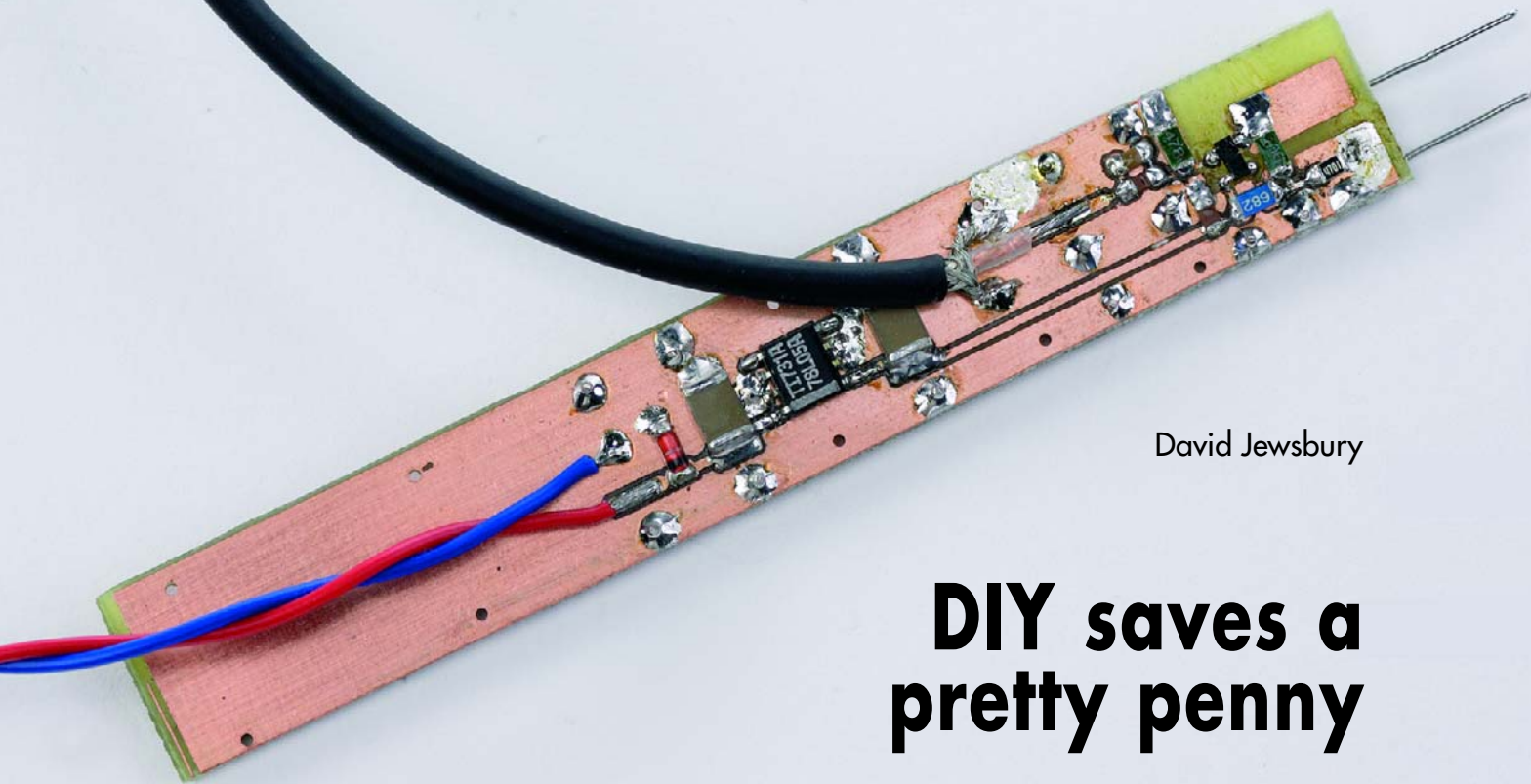


Poor Man's 1-GHz



David Jewsbury

DIY saves a pretty penny

When it is required to make a measurement at a node of an RF circuit, connecting to the circuit using a normal oscilloscope probe, even on the x10 setting can change the behaviour of the circuit. For those difficult cases, you need a special probe like the one described here.

Any probe presents extra impedance for the circuit to drive, usually consisting of some resistance and stray capacitance, resulting in reduction in gain, or in extreme cases, causing instability.

The loading effect of the resistance and stray capacitance can be largely removed by using an active probe. The major manufacturers in the oscilloscope market all offer suitable models (see also 'Scope for Scopes' elsewhere

in this issue), but costing over a £1000 they are too expensive for amateur use. This article describes a probe that can be constructed at home, for very little money and has useful performance.

Specifications

This probe has some compromises in performance, as you would expect. In **Table 1** it is compared to a commonly available commercial probe, the type 85024A from Agilent.

Admittedly the commercial probe, with 0 dB loss, is more convenient to work with, but for most applications a home-brew probe is no disadvantage.

Circuit Description

The circuit is shown in **Figure 1**. It is hard to imagine anything simpler. A dual gate MOSFET, T1, is used in a source-follower configuration. This provides a low output impedance to drive the coax cable and test equip-

Active Probe

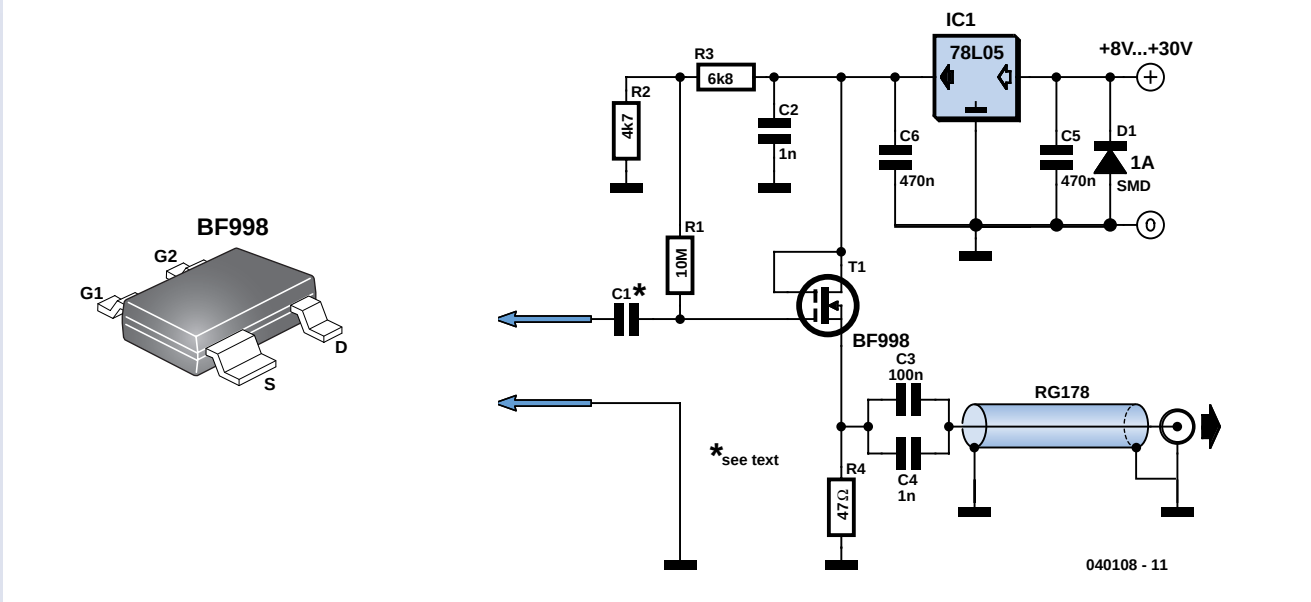


Figure 1. Circuit diagram of the DIY active probe. A dual-gate MOSFET guarantees light, uniform loading of RF signals over a frequency range extending well beyond the 1 GHz mark.

ment. The signal at the probe tip is applied to gate 1. The impedance at gate 1 is a very high resistance shunted by a few picofarads of capacitance. The choice of MOSFET used in the circuit is not critical, any one of the types listed in **Table 2** and housed in a SOT143 case can be used with impunity. Be sure however to steer clear of ‘-R’ suffix devices because they have a differ-

ent pinout and will not work on the proposed PCB.

Capacitor C1 has a value of about 0.5 pF, and is made by patches of copper on each side of the board. The gain of the buffer itself is a little less than one, but because of the voltage divider action of C1 and the input capacitance of T1, the overall loss of the probe is approximately 20 dB, or the input volt-

age is divided by 10. IC1 regulates the supply voltage to a stable 5 volts. D1 protects the probe in the event of the supply leads being reversed.

Construction

The PCB artwork is shown in **Figure 2**. The board has been designed to allow fitting in a metal tube. All

Table 1. Commercial / homebrew comparison		
	Agilent 85024A	Homebrew probe
Input Impedance	0.75 pF // 1 MΩ	0.75 pF // 10 MΩ
Bandwidth	300 kHz to 1 GHz (± 1.5 dB), or 1 GHz to 3 GHz (± 2.5 dB)	100 kHz to 1.5 GHz (± 2.5 dB)
Gain	0 dB nominal	–20 dB nominal
1-dB compression point	0.3 V RMS	not measured

Table 2. MOSFET selection guide		
Type	C _{IG1} (pF)	Noise figure (dB)
BF990	2.6	2
BF991	2.1	1
BF992	4	1.2
BF998	2.1	1

Masterclass

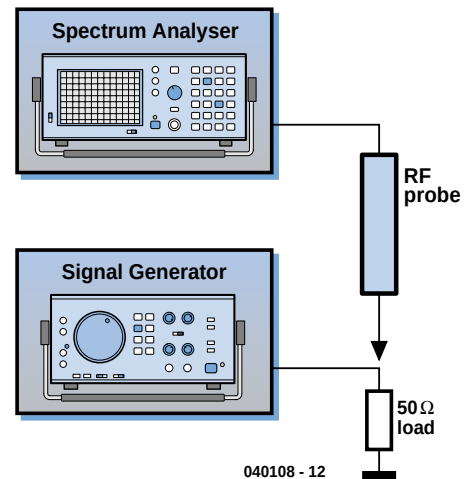
It is important to realise that the probe is measuring RF voltage, but the displayed quantity is usually the power that the probe is delivering to the spectrum or network analyser. The voltage at the probe tip is given by:

$$V = \sqrt{\frac{10^{\left(\frac{P-L}{10}\right)}}{20}}$$

Where P is the displayed power in dBm, and L is the loss in the probe in dB. If the probe is being used for faultfinding purposes or only an approximate measurement is needed, L can be taken as 20 dB. For accurate measurements the probe can be calibrated over its frequency range, using the setup shown here.

The 50-Ω load can be a 51-Ω 0805-style surface mounted metal film resistor, soldered at the end of a piece of semi-rigid coax. The resistor should be reasonably non-reactive up to 1 GHz.

The loss of the probe is designed to be slightly less than 20 dB so that if needed it can be set to exactly 20 dB by trimming small amounts of copper from C1 with a scalpel. After calibration, very accurate measurements are available in 50-Ω systems. With other impedances there is an additional small error due to the unavoidable residual loading effects of the probe.



the components are surface mounted (SMD), but assembly by hand is reasonably easy with a fine tipped soldering iron and tweezers. The parts are assembled on one side of a double sided 1.6-mm thick PCB. Connections are made between the ground plane on each side of the board with solid wire soldered on each side. Flying leads take the power to the probe and a length of coax ending with a BNC plug take the output to the test instrument. Heat shrink coax is used to strain relieve the leads. The RF and Ground probe are made from steel pins filed to a point. Pins 'borrowed' from the family's clothes repair kit are excellent.

Testing and use of the probe

After connecting the probe leads to a suitable power supply, the probe should draw between 10 and 30 mA. If all is in order, connect the probe to a spectrum analyser. Applying an RF signal to the probe should result in an output seen on the spectrum analyser. To get accurate results it is important that the ground probe contacts an RF ground close to the probed point on the circuit. It is also important to hold the board by the edges to prevent stray effects from fingers on the circuit. If the impedance at the probed point is 50 Ω,

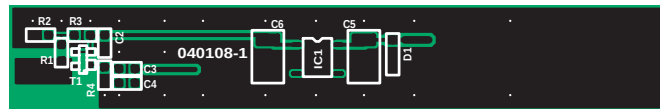


Figure 2. The PCB has been designed with compactness and low input capacitance in mind — hence the use of SMD parts.

COMPONENTS LIST

All resistors and capacitors:
SMD, '0805' case

Resistors:

R1 = 10MΩ
R2 = 4kΩ7
R3 = 6kΩ8

R4 = 47Ω

Capacitors:

C1 = PCB capacitor
C2, C4 = 1nF
C3 = 100nF
C5, C6 = 470nF

Semiconductors:

D1 = 1A diode, SMD
T1 = BF998 in SOT143 case
(see Table 2)
IC1 = 78L05 in SO-8 case

then the peak on the spectrum analyser should be about 20 dB less than the power at that point in the circuit. Commercial probes were notoriously sensitive to electrostatic discharge, but seem more robust these days. Although T1 has internal diodes to protect against ESD it is wise to take normal precautions against unwanted static, while using the probe, as for any sensitive electronics.

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reflected