Many high-quality, major brand, low-range counters are available for $50-200. They’re worth at least that much, if only for the time base, while a newer comparable counter may cost several times as much. The prescaler isn’t just for old counters; it’s for any counter you’d like to extend the range or sensitivity of, or provide with an LED bargraph indicator.

Several divider schemes were considered for the prescaler, trading off bandwidth against cost: the original goal was 50 MHz—1.5 GHz performance with excellent sensitivity. The prescaler divides (prescales) by 10 from 30–500 MHz, and by 100 from 300 MHz—1.6 GHz, for optimal resolution from a basic counter.

If you want to use a direct 50 MHz counter with 14-bit resolution and a one-second gate to measure up to 450 MHz, you’d have to prescale by 10 for a 7-digit resolution in one second, compared with 6-digit resolution if you prescale by 100. To maximize display resolution requires that the prescaler be able to divide by 10 to reach 500 MHz. Binary dividers are cheaper and more common than decimal versions, and prescaling by 256, 512 or 1024 is easier than by 100 or 1000, but decimal division lets you move a decimal point mentally, and easily understand the reading.

Circuit description

Figure 2 shows the block diagram of the prescaler, and Fig. 3 shows its schematic. IC5 has both 2 and 8 outputs, the one in use being selected using S2. With S2 set to 100, IC3 is +4, and IC4 and IC5 are 5×, for a 100. With S2 set to 10, the input is routed around IC3 to IC4 by PNP diode D4 (acting as a bandswitch). IC4 is a +5 counter, and IC5 is a +2 counter, creating a 10-counter overall. IC1 and IC2 are broadband Monolithic Microwave IC (MMIC) amplifiers used on both ranges. The output of IC1 drives LED bargraph DSPI, the RF signal strength indicator. It’s very useful as a relative field strength meter, for peaking the output of a circuit, or just as a convenient indication of signal presence.

In the prescaler, D4 is used for bandswitching. When reverse-biased, its capacitance is almost constant (0.65–0.75 pf). When forward-biased, its capacitance rises rapidly to 6 pf or more. Its cathode is kept at about +2.5 volts DC by voltage divider RT-R8; the drop across L4 is neg-
The reason is that C10 still looks into pin 7 (out 2), and would see too low an impedance if IC3 were totally off, and too much of IC2’s output would be diverted away from IC4. The value of R5 was found by trial-and-error, to maximize the impedance looking into pin 7 (out 2), while keeping IC3 off. Conversely, when S2 is on — 100, IC3 is now on, since it’s now connected to +5 volts DC through R5 and R6, and their combined value is about 1.5 ohms. The cathode of D4 is still at +2.5 volts DC, but the anode is effectively grounded, so D4 is reverse-biased.

The capacitance of D4 is now about 10% of its forward-biased value, increasing capacitive reactance. The impedance looking into the anode of D4 thus increases, and almost no output from IC2 reaches IC4 directly. The output of IC2 is thus divided, and passed to IC4.

To avoid splitting the output of IC3 between IC4 and the path along C9, trial-and-error again resulted in a high-impedance path looking into the top of C9. In other words, the high impedance of a reverse-biased D4 works both ways. It keeps the output of IC2 from being diverted to IC4, while keeping the output of IC3 from being diverted backward. The loss of output of IC3 through C9-L4 is minimal.

The input enters through J1 and is AC-coupled through IC1 and IC2. Avantek MS4014 MMIC amplifiers. They have double grounds and indirect biasing through R1-L1-C26 for IC1, and R3-L2-C15 for IC2. Carbon-composition resistors R1 and R2 temperature-compensate collector current in IC1 and IC2. L1 and L2 prevent R1 and R2 from affecting the load impedance, which would reduce amplifier gain. IC3 is an NEC UPB582 — 4 MMIC pre-amplifier, with R3, C8, C9, and D4 as its bypass for the — 10. D4 is a Motorola MNP3401 PIN diode, while R7 and R8 produce a +2.5-volt DC bias at the cathode (the output) of D4 via L4. D4 is biased on or off by the 0 or 5 volts DC switched through L3 at its anode.

Device IC4 is a Motorola MC12090 emitter-coupled logic (ECL) +5 prescaler, with a built-in ECL-to-TTL output level converter. R9 keeps the circuit stable without a signal input. IC5 is a TI 745196 presettable binary-de-
The code counter. It has separate +2 and +5 sections; the prescaler drives both, and you select the desired output using S2. R14 and R15 shape and pull up the output; the output will be 1–2 volts peak-to-peak into a load of 50 ohms or more.

Display DSP1 is the Three-Five Systems, Inc. TSM9315 (formerly the National Semiconductor NSM3915) 10-segment LED bar-graph display. Fig. 4 shows the block diagram. It has an on-board monolithic IC with an adjustable internal voltage reference, high-impedance input buffer, accurate 10-step voltage divider, and 10 comparators. R11 and R22 bias D3 as an RF level detector coupled by C26 from ICl. D2 is directly connected to the high-impedance input buffer at pin 6. Within DSP1, the signal is applied to 10 comparators, each biased differently by the precision voltage divider, and driving one LED.

A low-voltage reference signal from R21-D2-R16 is applied to pin 5, to offset the input bias voltage making R16 the zero adjustment. R17 sets full-scale sensitivity by varying the internal reference voltage across the comparators. The current from source (pin 30) determines the display current and brightness. About 10 times this current is drawn through a bit segment, and is fairly constant despite voltage and temperature changes.

The display is logarithmic, with segment thresholds at 3:1 intervals. If you remove Vcc from mode (pin 10) and pin 30 (pin 10) and LED (pin 11), the display changes from a bar graph to a dot graph, with only the top LED of a reading lit. That saves current, but the bar graph is easier to read.

The power supply provides regulated +7.2 volts DC from ICl for IC1, IC2, and DSP1, and +5 volts DC from ICl7 for all else. R36 is an LM317T adjustable regulator set by R15 and R19. The input is polarity protected by D1. Capacitor C23 bypasses high-frequencies to avoid instability and C34 filters 60-Hz ripples. Power jack J3 needs a center-positive, 2.1–2.5-millimeter coaxial plug.

The maximum current through DSP1 with all segments lit is about 400 milliamps. An
The PC board was laid out with tape 4 × actual size. using 50-ohm microstrip signal paths, size calculated for a 0.062-inch glass-epoxy FR4 PC board. The 29 surface-mount devices (SMDs) improve RF performance by reducing size, component lead inductance, impedance mismatch, and poor grounding common in larger parts. MMICs like IC1 and IC2 are mandatory for microwave circuits, and can be handled manually with practice; the prototypes shown here were built with no special tools. The parts are very small, so be careful.

At bare minimum, you’ll need a magnifier lamp, small-tip soldering iron, tweezers, miniature long-nose pliers, and a sharp knife with a small, pointed blade. There are small vacuum tools with different tip sizes available for about $80: a complete kit of soder-creme dispenser gun with cartridges (called capellets), and vacuum tools, is $675 (see the parts list). The PC board is available, or you can use the foil patterns provided here.

The parts-placement diagram for side A is shown in Fig. 5, and for side B in Fig. 6. Install J1 and J2 last, modified as shown in Fig. 7, with a 1/4-inch wide

**FIG. 4—THE BLOCK DIAGRAM OF THE TSM9510 10-segment LED bar-graph display. The on-board IC has an adjustable voltage reference, high-impedance input buffer, 10-step voltage divider, and 10 comparators. The display is logarithmic, each segment represents another 3 dB. Maximum current with all segments lit is about 400 milliamps.**

AC-to-DC adapter should provide +10—+12 volts DC under load at J3, but be careful, since excess voltage will burn out IC6. Such adapters aren’t regulated, so their voltage may vary greatly with load. The prescaler works fine with an adapter rated at +9 volts DC and 500 milliamps, that actually delivers +10.5—+11.5 volts DC. Diodes D5—D7 provide an additional 1.8—2.1 volt DC drop, to avoid overheating IC6.

**Construction**

Build the PC board for the prescaler exactly as shown. Don’t drill any additional holes, or modify the microstrip foils. If you do, you’ll ruin the ground plane needed to achieve the 1.6-GHz bandwidth and excellent sensitivity. The cabinet-mounted and panel-mounted versions were designed for a 3.0 × 3.5-inch, double-sided, plated-through PC board, with solder masks and component screens on each side.

**FIG. 5—PARTS PLACEMENT DIAGRAM FOR side A of the PC board. C15 has a hole for the negative lead; the positive lead is soldered to the foil where R3 meets L2. On IC1 and IC2, the data are the outputs (pin 3); the input (pin 1) is opposite, and pins 2 and 4 are the grounds. D4 is black, rectangular, and has a brown ridge on the cathode end.**
groove. Use a medium iron for them, and the small iron elsewhere. The kit in the parts list has IC socket pins for IC3 and IC4, to shorten the leads and get them closer to the ground plane for better frequency response. For IC5, use a regular 14-pin DIP socket, since it operates over a lower frequency range.

Install the SMDs next; note the polarity of any capacitors IC1 and IC2, tantalums C4, C5, C7, and C16, and LED1 and LED2, and install all parts from smallest to largest. IC1 and IC2 should both have dots indicating their outputs (pin 3); the input (pin 1) is opposite this, and pins 2 and 4 are the grounds. With the dot on pin 3 pointing toward the bottom as in Fig. 5, pin 1 points upward, pin 2 points left, and pin 4 points right.

For the SMD tantalums, C4, C5, and C16 are the same size.

While C7 is much larger in the prototypes and the kit in the parts list, C4, C5, and C16 are orange in the center and silver on each end. They have a small tip on the positive end, and a green dot on the top side. C7 is yellow, with a brown band on the top of the negative end. Capacitor C15, at the middle right, will partially block IC2 and L2, so install them first. There’s a hole for the negative lead of C15, but the positive lead is tack soldered to the foil where R6 meets L2. Insert the negative lead into its proper hole, and bend the positive lead outward at right angles. Diode D4 is black, rectangular, and has a brown ridge on the cathode end, the brown ridge faces to the right.

Install LED1 and LED2 last in the prescaler. For the case-mounted version, insert the LED’s into their PC board holes without soldering. Hold them in place with your fingers and pull the leads through the holes, until they both almost touch the surface of side B. Fold the leads over slightly, so they can’t fall out. Insert the PC board into the case, with side A facing out. Bend the LED leads back to vertical so they slide freely, maneuver the LED’s so they protrude through their holes in front, then solder and trim. If you remove the PC board from the case, the LED’s should slide out freely. When you put the PC board back in the case, the LED’s should slide back into their holes.

For the panel-mounted version, don’t install the LED’s until you attach J1 and J2 to the faceplate, and are ready to attach the PC board. Pull the LED’s through their holes in the PC board, and bend the leads to hold them in place. Insert the center pins and ground lugs of J1 and J2 into the holes next to the notches, and bolt the bottom of the PC board to
FIG. 8—PROTOTYPE OF THE CABINET-MOUNTED version; side A appears in (a), side B appears in (b). The header pins protrude through from side A, and are soldered to DSP1 using the bottom 10 pin holes on the display PC board.

FIG. 9—PROTOTYPE OF THE PANEL-MOUNTED version, showing side A. The header pins are inserted into side B; the separator is on the same side. PL1 connects two twisted pairs; the output to the HP 5245L, if from the header pins at upper left, and the -13 volts DC from the HP 5245L to those at lower right. The TMA07 on pin 13 of PL1 has been replaced by DS-07 at S1's location (see text), to avoid damaging IC6. Use heatshrink tubing with all four wires to avoid shorts.

FIG. 10—SENSITIVITY CURVES FOR BOTH the -10 and -100 ranges. The -10 range covers 30-400 MHz, and the -100 range covers 330 MHz-1.6 GHz.

the faceplate with nylon washers and a nonconductive spacer. Solder the center pins and lugs for J1 and J2, use two lugs for J1, and one for J2. When the PC board is attached to the faceplate, maneuver the LEDs as before, solder and trim.

If you have no SMD tools, hold the SMD in place with a small, sharp knife, a pencil, or a probe. Tack solder one side to hold it in place so you can solder the remainder with both hands; then, resolder the front side. There are kits of SMD tools available that can make working with the devices easier.

Solder creme is powdered solder mixed with flux. With a gun dispenser, place a very tiny spot on each SMD solder pad, and position the SMD with a vacuum tool; it should stick to the solder creme. Heat the foil, and the solder creme should melt; never heat the solder creme directly.

Figure 8-a shows side A of the cabinet-mounted prototype, and Fig. 8-b shows side B. In Fig. 8-a, IC7 has been soldered over to lie on its heatshrink pad. You can't bolt the heatshrink to the PC board in the prescaler, since DSP1 is in the way, but even if you could, it's unnecessary. The center pins of J1 and J2 are on side A; both the threads and center pins were separately soldered. In Fig. 8-b, IC6 has been folded over like IC7, but holes 1–10 on DSP1 on side B; the plastic separator is on side A. Figure 9 shows side A of the
panel-mounted prototype. PLL is connected to the PC board by two twisted pairs and two pairs of header pins. The output led back into the HP 5245L comes from the header pins at upper left. The lower pins are the output, the lower pin is ground. Power goes into the header pins at lower left; the left one goes to the +13 volts DC from the HP 5245L, and the right one is ground.

The prototype was built before using D5–D7; the anode of a IN4007 was soldered to pin 13 of PLL, and the cathode to the positive power wire (blocked by the black heatshrink tubing). PLL is a standard male Centronics plug. Cover both ends of all four wires with heatshrink tubing to avoid shorts. However, one IN4007 didn't provide a sufficient drop, so D5–D7 were used thereafter.

Figures 3, 4, 5, and 6 all show D5–D7; in the panel-mounted version they replace S1, to provide an additional 1.8–2.1 volt DC drop, as mentioned above, to reduce the +13 volts DC from the HP 5245L. IC5 doesn't overheat to the point of exceeding specification. The drops across D1 and D2 reduce the +13 volts DC from the HP 5245L to +10.2–10.6 volts DC, enough to run IC6 with minimum heat dissipation.

To install D5–D7, wrap the cathode of D5 around the anode of D6, and the anode of D7...
around the cathode of D6, solder and trim. Insert the anode of D5 and the cathode of D7 into their PC board holes, and leave enough lead length on side B to bend D5-D7 flat to the PC board.

In the panel-mount version, install the DSP1 header pins with the plastic separator on side B (the separator is on side A for cabinet installation) to hold DSP1 off the PC board and flush with the red lens and panel.

The PC board and red lens is a precise fit inside the case and shouldn’t move around. In the panel-mounted version, the lens is sandwiched between DSP1 and the rear of the faceplate, and has a hole drilled in its bottom for the screw that attaches the PC board to the bottom of the faceplate.

The lens goes between the rear of the faceplate and the nylon washer at the base of the nonconducting spacer.

Power-on checkout

Turn the power on, and check for proper voltages:

- At J3, +10.5 ± 1.2 volts DC, input power.
- At the output of IC6, +7.1 ± 0.3 volts DC (adjust R10).
- At the output of IC7, +4.9 ± 0.5 volts DC.
- At the outputs of IC1 and IC2, a bias of 4.0 ± 0.7 volts DC (with no input signal).

For the panel-mounted version, J3 is included to let you test it without connecting it to the HP 5245L, if all voltages are right, adjust R16 to zero the bar graph, and R17 for full scale. The two potentiometers interact, but you should get a good setting with a signal generator and some experimenting. The bar graph varies with frequency, but is a convenient relative RF signal strength indicator. With careful assembly, sensitivity should be 1–9 millivolts RMS from 50 MHz–1.6 GHz, consistent with the curves shown in Fig. 10.

IF YOU WANT SMD TOOLS, (a) shows a kit mentioned in the parts list. Solder creme is powdered solder mixed with flux. With the gun in (b), place a spot on each pad, and position the SMD with the vacuum tool in (c); it should stick to the solder creme. Heat the foil, and the solder creme should melt. In (d) a close-up of the gun and three capellets is shown.