BUILD THIS BENCHTOP FREQUENCY COUNTER

Add frequency-measurement capabilities to your workbench with this inexpensive counter.

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THE INTERSIL ICM7216 frequency-counter IC's (models A–D) have an impressive array of functions. All have a high-frequency oscillator, decade timebase counter, 8-decade data counter and latches, 7-segment decoder, digit multiplexers, and 8-digit multiplexed LED-display drivers.

There are four models; the 7216A and 7216B are universal counters, capable of measuring input frequency, oscillator frequency, frequency ratio, period, and time interval, and can perform unit counting. The frequency counter discussed here uses the 7216C with a common-anode display (the 7216D is similar). It'll become one of the most versatile pieces of test equipment on your bench, and simply fun to use. You can build it for about $80.

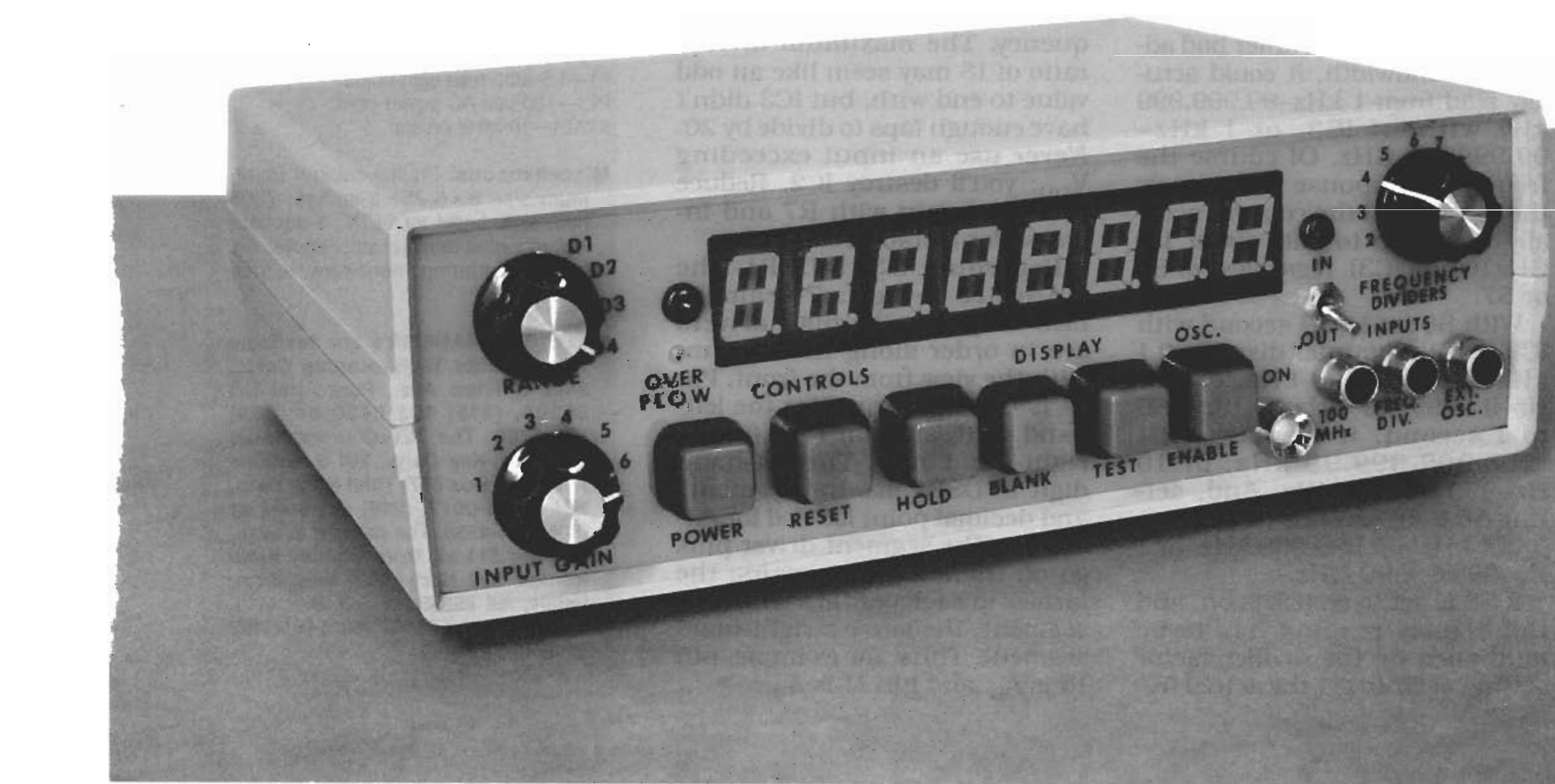
Circuit description

Figure 1 shows the pinouts for all four 7216 versions; the 7216A/B use two inputs for measurements like the ratio of two frequencies. The 7216C/D use single inputs, but have external decimal point (EX DP INPUT) inputs (pin 13), and MEASUREMENT IN PROGRESS outputs (pin 2).

The frequency counter schematic is shown in Fig. 2. IC2 decade counts the input frequency, stores the result in latches, drives an 8-digit multiplexed LED display, and blanks all leading zeros. While the internal oscillator normally uses 10-MHz crystal XTAL1, an external source can go on J3 to pin 24 of IC3 (EXT OSC INPUT). Some other 7216C features are display blanking, measurement holding, and display test-reset.

Since IC2 is designed for a maximum reading of 10 MHz, IC1, a 7490 decade counter, expands the range to 100 MHz by connecting pin 1 (B_{IN}) to pin 12 (Q_A) for the maximum count period. Pin 8 (Q_C) is tied to pin 28 (INPUT A) of IC2 for measurement. For more expansion, IC3, a CD4017 decade counter, is an adjustable divide-by-N.

As mentioned earlier, there are four ranges, and operation is possible with or without IC3. When S8 is set to OUT, IC3 isn't used, and the display reads 1:1, showing the actual undivided frequency of the input on J1 or J2 in kHz. Obviously, if the frequency of the input goes below the nominal minimum possible for any given range, the display will read zero.



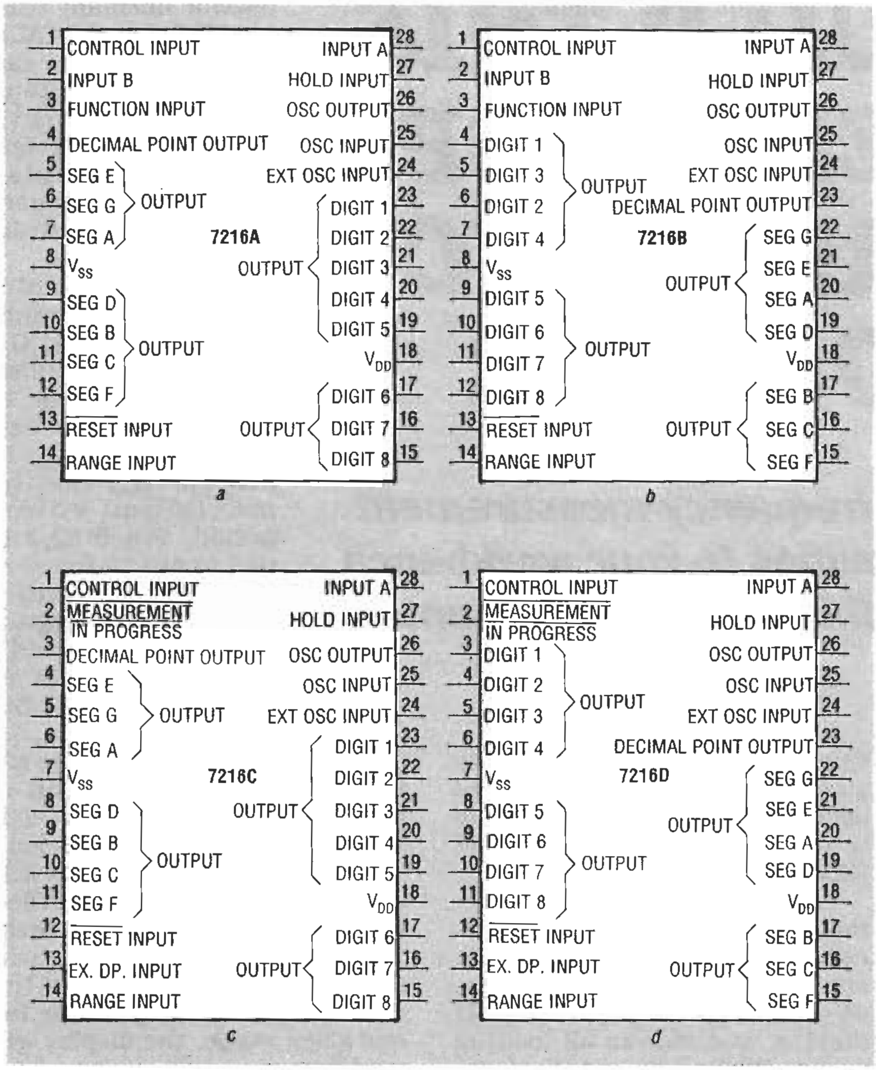


FIG. 1—THE PINOUTS OF ALL FOUR VERSIONS of the 7216. The 7216A/B both take two inputs, for measurements like the ratio of two frequencies, while the 7216C/D have single inputs.

If the frequency counter had adequate bandwidth, it could actually read from 1 kHz–99,999,999 kHz without IC3, or 1 kHz–99.999999 GHz. Of course the frequency response isn't nearly that good, and the counter actually works up to only about 1.8 GHz (using IC3), regardless of S6 or S7.

With S6 set to 0.1 second with IC3 out, the counter displays 0.1 kHz–9,999,999.9 kHz, or 100 Hz–9.9999999 GHz. Setting S6 to 1 second, it displays 0.01 kHz–999,999.99 kHz, or 10 Hz–999.99999 MHz. And, setting S6 to 10 seconds, it displays 0.001 kHz–99,999.999 kHz, or 1 Hz–99.999999 MHz.

If S8 is set to IN, IC3 is on, and the display reading has to be multiplied by the divider factor setting of S7 to get the actual frequency. The maximum divider ratio of 18 may seem like an odd value to end with, but IC3 didn't have enough taps to divide by 20. *Never* use an input exceeding V_{DD}; you'll destroy IC2. Reduce the input gain with R7 and increase for a stable reading.

Regarding DSP1–DSP4, the MAN6710 2-digit, 7-segment LED displays, the digit drivers are in order along the bottom, with the view from the front. Pin 14 is the digit driver for the left-hand digit, and pin 13 is for the right-hand digit. The left-hand digit in DSP4 has the segments and decimal point labeled for reference. The segment driver pins go on the left side in pairs; the former in each pair is a left-hand segment, the latter a right-hand segment. Thus, for example, pin 16 is A_L, and pin 11 is A_R.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—3300 ohms
R2—100,000 ohms
R3, R5—10,000 ohms
R4—22 megohms
R6—22,000 ohms
R7—500,000-ohm front panel potentiometer
R8—470 ohms
R9—1-megohm PC-board potentiometer
R10—1000 ohms

Capacitors
C1—100 pF, ceramic disc
C2—27 pF, ceramic disc
C3—6–50-pF PC-board trimmer
C4, C8—0.1 µF, ceramic disc
C5—3300 µF, 25-volt electrolytic
C6—1 µF, 10-volt electrolytic
C7—100 pF–1 µF PC-board trimmer

Semiconductors
D1–D4—1N914 diode
BR1—1.5-amp bridge rectifier
DSP1–DSP4—MAN6710, 2-digit, red, common-anode, 0.506-inch, 7-segment LED displays
IC1—7490 BCD counter
IC2—Harris 7216C frequency counter (Digi-Key ICM7216CIJI)
IC3—CD4017 decade counter
IC4—7805 5-volt DC regulator
IC5—555 timer
LED1—miniature red T-1 light-emitting diode
LED2—standard green, jumbo, diffused, T-1-¾ light-emitting diode

Switches
S1, S5—SPST momentary push button
S2–S4—SPST ON/OFF push button
S6—SP4T rotary switch
S7—SP9T rotary switch
S8—DPDT toggle switch
S9—SPST ON/OFF push button

Other components
J1, J2—RCA jack
T1—120-to-12.6-volt, 1.2-amp, AC power transformer
F1—1.5-amp fuse with holder
PL1—120-volt AC power cord
XTAL1—10-MHz crystal

Miscellaneous: Plastic cabinet (minimum size 8 × 6.25 × 3-inches, 7805 heat sink, bezel for LED2, 5-pin cabinet-mounted terminal strip, knobs, dry transfer lettering, hardware, solder, wire, etc.

NOTE: The MAN6710's are available from Quality Technologies Corp., 3400 Hillview Ave., Palo Alto, CA 94304, (415) 493-0400 or (800) 533-6786. The 7216C is available from Digi-Key Corp., 701 S. Brooks Ave., P.O. Box 677, Thief River Falls, MN 56701-0677, (218) 681-6674 or (800) 344-4539. The cabinet is available for $14.95, from Chaney Electronics, 932 North 94th Way, Scottsdale, AZ 85258, or P.O. Box 4116, Scottsdale, AZ 85261, (602) 451-9407 or (800) 227-7312.

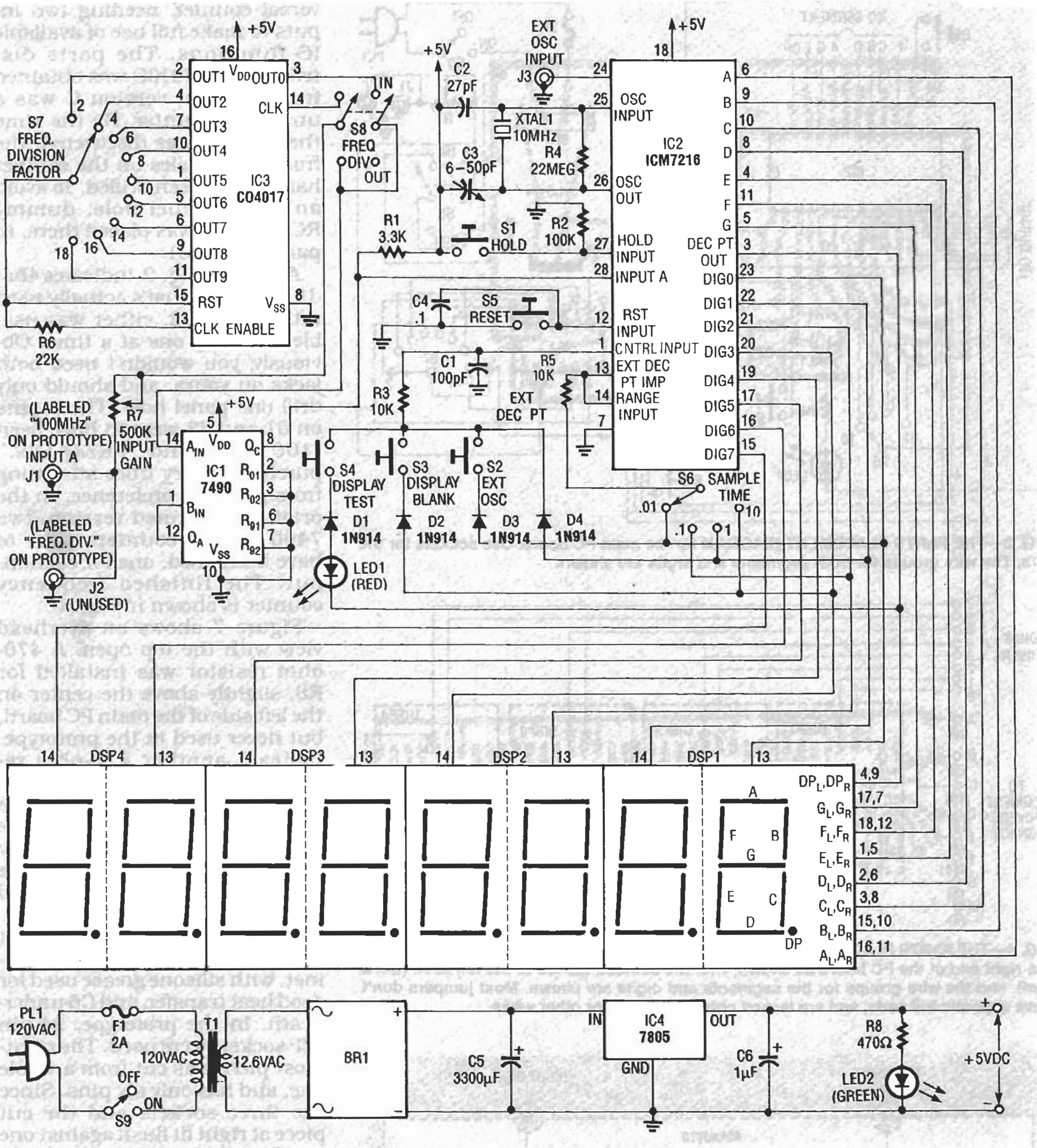


FIG. 2—THE FREQUENCY COUNTER SCHEMATIC; IC2, the 7216C, counts input frequency in decades, stores the result in latches, and drives an 8-digit multiplexed LED display, with leading zero blanking. While the internal oscillator normally uses with 10-MHz crystal XTAL1, J3 takes an external source. Other 7216C features include display blanking, measurement holding, and display test/reset.

Construction

The parts-placement diagram for the main PC board is shown in Fig. 3, and the display board is shown in Fig. 4; the foil patterns are also provided in this article. The prototype version omitted the power supply now incorporated in the main PC board. Use 18-pin DIP sockets for the LED-display PC board, and appropriate sockets for the main PC board. The wire groups for both the segments and the digits are indicated in both Figs. 3 and 4, and are omitted for clarity.

The Monsanto MAN6710's are 2-digit, 7-segment, multiplexed, common-anode LED displays; their pinouts are shown in Fig. 5. The B, D, F, and DP segments were connected by PC-board foils, and the A, C, E, and G segments using jumpers; the G jumpers criss-cross the display PC board as they progress. Use multi-colored wire to identify the various segments and digits; digit drivers D1–D8 go to the top of

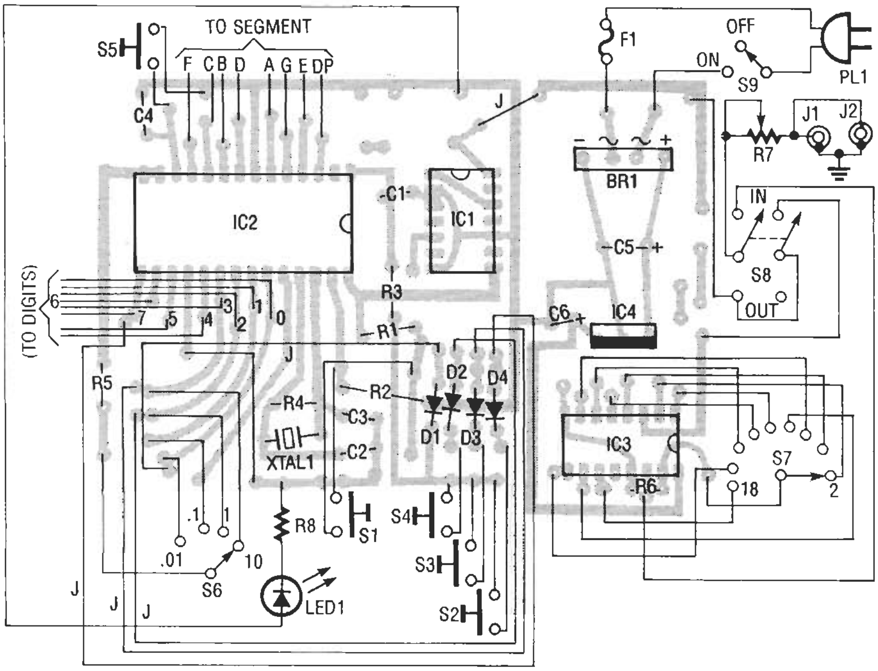


FIG. 3—THE PARTS PLACEMENT DIAGRAM for the main PC board. Use sockets for the IC's. The wire groups for both segments and digits are shown.

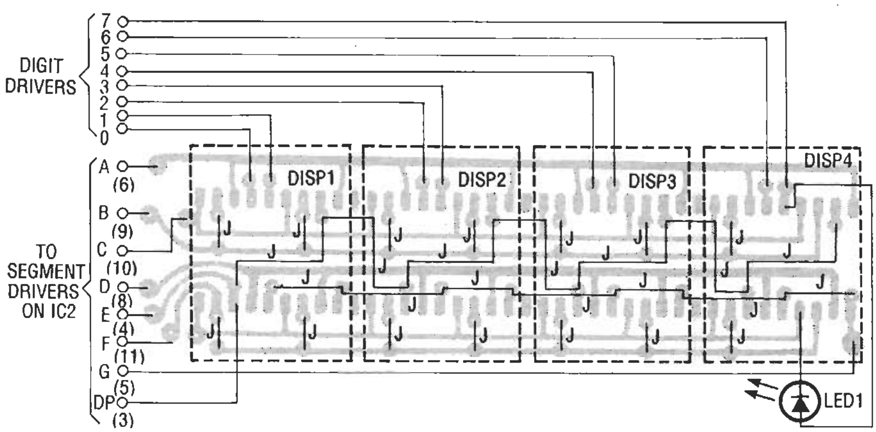


FIG. 4—THE PARTS PLACEMENT DIAGRAM for the LED-display PC board. LED1 goes on the right end of the PC board as shown, with the cathode tacked to the foil itself (not a pad), and the wire groups for the segments and digits are shown. Most jumpers don't have separate foil pads, and are tacked onto pads used for other wires.

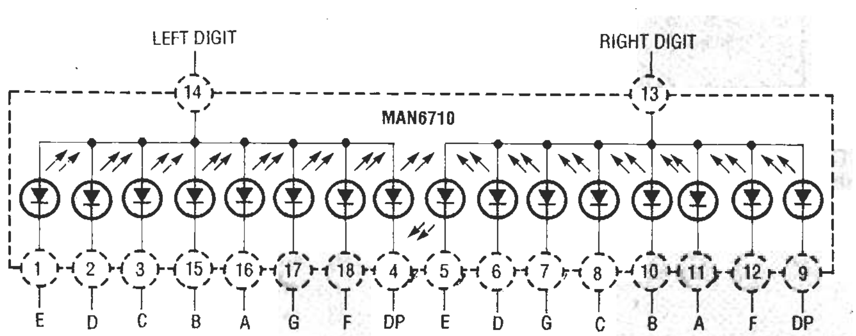


FIG. 5—PINOUTS FOR THE MAN6710 2-DIGIT, 7-segment, common-anode, multiplexed LED display.

the display board. Several jumpers must be tack soldered to the pads on the foil side of the display board.

The reason J1 and J2 are connected together is because in the prototype, the original plan (later abandoned) was to make a universal counter, needing two inputs to make full use of available IC functions. The parts distributor the 7216C was obtained from thought version C was a universal counter. By the time the mistake was discovered, the front-panel holes on the cabinet had already been drilled. To avoid an empty panel hole, dummy RCA jack J2 was placed there, in parallel with J1.

Although Fig. 2 indicates that J1 is the one that's actually used rather than J2, either was usable, but only one at a time. Obviously, you wouldn't need both jacks on yours, and should only drill one panel hole. The inputs on J1 and J2 were to have been "100 MHz" and "FREQ DIV," purely arbitrary titles stemming from personal preference. In the originally planned version, two 7490 decade counters were to have been used, one for each input. The finished frequency counter is shown in Fig. 6.

Figure 7 shows an overhead view with the top open. A 470-ohm resistor was installed for R8, slightly above the center on the left side of the main PC board, but never used in the prototype. Instead, another 470-ohm resistor was placed off-board, in series with LED2, behind where LED2 and its bezel fit into the front panel. The prototype really used four boards, but only the main and display boards had foils.

The IC4 heatsink is of sheet aluminum, bent to fit in the cabinet, with silicone grease used for good heat transfer, and C6 underneath. In the prototype, 24-pin DIP sockets were used. The rightmost piece was cut from a whole one, and has only six pins. Since the three sockets and the cut piece at right fit flush against one another, there's an unused hole between individual displays. To avoid cutting a socket, use 18-pin versions in yours. The 5-pin terminal strip is used as a feed point for the +5 volts from IC4.

Figure 8 shows a closeup view of the LED-display PC board from the foil side. Since three holes were needlessly drilled for J1–J3, there wasn't enough room left for S8, so a notch was cut in the lower left corner of the display PC board, clearly visible in Fig. 8. The wires to LED1 are at upper

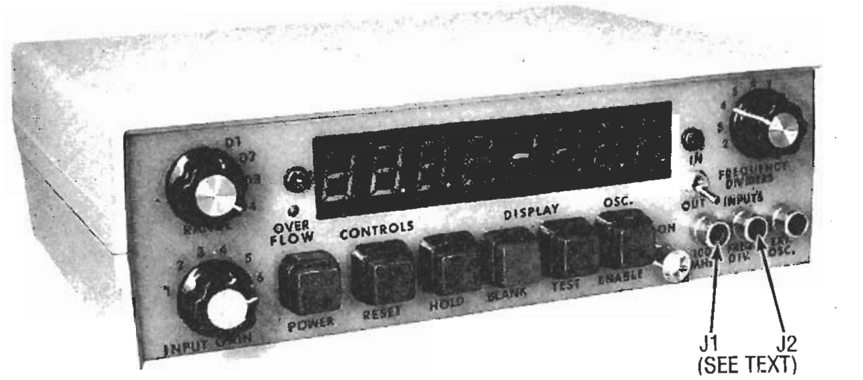


FIG. 6—THE FINISHED FREQUENCY COUNTER, shown in display-test mode, with all digits and decimal points lit. J1 and J2 are wired together, but one is unnecessary (see text).

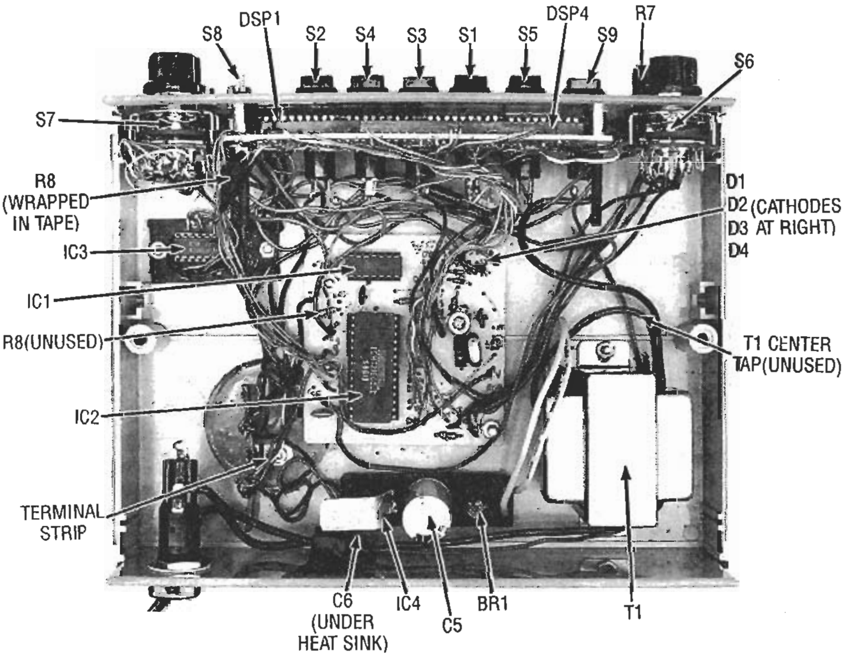


FIG. 7—AN OVERHEAD VIEW OF THE PROTOTYPE; R8 on the main PC board wasn't used. Another off-board 470-ohm resistor is in series with LED2, and IC3 and IC4 were later added to the main PC board. The IC4 heatsink is sheet aluminum with silicone grease; C6 is underneath. The prototype had three complete 24-pin DIP sockets for the LED displays, and part of another, with an unused hole between displays; use 18-pin sockets in yours. The markings shown on D2 and D4 are wrong; the cathodes all point right. The terminal strip is a feed point for the +5 volts from IC4.

right: normal polarity is reversed, with black going to the anode, and white to the cathode. Note the unused pads between individual LED displays, where they fit against one another on the component side.

The prototype cabinet is 8 × 6.25 × 3-inches; drill the front panel holes, and do the labeling before installing the switches, jacks, and display. Use dry transfer lettering with a light coat of clear enamel to prevent damage. The prototype has the labels of the digit drivers used on S6 for setting the display decimal point; instead, use the sample times shown in Fig. 2. Mount T1, anchor the PC boards, and check for wiring errors.

Power-up, test, and calibration

When you apply power, LED2 should glow. Press S4 (DISPLAY TEST), and the display should show all 8's and decimal points, and LED1 should light. If not, disconnect the power and recheck the wiring. With S8 in the OUT position, IC1 is off; set R7 for maximum gain, and apply a signal of known frequency no more than 5 volts in magnitude to J1 or

TABLE 1—IDEAL FREQUENCY COUNTER DISPLAY RANGES FOR ALL S6/S7 SETTINGS

Frequency Divider Setting (S7) / Sample Time Setting (S6), s	1	2	4	6	8
0.01	1–99,9999,999	2–199,999,998	4–399,999,996	6–599,999,994	8–799,999,992
0.1	0.1–9,999,999.9	0.2–19,999,999.8	0.4–39,999,999.6	0.6–59,999,999.4	0.8–79,999,999.2
1.0	0.01–999,999.99	0.02–1,999,999.98	0.04–3,999,999.96	0.06–5,999,999.94	0.08–7,999,999.92
10.0	0.001–99,999.999	0.002–199,999.998	0.004–399,999.996	0.006–599,999.994	0.008–799,999.992

Frequency Divider Setting (S7) / Sample Time Setting (S6), s	10	12	14	16	18
0.01	10–999,999,990	12–1,199,999,988	14–399,999,986	16–1,599,999,984	18–1,799,999,982
0.1	1.0–99,999,999.0	1.2–119,999,998.8	1.4–139,999,998.6	1.6–159,999,998.4	1.8–179,999,998.2
1.0	0.10–9,999,999.90	0.12–11,999,999.88	0.14–13,999,999.86	0.16–15,999,999.84	0.18–17,999,999.82
10.0	0.010–999,999.990	0.012–1,199,999.988	0.014–1,399,999.986	0.016–1,599,999.984	0.018–1,799,999.982

Note: The actual frequency response is limited to approximately 1.8 GHz for all S6/S7 settings; all values shown here in kHz.

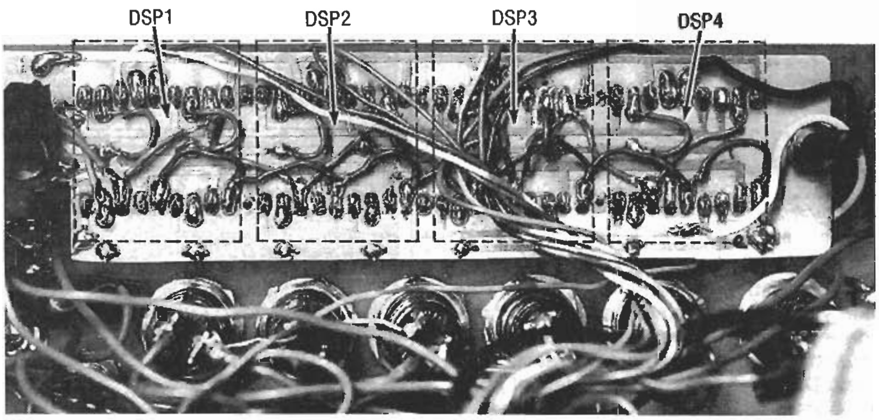


FIG. 8—A CLOSEUP OF THE FOIL SIDE OF THE LED-display PC board. Most jumpers go directly to the foil-side pads; there are no separate holes. Since holes were drilled for J1–J3, there wasn't room for S8, so a notch was cut in the lower left corner. The wires to LED1 (beneath the PC board) are at upper right, black to anode, white to cathode. The pads between the displays are unused, where they fit against one another on the component side.

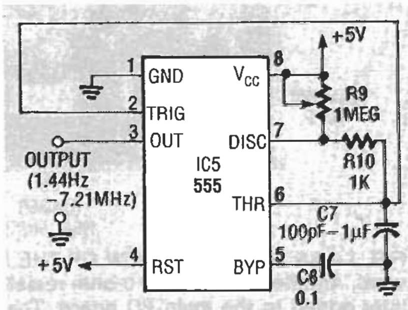


FIG. 9—AN OPTIONAL 555-TIMER ASTABLE square-wave generator for debugging the frequency counter. Both R9 and C7 are variable, to vary the output frequency from 1.44 Hz–7.21 MHz. The breadboard with this circuit on it appears in the lead photo.

J2 from a digital pulse generator.

Tune C3 until the display shows the same frequency as your standard, and the counter is calibrated. Switch S6 controls the number of digits of resolution following the decimal point. The frequency is in kHz, so 1 kHz on the 10-second setting of S6 should show up as 1.000. As you increase the sample time on S6, the accuracy increases but so does the measurement interval. On the 0.1-second setting, the reading is to one decimal place but takes only 0.1 second, whereas on 10.0-second setting, there should be three decimal places, but the sample time also increases accordingly.

The setting on S7 is the factor an input frequency is divided by. Thus, a 100-MHz signal reads 50 MHz on setting S7 to 2, 25 MHz on setting S7 to 4, etc. Conversely, 100 MHz on the display on setting S7 to 10 implies a 1-GHz input. S5 resets the display to zero, S1 retains a readout as long as needed, S3 just blanks the display, S2 introduces clocking from an external source on J3, and LED1 indicates overflow.

A simple astable multivibrator square-wave generator is shown in Fig. 9 for calibrating the frequency counter. Adjusting R9 and C7 will vary the output frequency from 1.44 Hz–7.21 MHz. **R-E**