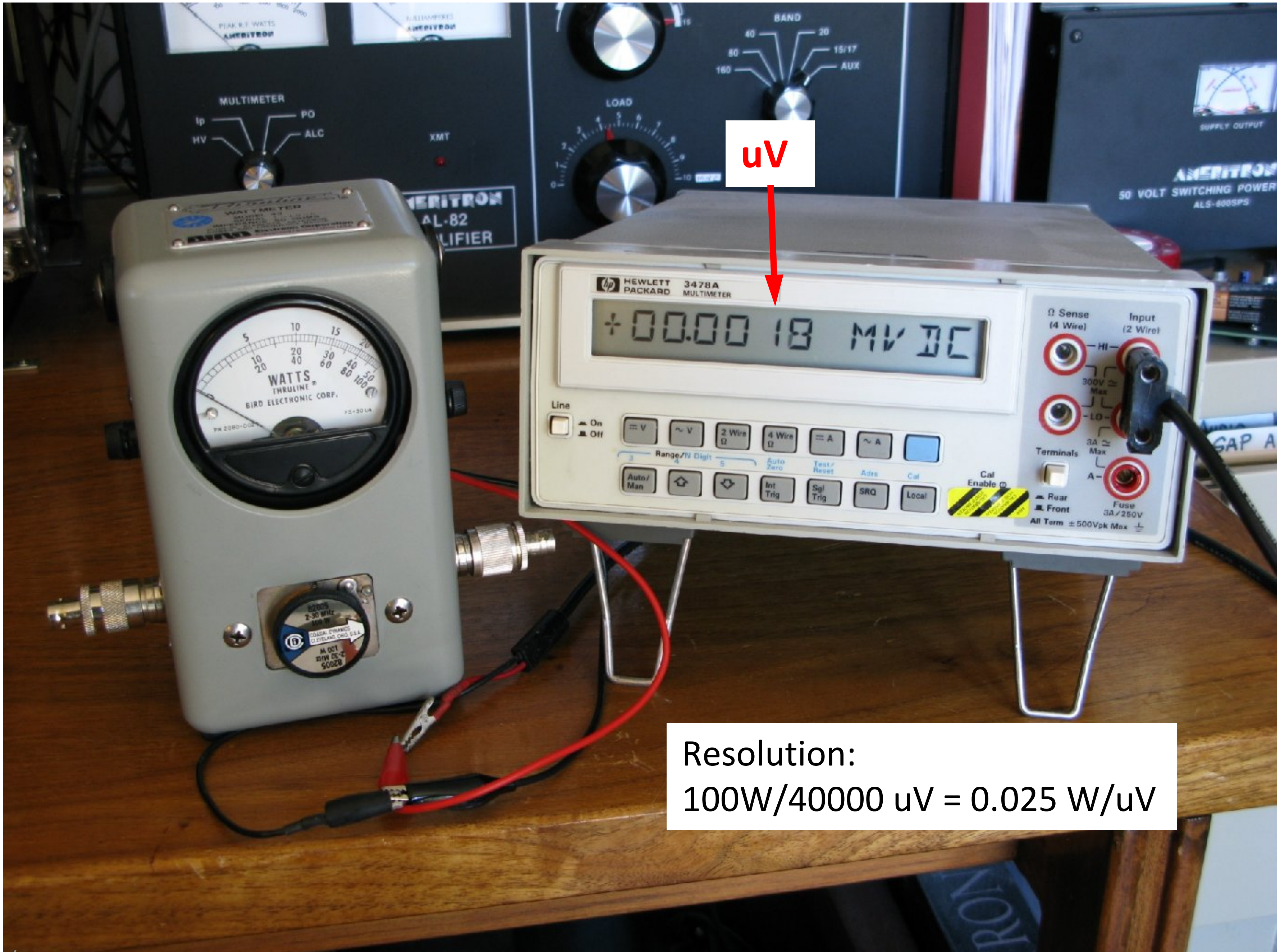
SWR/Power Meter - Digital



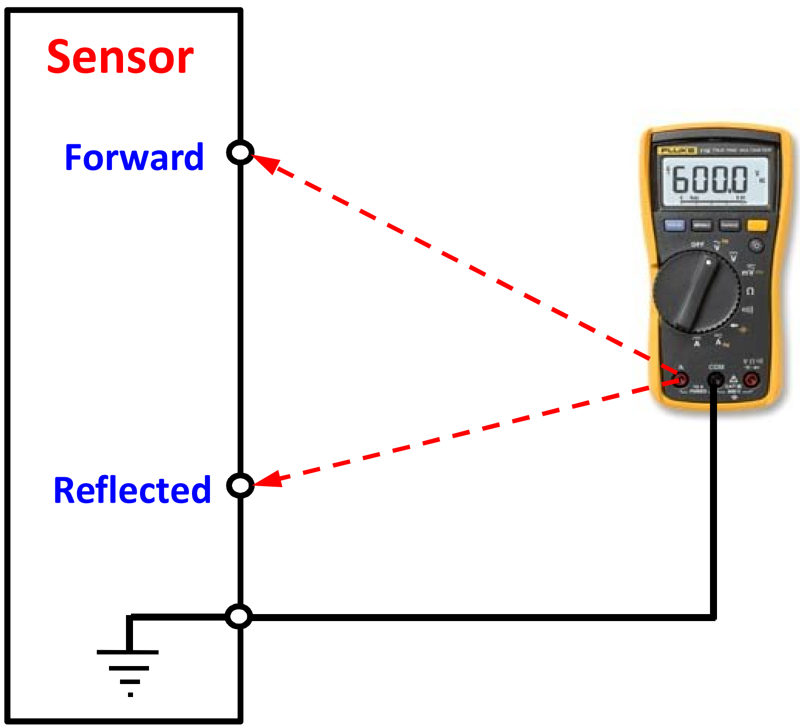
SWR/Power Meter - Digital



My Digital Power Meter



What is the main difference?

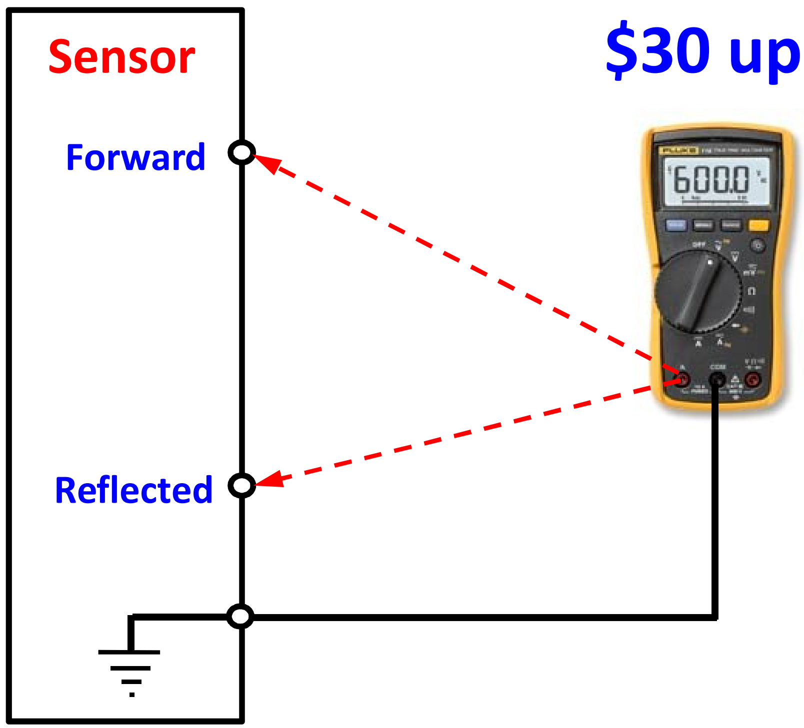


Alpha 4520

Digital Power/SWR Meters

Cost!

$30 up



~$0-50

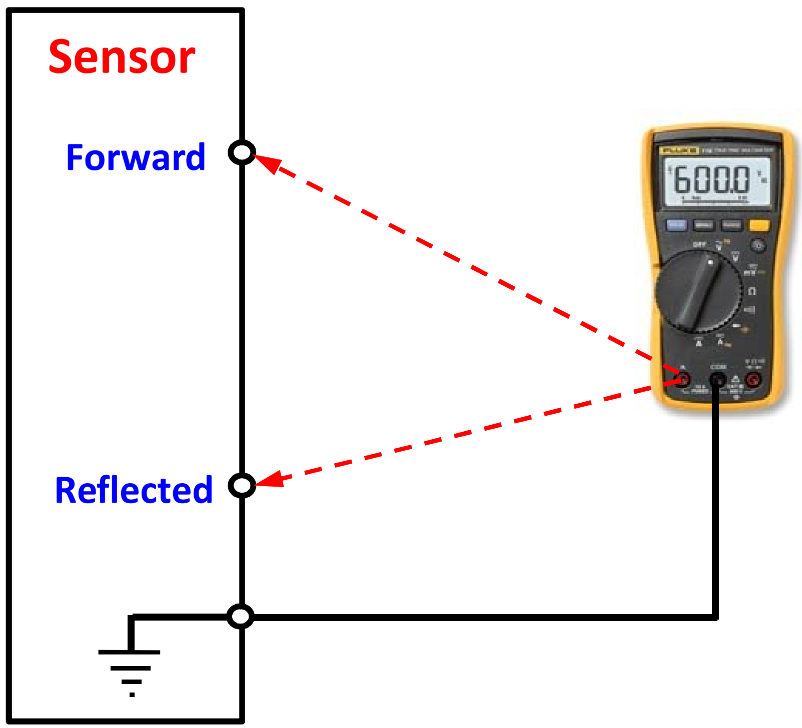
Alpha 4520

$800

Digital Power/SWR Meters

Accuracy varies from ~5% to ?

- **Power reading accuracy is *<u>very</u>* dependent on Sensor *<u>calibration accuracy</u>*** (both Forward & Reflected)



Alpha 4520

Accuracy: 5-10% achievable

Accuracy Spec = <5%

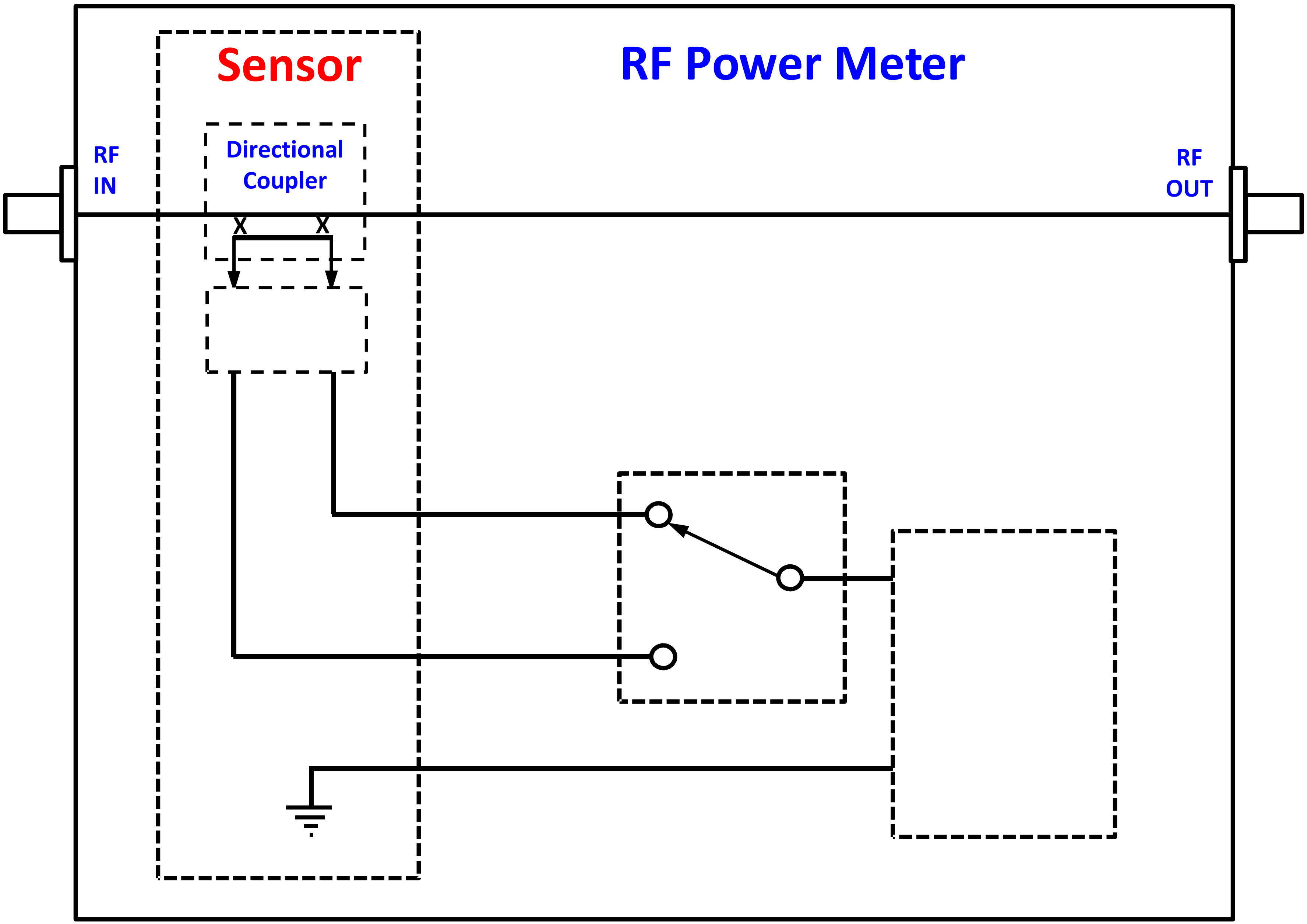
Ultimate Limit on Accuracy?

- **Sensor Calibration!**
  - **Initial CAL accuracy**
    - **Volts out vs Power In**
    - **SWR is a calculation, *not a measurement***
  - **Volts out vs Frequency**
  - **Traceable to NIST?**
  - **Drift with time**
  - **Load impedance drift with heating (1-3 KW???)**
- **Having a digital readout:**
  - **Doesn't improve accuracy**
  - **Improves resolution**
  - **May improve repeatability**
- **Having a digital processor does allow for better calibration of sensor characteristics**

Telepost LP-100A Digital Vector Wattmeter

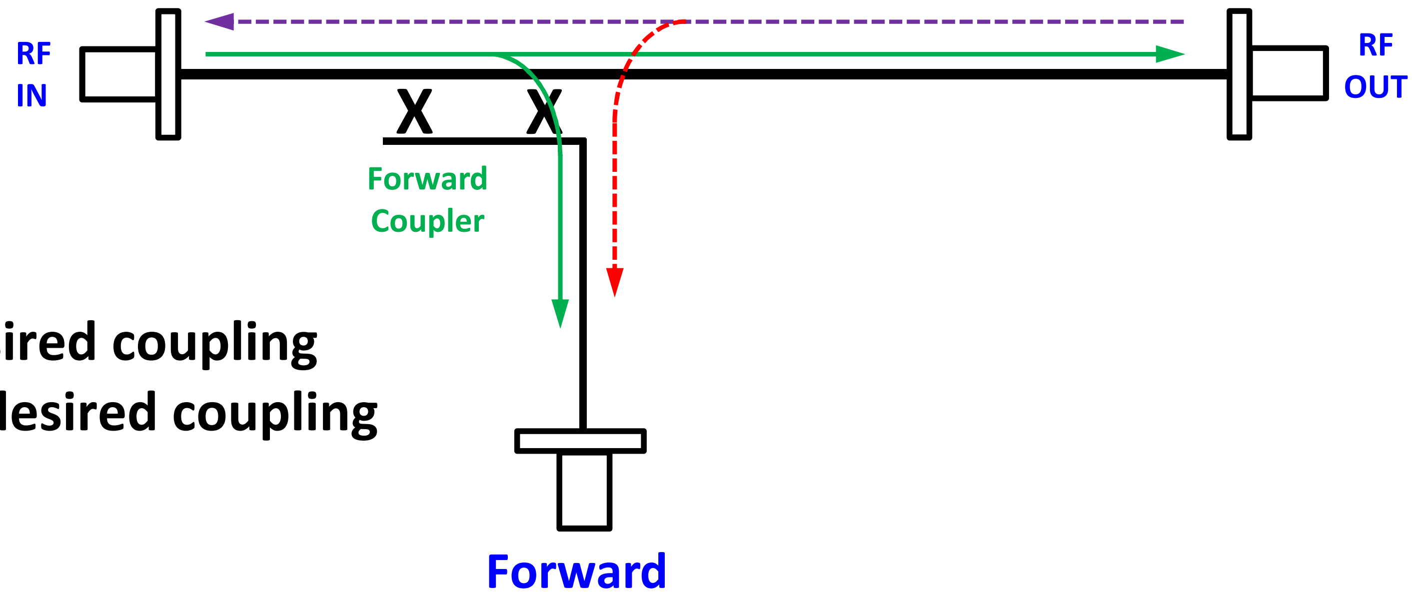
- Accuracy:
  - Same specs as Alpha 4520
    - 5% maximum
    - 3% (typical)
  - **NIST traceable factory calibration**
    - **What does this mean?**
- eHam rating: 5.0/5 (121 reviews)
- **$435**

Directional Coupler



Directional Coupler

- **Only couples power flowing in one direction**
- **Only couples a small sample of the power flowing in the desired direction**

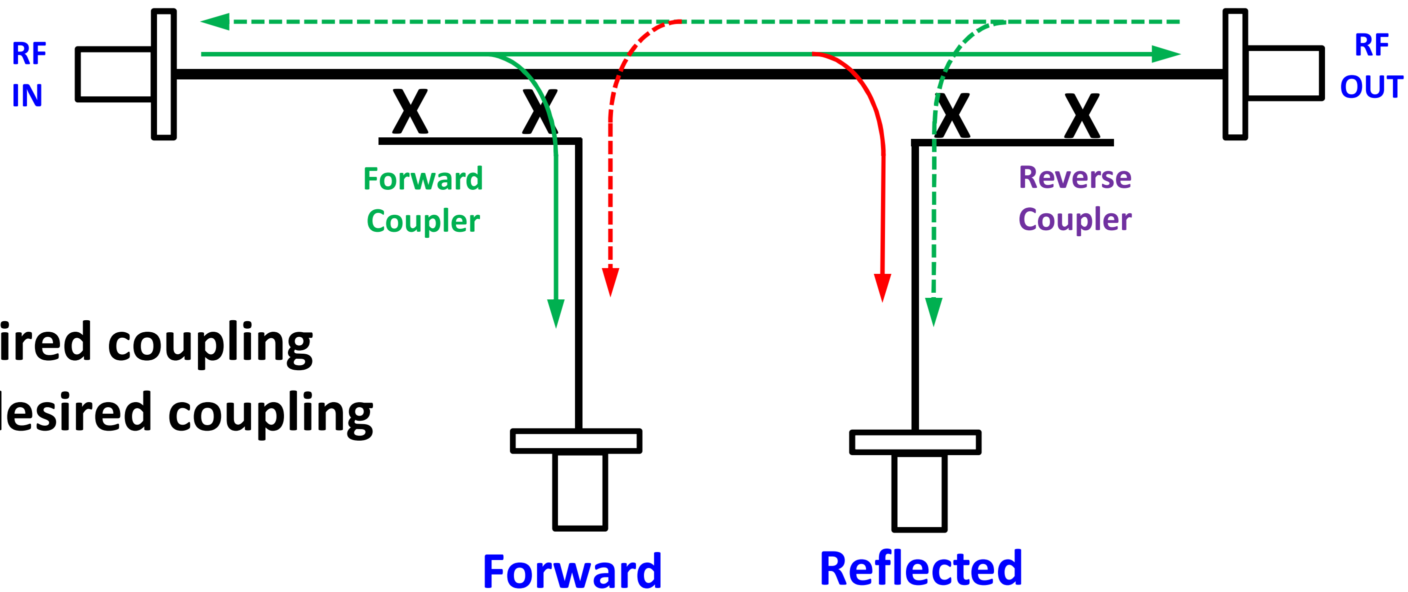


Green = desired coupling

Red = undesired coupling

- **Coupling factor** represents the primary property of a directional coupler
  - To reduce 100 w to 100 mw => Coupling factor = -30 dB
- **Directivity** is the measure of how well a coupler isolates two opposite-travelling (forward and reverse) signals
  - ***Creates region of uncertainty around all measurements***
  - Bird 43: Directivity >30 dB

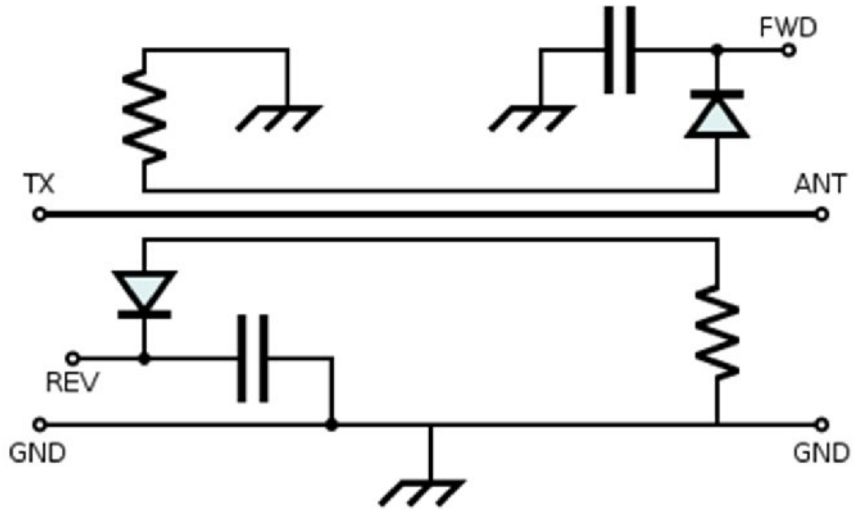
Dual Directional Coupler

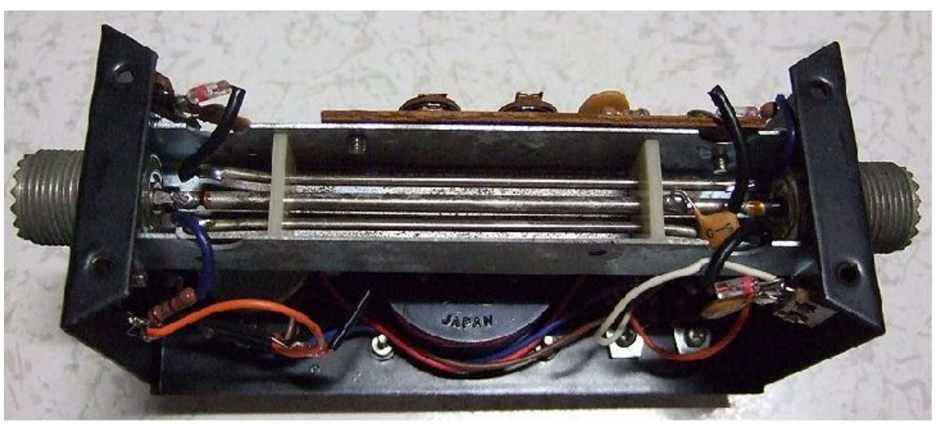


Green = desired coupling
Red = undesired coupling

Common Directional Couplers

Coupled Transmission Line Coupler

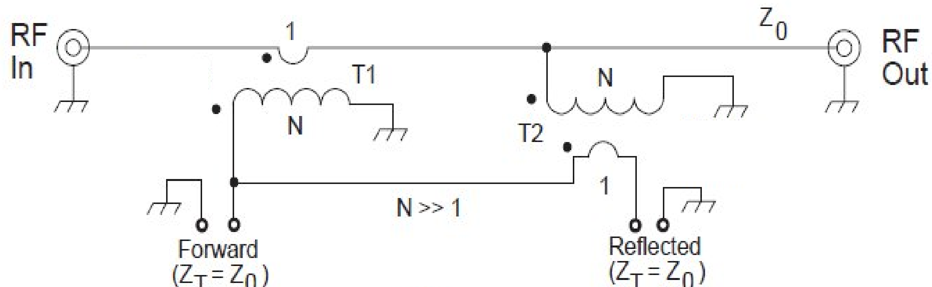




Bird 43

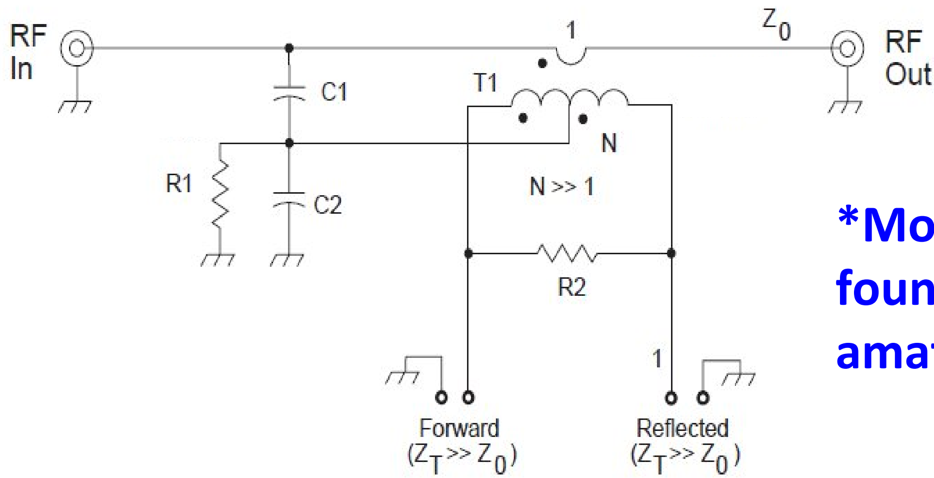
Common Directional Couplers

Tandem Match Coupler



(A)

Bruene Bridge*

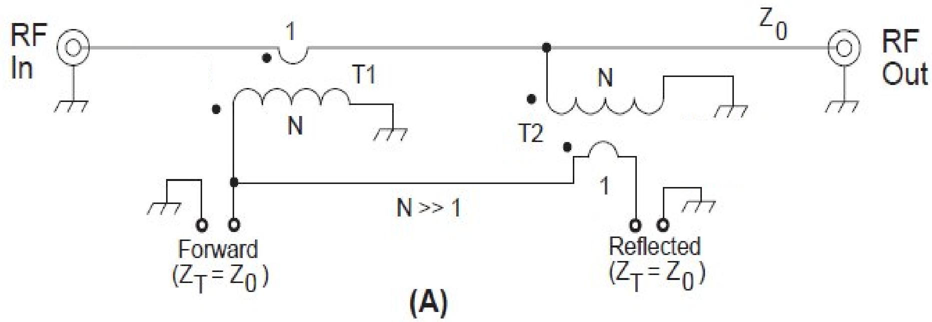


(B)

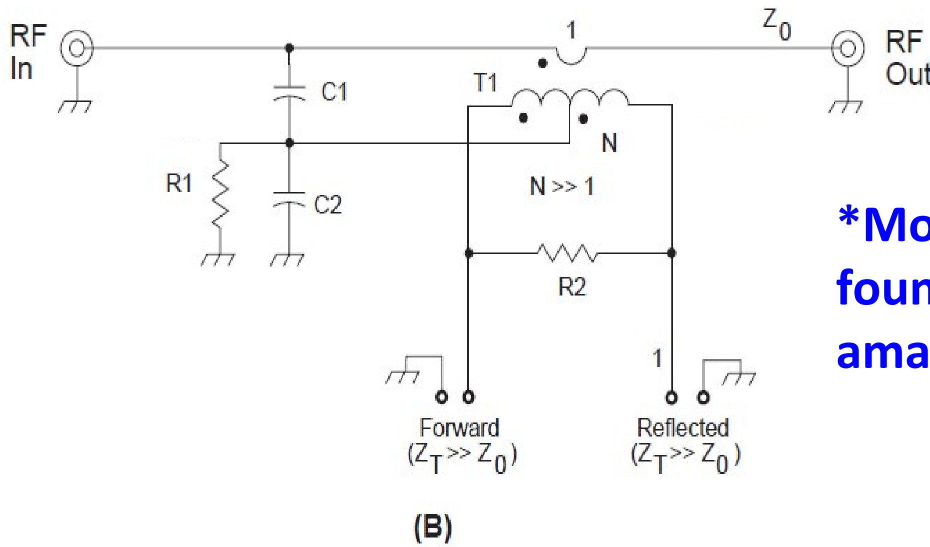
***Most common type found in commercial amateur transmitters**

Common Directional Couplers

Tandem Match Coupler



Bruene Bridge*

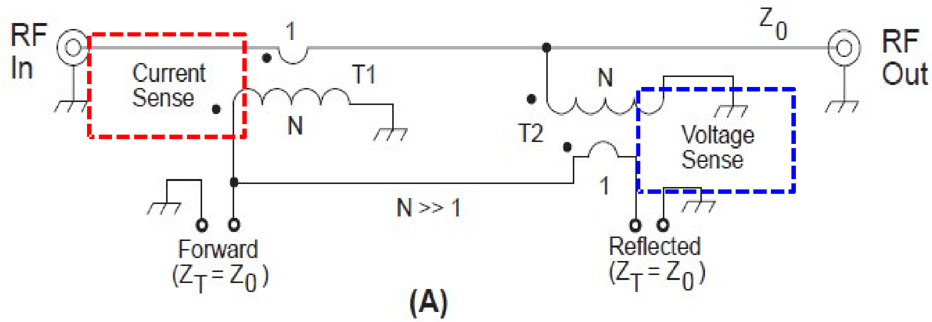


***Most common type found in commercial amateur transmitters**

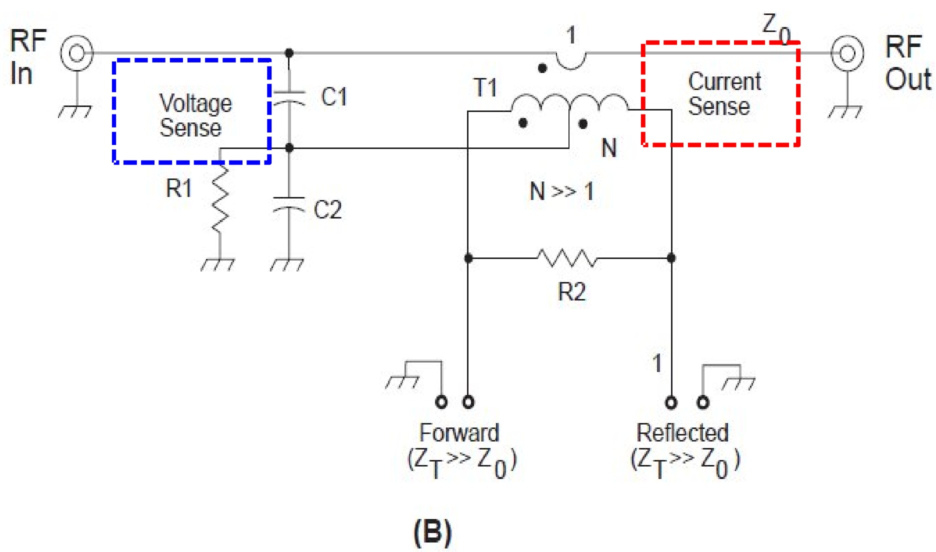
How do we get Voltage & Current?

Common Directional Couplers

Tandem Match Coupler

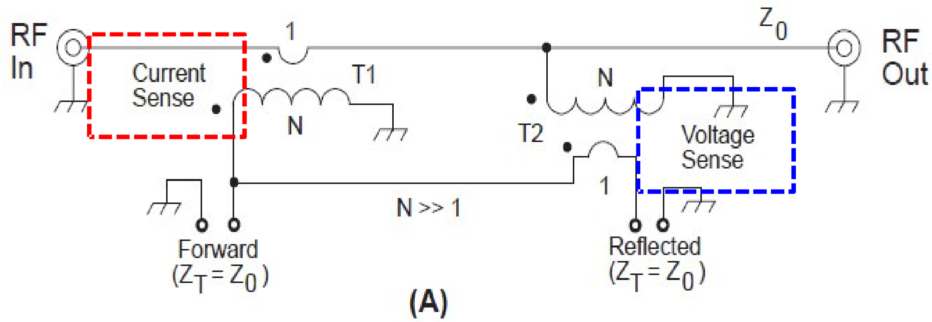


Bruene Bridge*



Common Directional Couplers

Tandem Match Coupler



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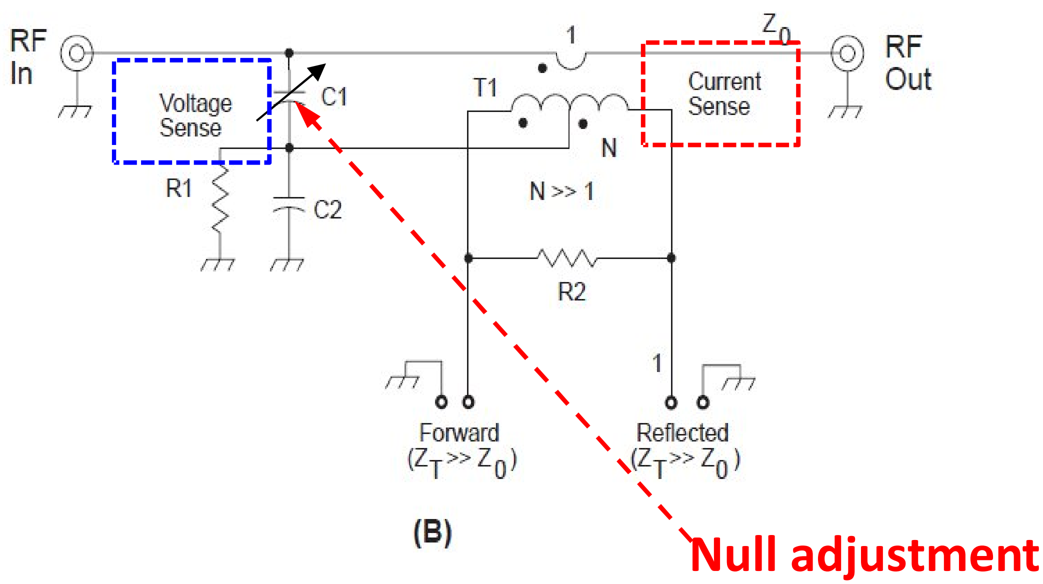


Common Sensors

- **Tandem Match Coupler**
  - This coupler has some nice features:
    - Simplicity, excellent directivity
    - Scalable to other power levels, and
    - 50-Ω load impedances on all ports
  - Covering 1.8-30 MHz requires careful transformer design
  - Input VSWR can degrade rapidly as frequency drops below 7 MHz

- **Bruene Bridge**
  - **Requires comparatively little space**
  - Most commonly used design by Ham equipment manufacturers
  - Primary challenges with this design:
    1. Parasitic lead inductance associated with C2
    2. High values for C2
    3. Excessive secondary wire length on T1, and
    4. Impedance control in the bifilar secondary winding
  - The lead inductance and C2 result in a series resonance that progressively deteriorates bridge balance as the frequency is raised

Tandem Match Coupler

SWR Sensor (from 2010 ARRL Antenna Handbook)

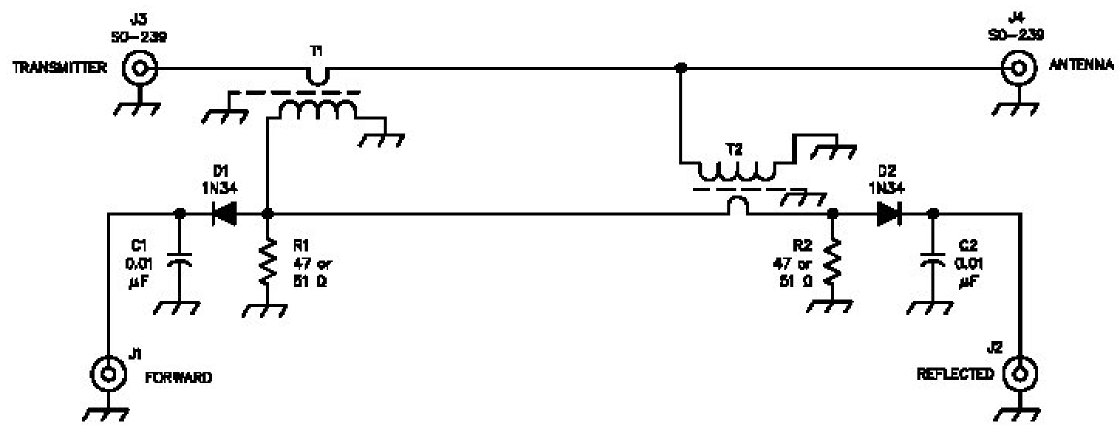
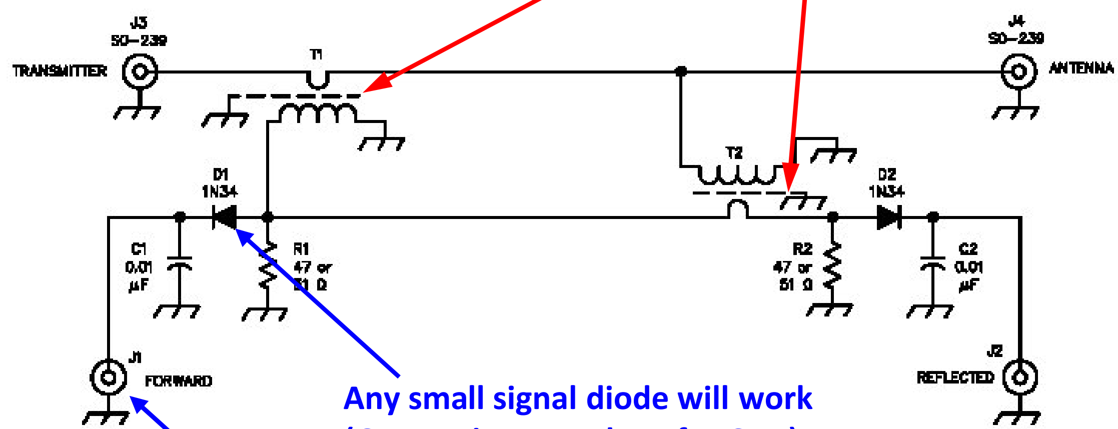


Fig 19—Schematic diagram of the high-power directional coupler. D1 and D2 are germanium diodes (1N34 or equiv). R1 and R2 are 47 or 51-Ω, ½-W resistors. C1 and C2 have 500-V ratings. The secondary windings of T1 and T2 each consist of 40 turns of #26 to #30 enameled wire on T-68-2 powdered-iron toroid cores. If the coupler is built into an existing antenna tuner, the primary of T1 can be part of the tuner coaxial output line. The remotely located meters (M1 and M2) are connected to the coupler box at J1 and J2 via P1 and P2.

Tandem Match Coupler

Shield on coax used as a Faraday shield (grounded on one end only)

SWR Sensor (from 2010 ARRL Antenna Handbook)



Any small signal diode will work
(Germaniums are best for QRP)

At 100 watts, I_{FWD}OUT (into a short) > 6 mA
At 100 watts, V_{FWD}OUT (into an open) > 2.0 vdc

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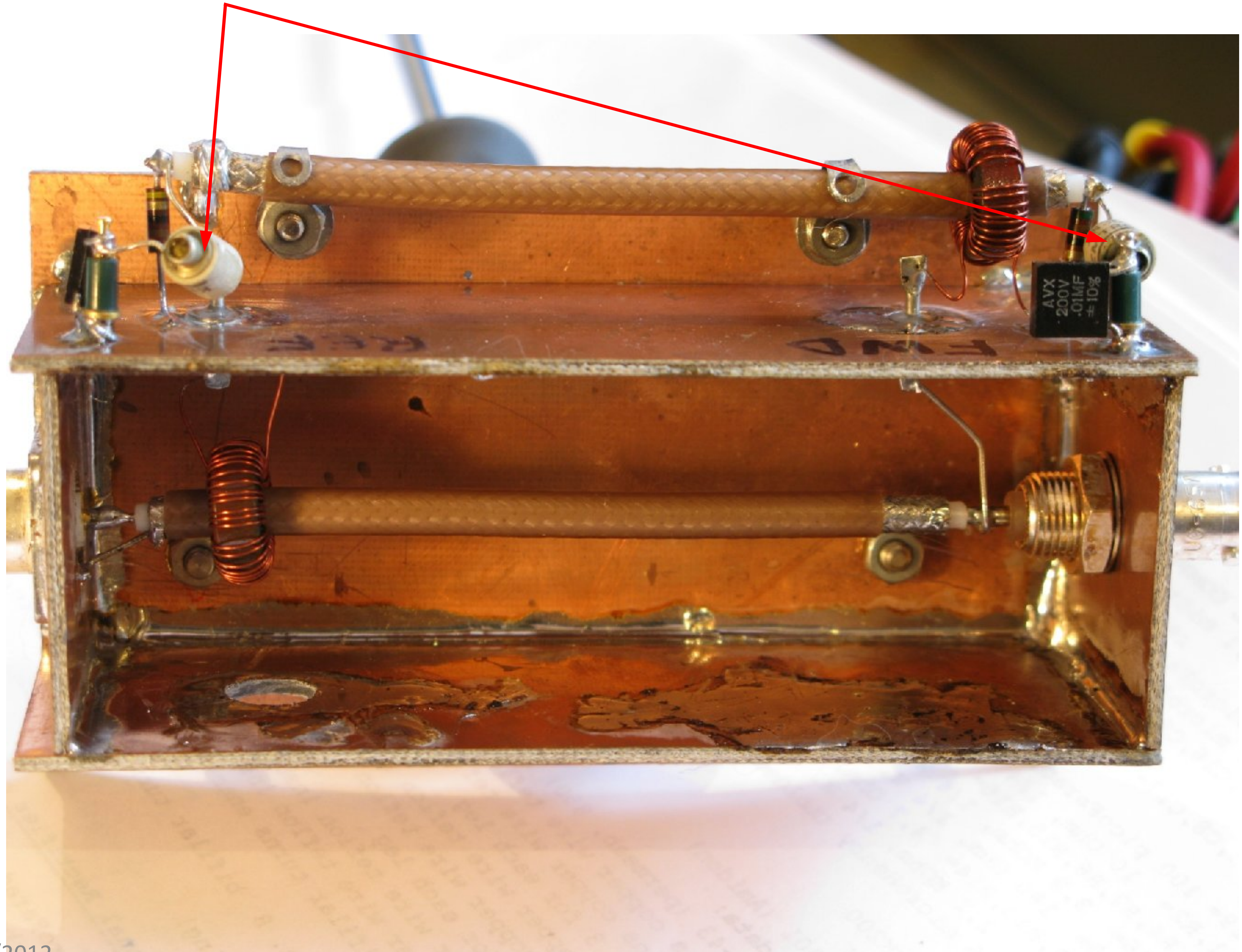
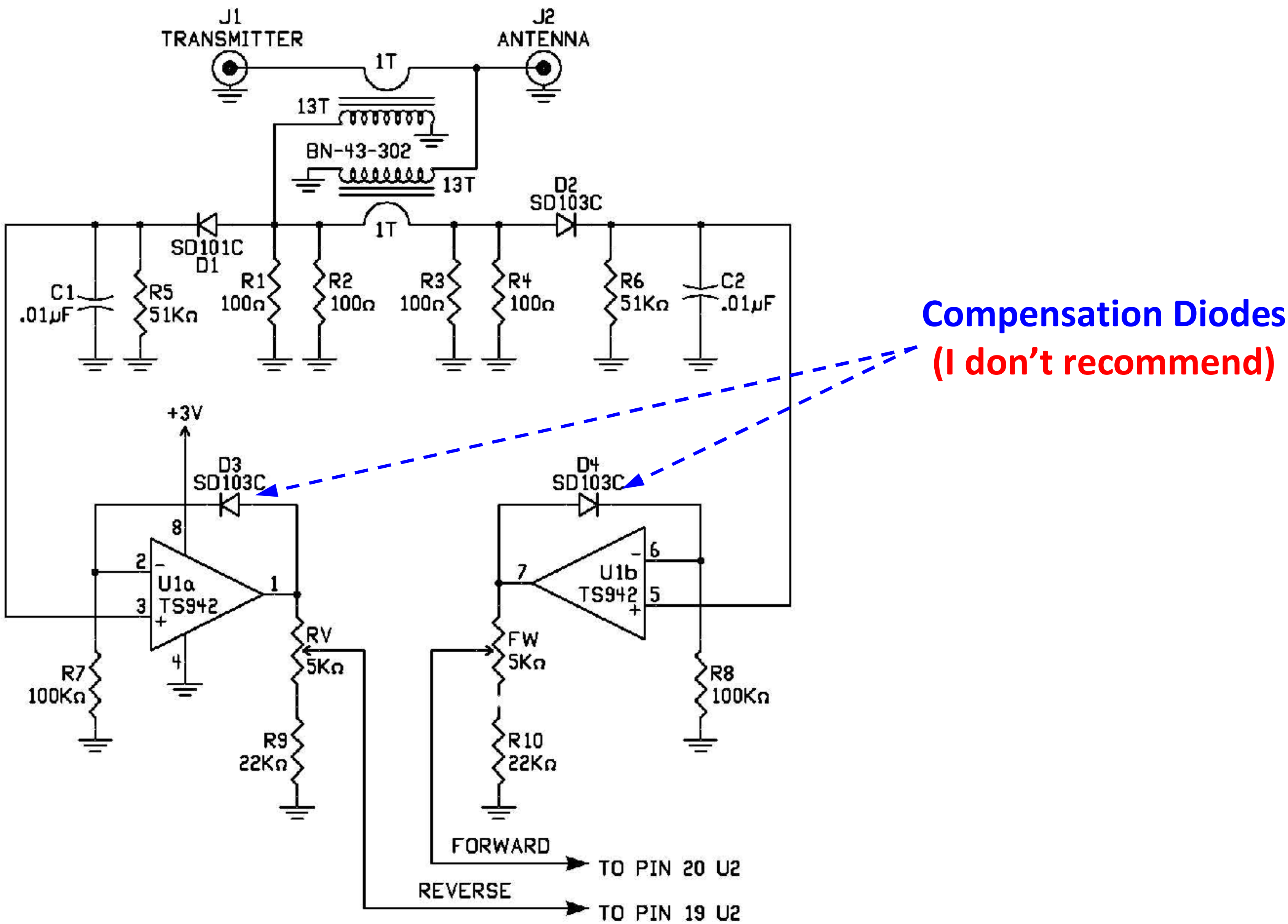
Tandem Match Coupler

Caution: Germanium diodes don't like heat



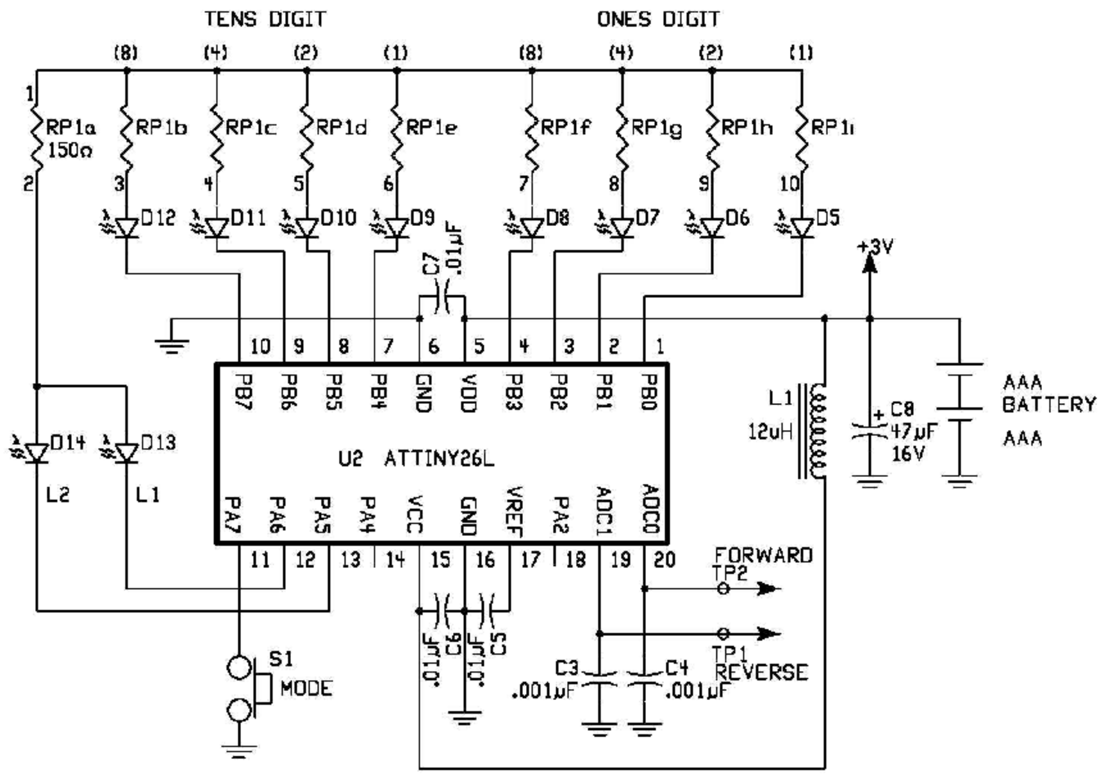
Tandem Match Coupler Using Balun Core

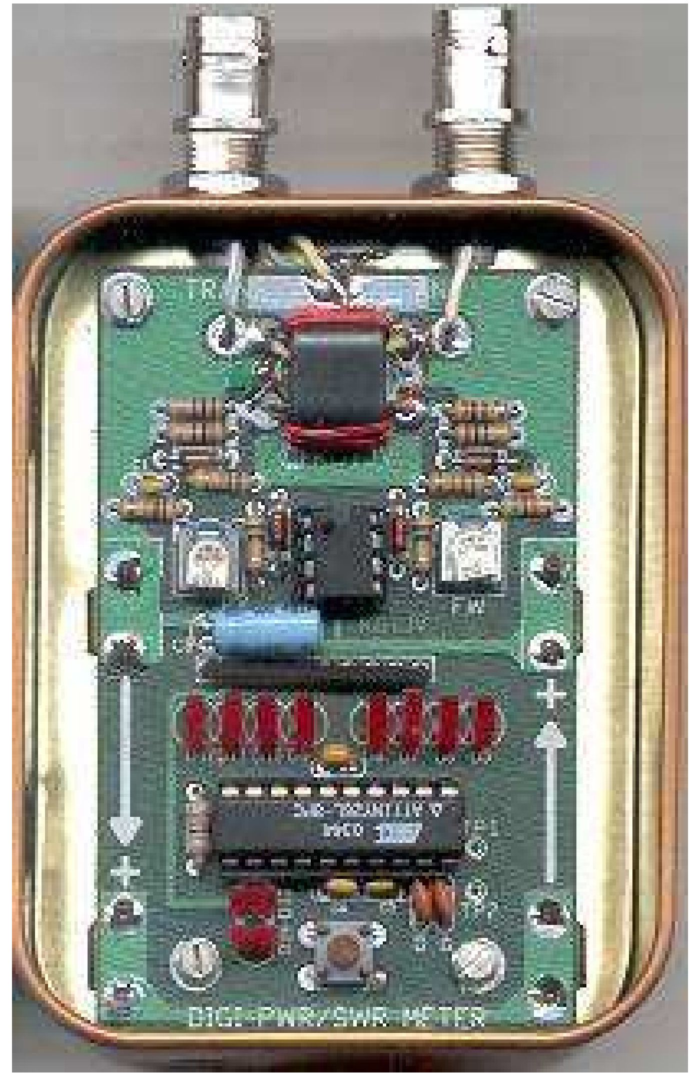
DX Zone.com "Digital QRP SWR/ Power Meter" by KD1JV



Processor/Display

DX Zone.com ”Digital QRP SWR/ Power Meter” by KD1JV

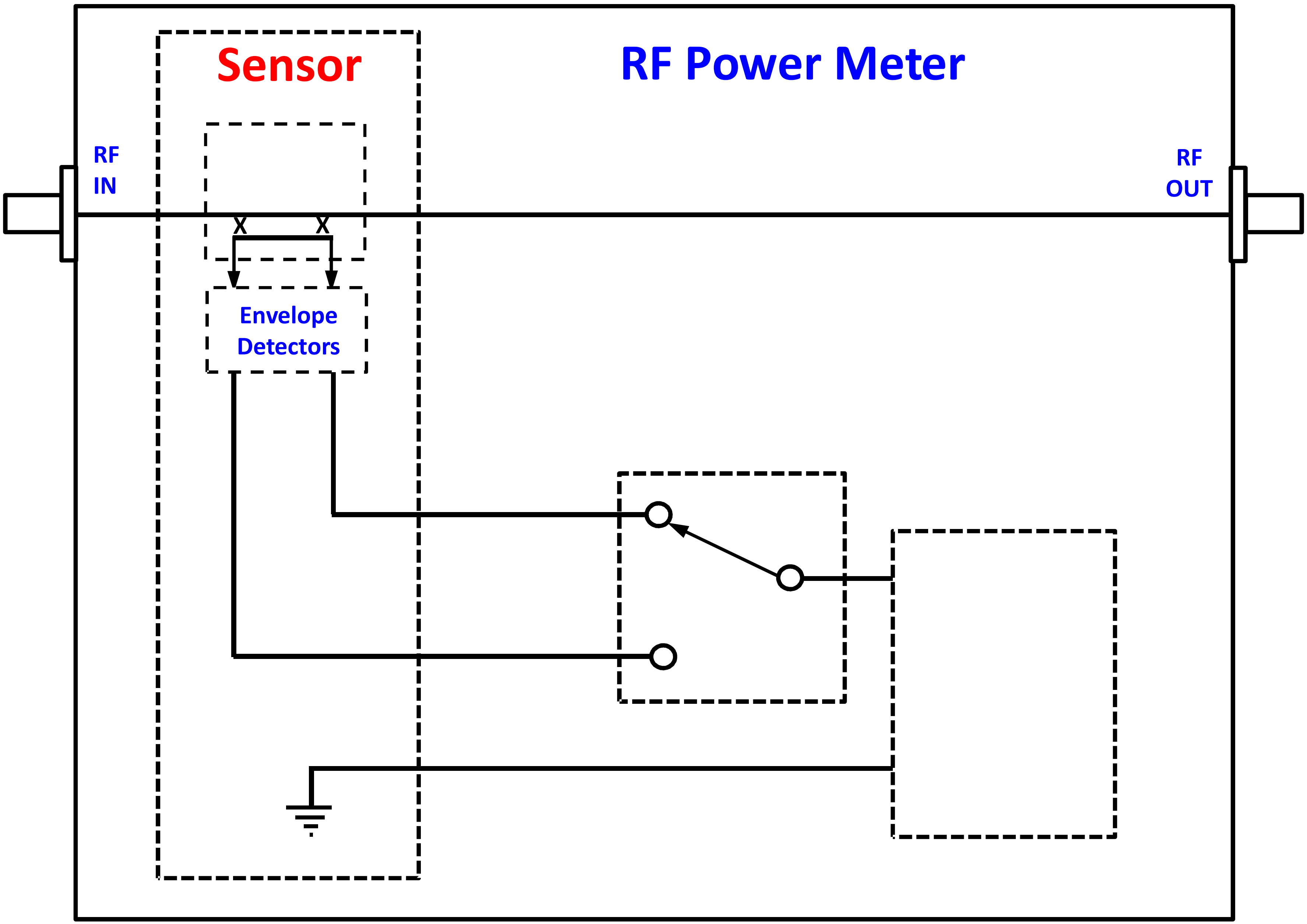




“Whitman’s Sampler” tin

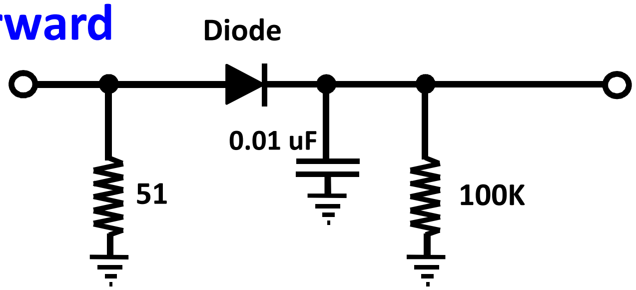
- **http://kd1jv.qrpradio.com/**
- http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=18048

Envelope Detector



Common Envelope Detector

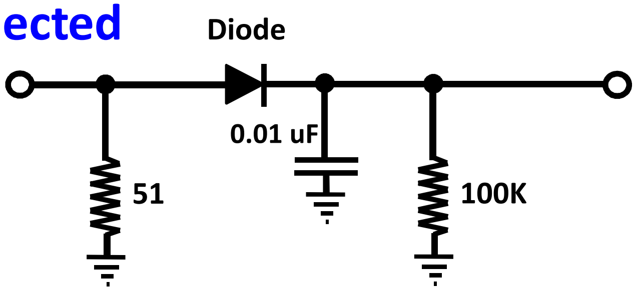
Forward



Diodes:

- Type not critical
- Germanium best for QRP
- Matched is desirable, but not required

Reflected



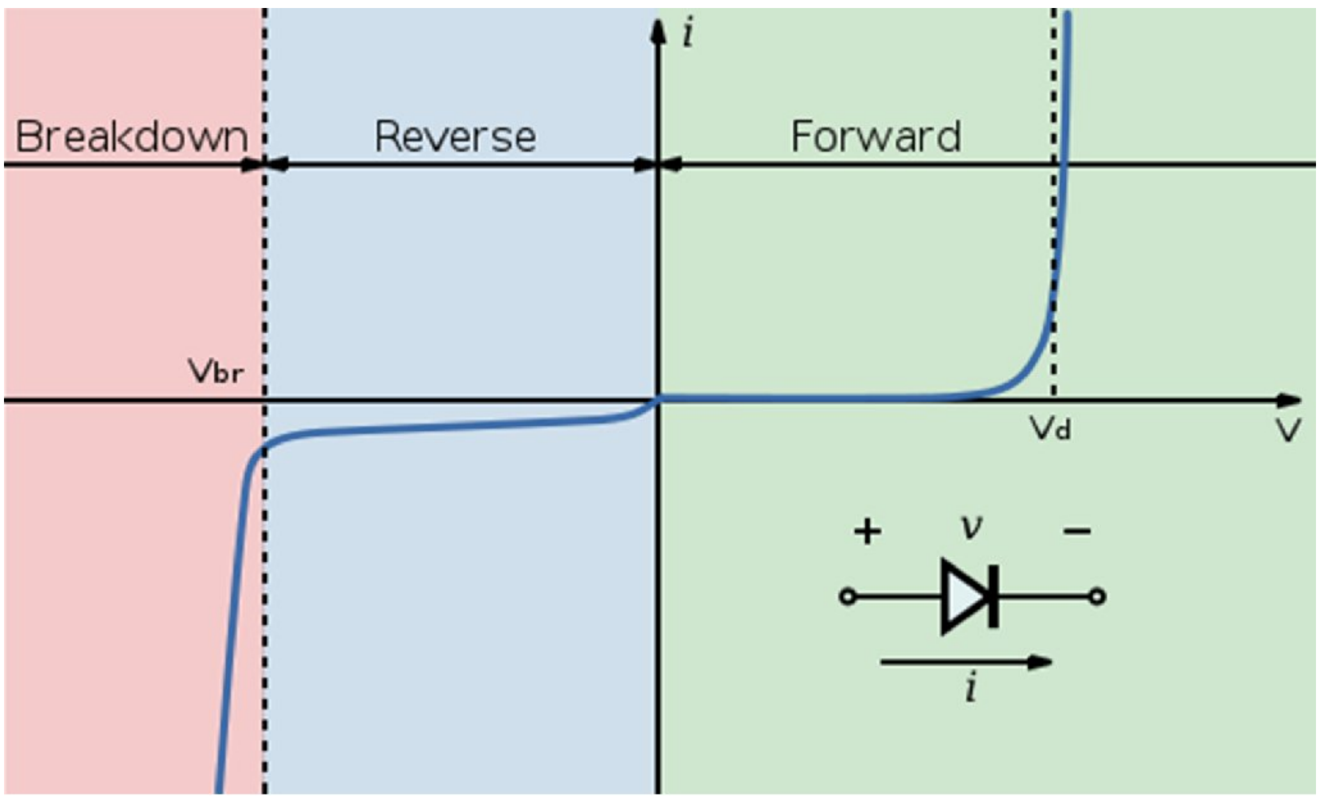
Diode Options

Silicon:

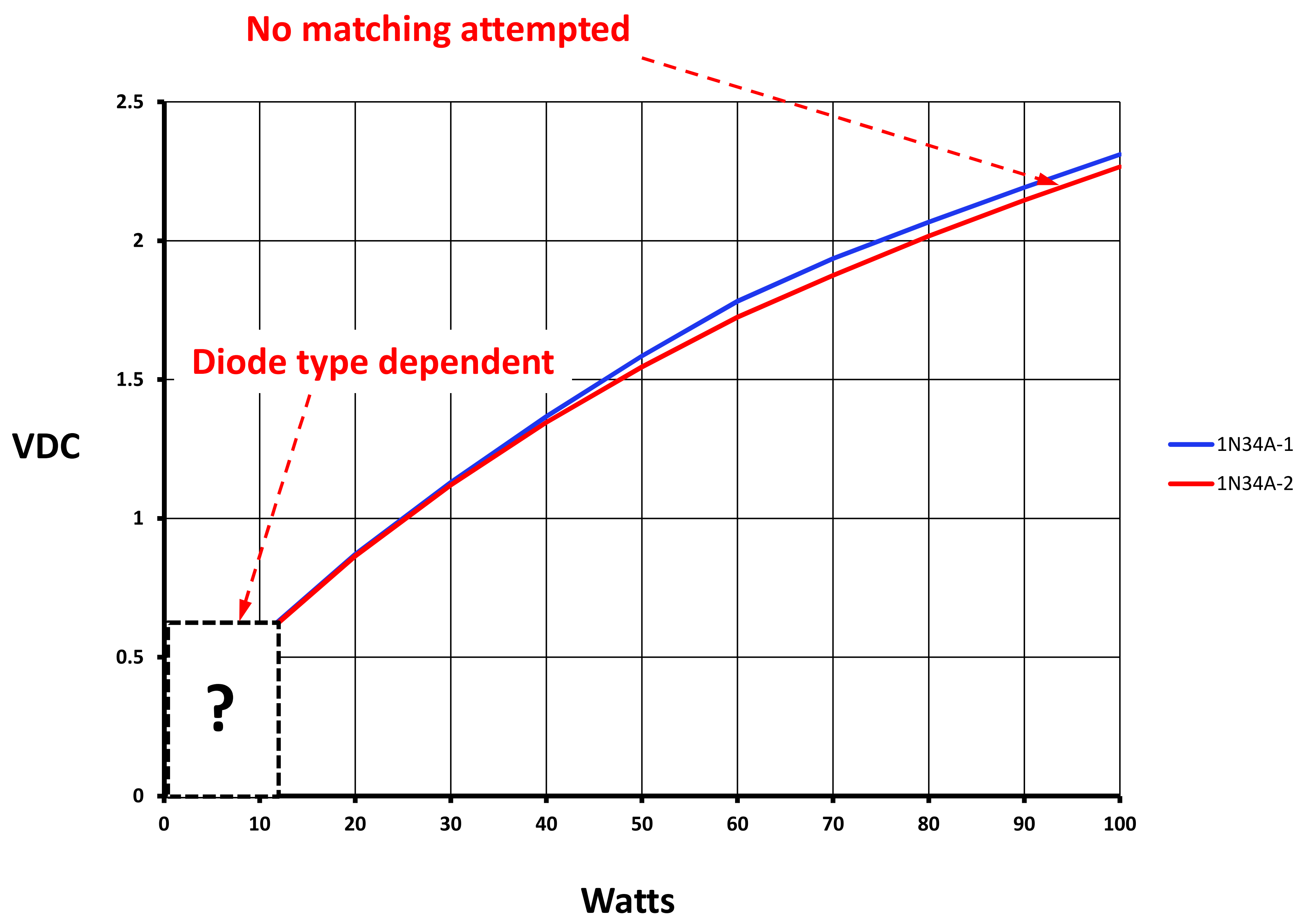
- **1N3600 => V_D ~0.7 volt**

Germanium:

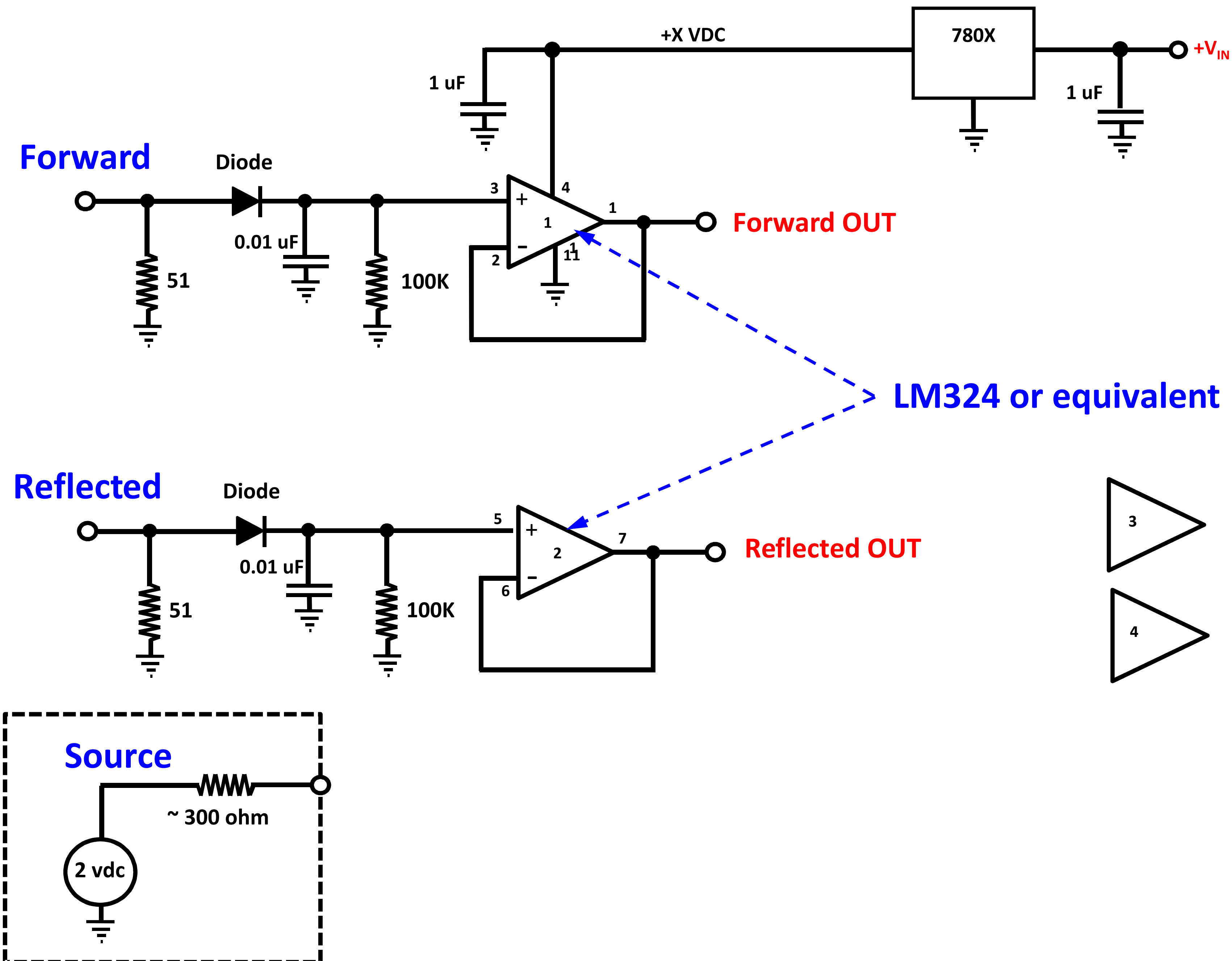
- **1N34, 1N60, 1N270 => V_D ~ 0.3 volt**



Diode Matching -Tandem Match Coupler



Isolated Meter Circuit



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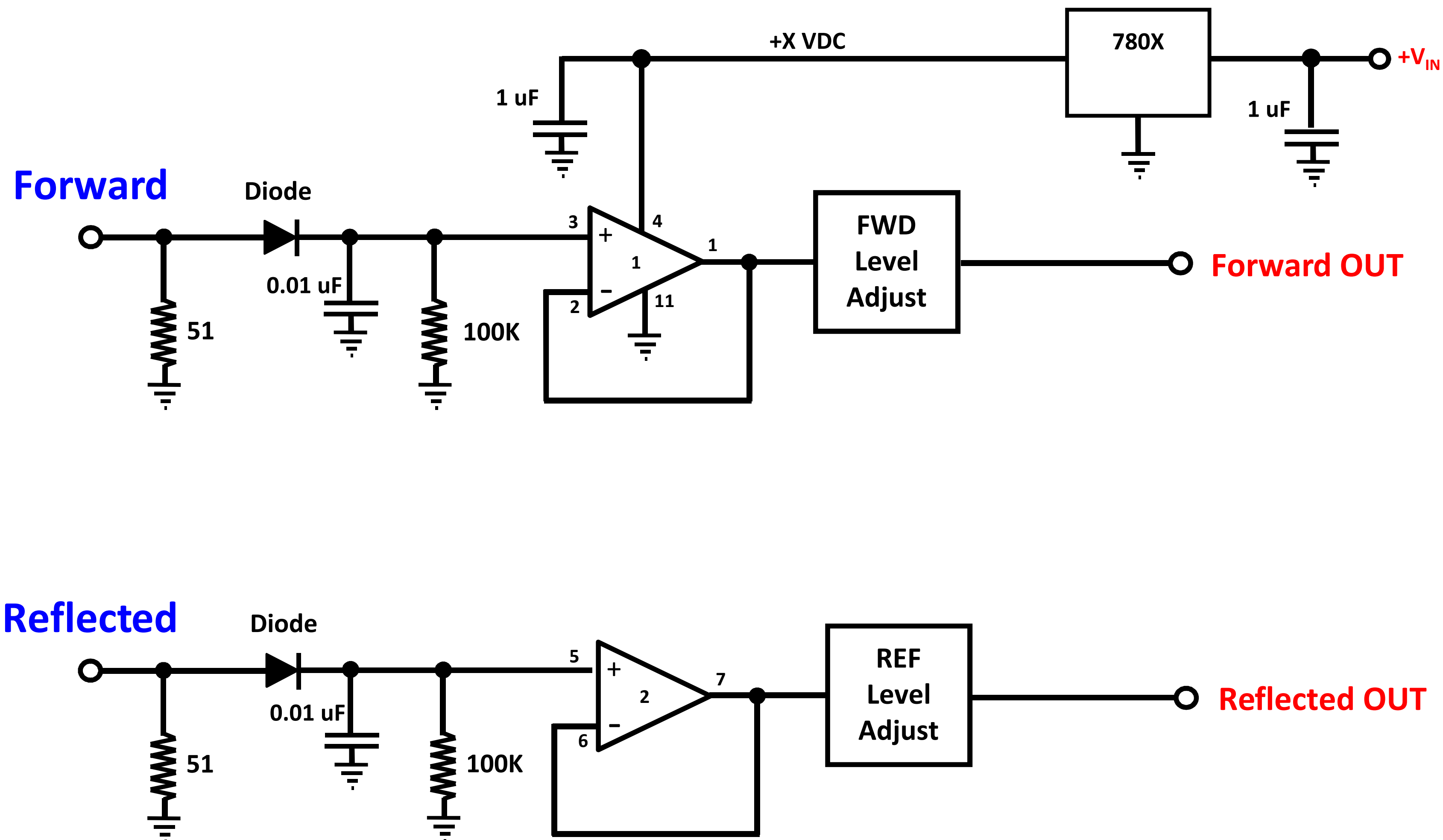
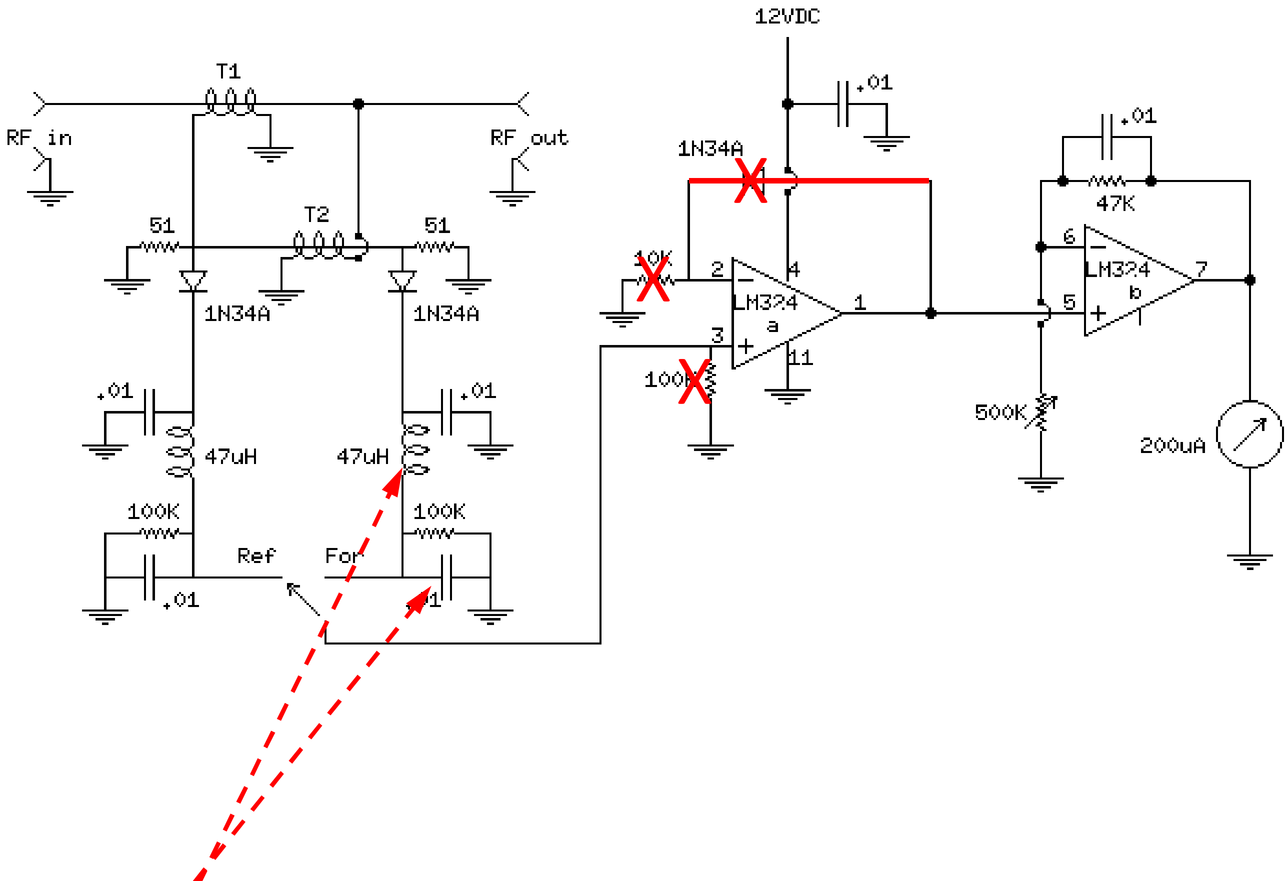
Meter Adjustment



A SIMPLE SWR METER FOR QRP (1 WATT) LEVELS



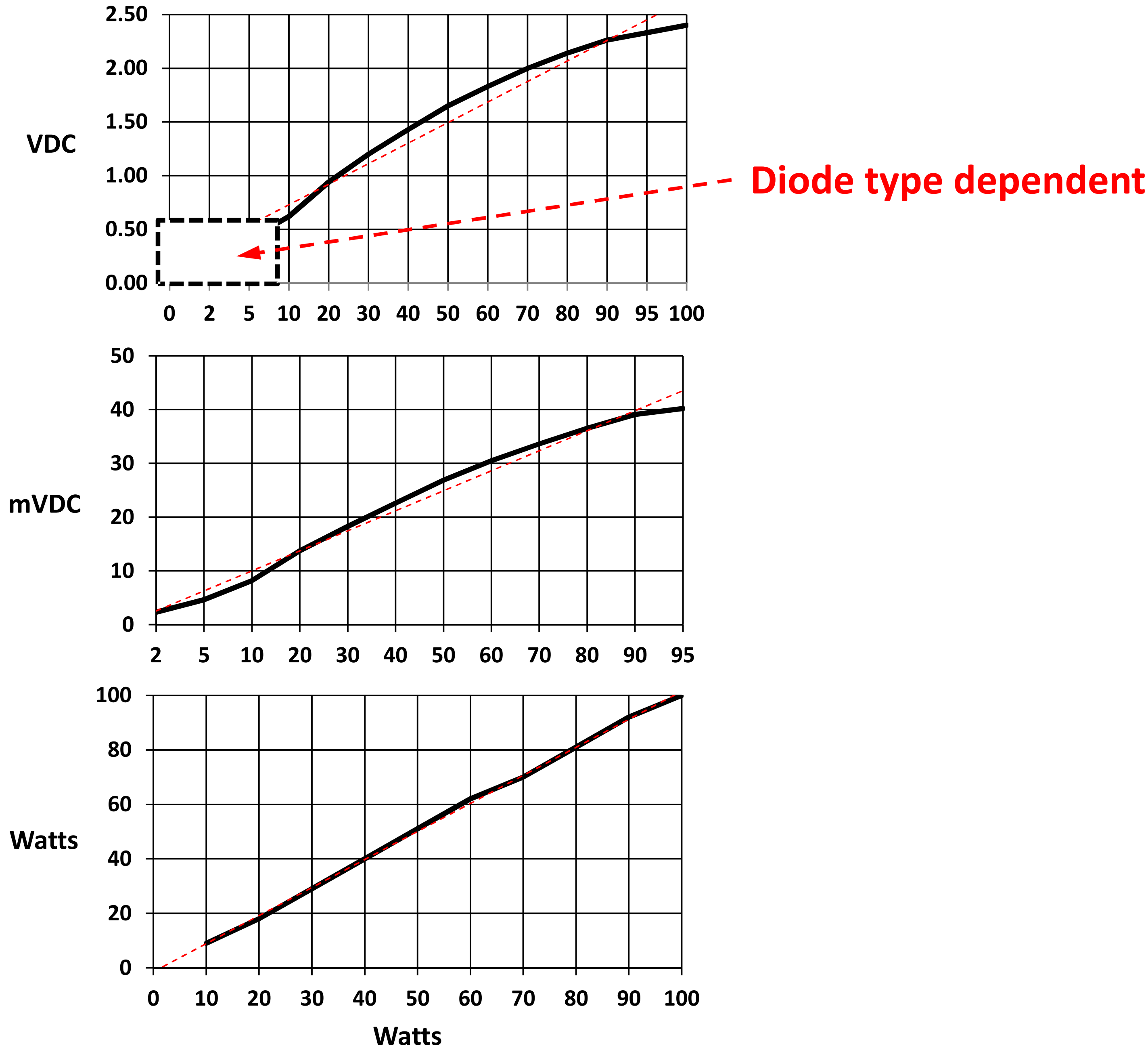
Not required

Performance – Power Measurement

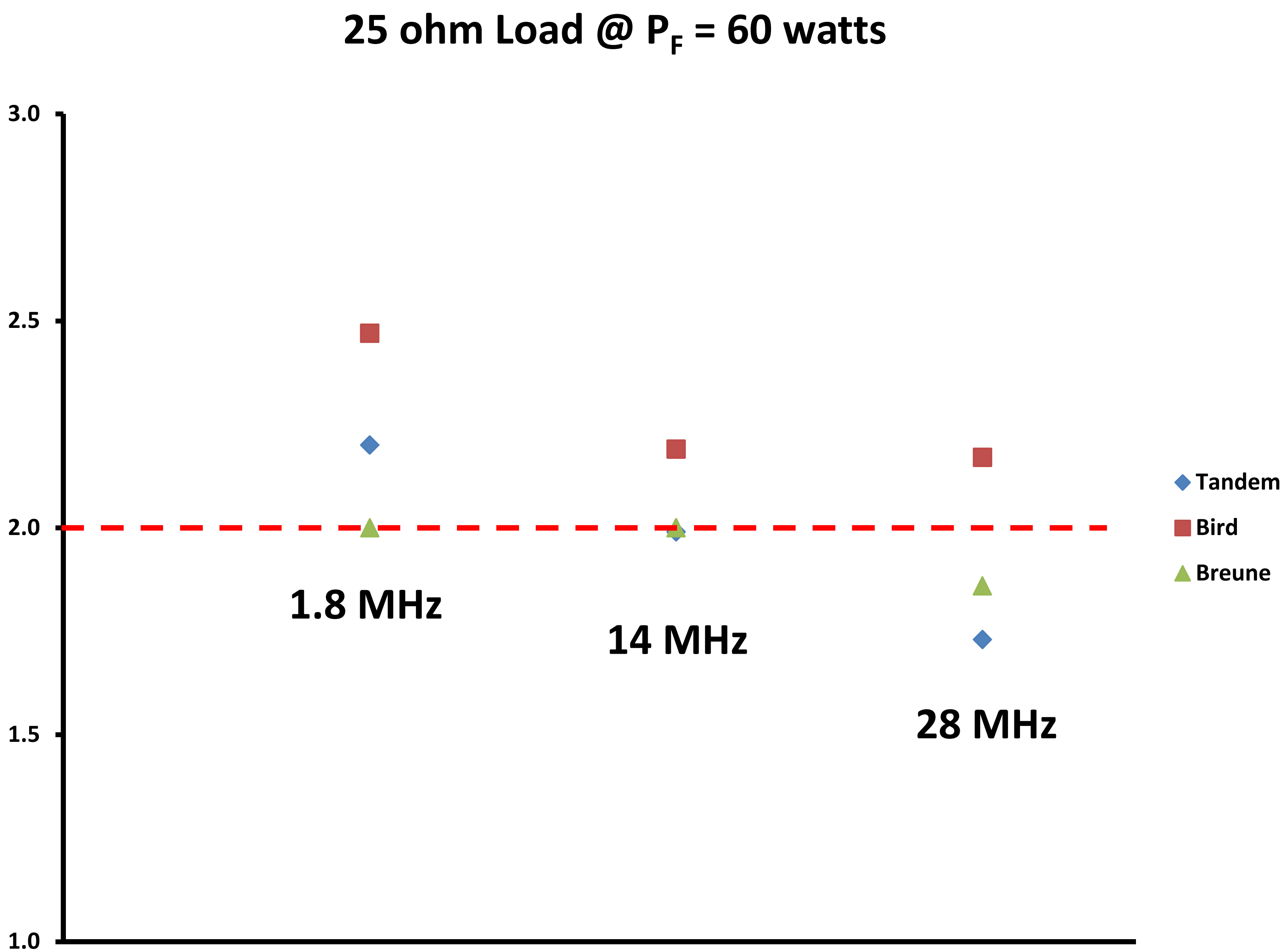
Homebrew (Tandem Match)

Bird (Coupled Line/Digital)

Pride (Breune)



Performance – SWR Measurement



SWR Protection Circuit