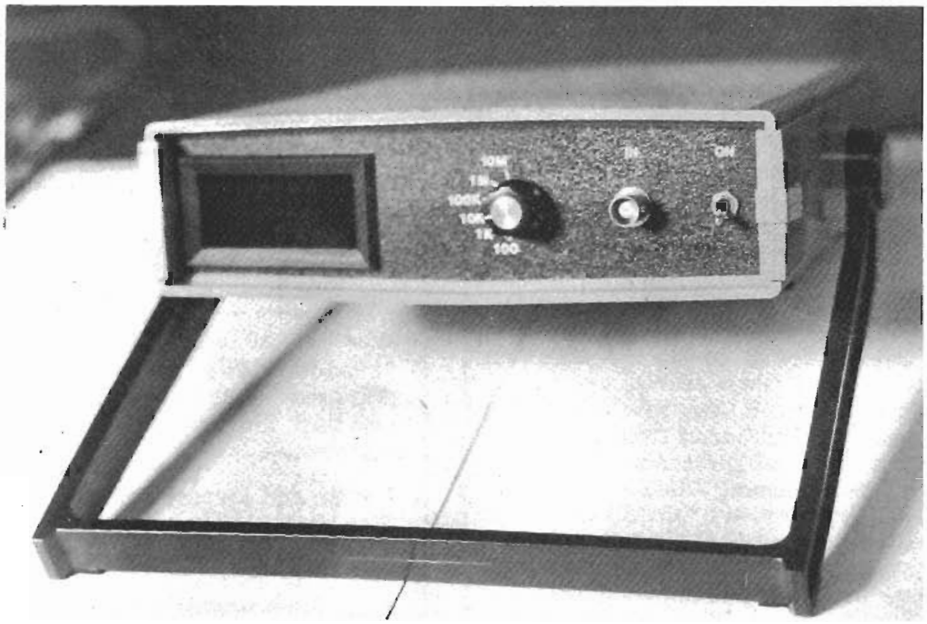
Frequency Counter

PROJECT

For those who need frequencies counted, ETI presents a simple, easy-to-build digital frequency counter. Design by Dave Bedrosian



A FREQUENCY COUNTER is a very useful piece of test equipment as it can be used for troubleshooting both analog and digital circuitry. The design shown in this article uses readily available TTL and CMOS ICs for measuring frequencies from below 10 Hz up to 10 MHz.

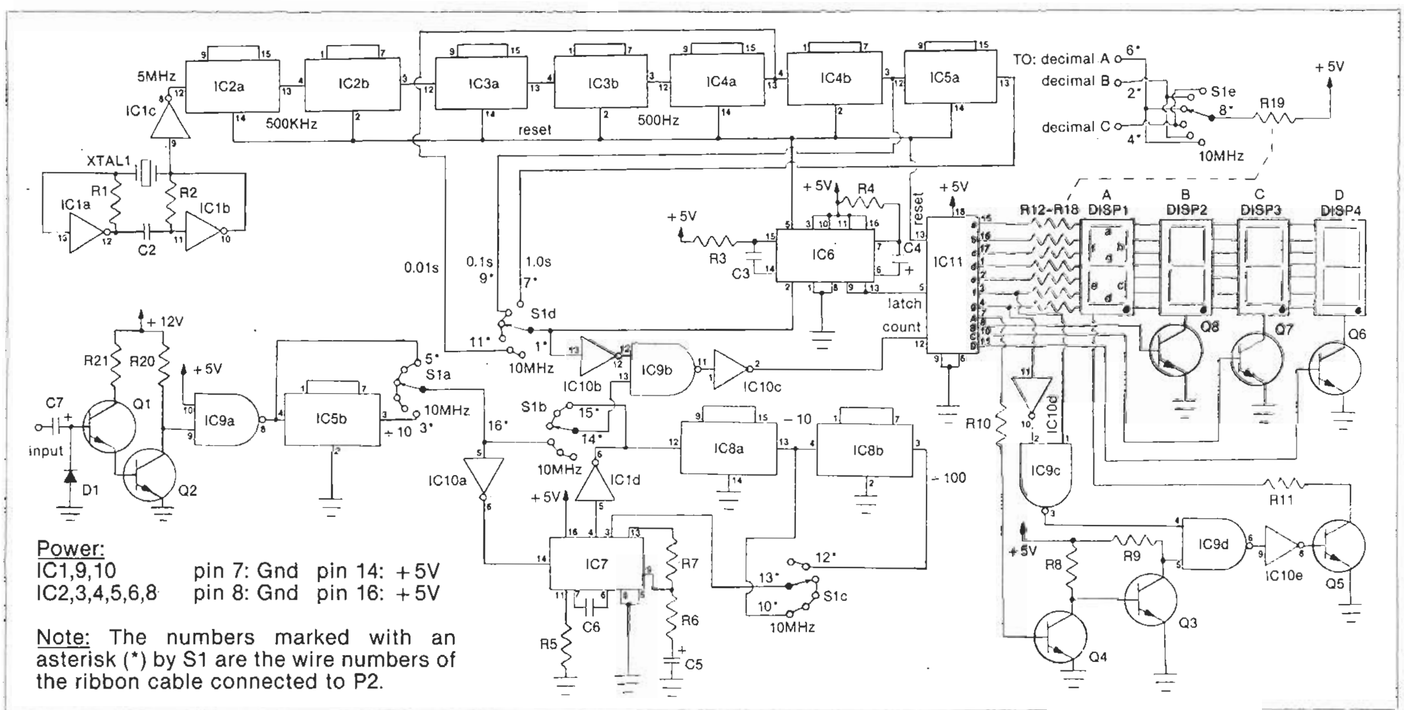
This counter differs from others in several important areas:

The gating times are generated by a crystal controlled clock which is very accurate and will not drift significantly with time as opposed to the more commonly used monostable multivibrator.

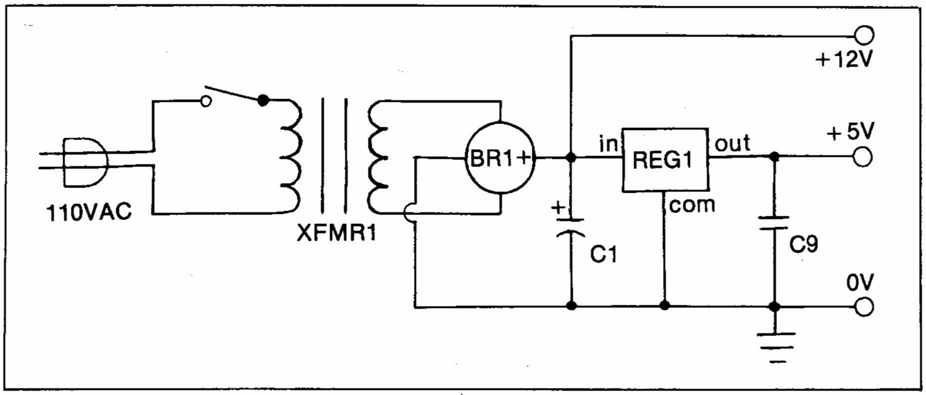
When measuring low frequencies (below 10 KHz), the input signal is multiplied by up to 100, thereby reducing the reading time to one second or less.

This frequency counter automatically updates its display about three times every second (approximately once per second on the 100 Hz range), and a latch is used to provide a flicker-free display of the input frequency.

A block diagram of the frequency counter is shown in figure 1. The input signal, after being conditioned by the input circuit, is "anded" with the gating pulse and the resulting signal is fed to the counter, which counts the number of high to low transitions at its input. This count is then latched and displayed on the four



Schematic diagram for the frequency counter.



Power supply schematic for the frequency counter.

seven-segment displays. If, for example, the gating pulse is set at one second and the input frequency is 2259 Hz, the counter will 'see' 2259 high to low transitions in the one second gating period and thus 2259 will be displayed. Refer to the "How it Works" section for a more detailed description of the frequency counter.

Construction

The printed circuit boards shown in this article are recommended to speed construction and reduce the possibility of wiring errors; however, wire-wrapping techniques could be used if desired. The following construction details apply when the suggested Hammond case is used with the printed circuit boards.

Start by assembling the large board. First solder in the jumpers; there are 24 of them. Use a short piece of insulation to insulate J1 from the crystal leads. Next, solder in the IC sockets and the power supply parts. Be sure to attach heatsinks to both the bridge rectifier and the regulator before soldering them in place. Neither silicone nor mica insulators are required for either heatsink. The remaining parts can now be soldered in place. Pay attention to the orientation of the tantalum capacitors, transistors and diode.

Before inserting the ICs, temporarily apply power to the board and check the power supply. The input to the regulator should be 9V or greater (depending on the transformer used) and the outut of the regulator should be 5V, within half a volt. Check each IC socket separately for +5V and ground (excluding the two 16 pin header sockets and the DIP resistor socket). Pin 7, 8, or 9 should be ground and pin 14, 16, or 18 should be +5V for 14, 16, and 18 pin sockets respectively. If there is a problem, check that all of the jumpers are installed correctly. With ground and +5V at each IC socket, power should be removed and the ICs inserted; note the proper orientation of each one. The DIP resistor obviously can go in either way; if, however, it is not available eight 33 ohm resistors bent for 0.4 inch insertion can be used instead.

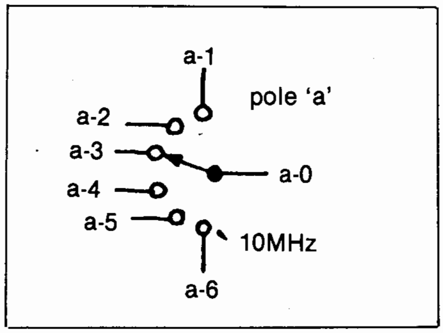
With the main board completed, the display board can be assembled next. Solder in the ten jumpers and the two IC sockets, then insert the four displays using the parts overlay and figure 2. The decimal point of each display should be on the bottom half of the display board. Next a six inch sixteen pin header cable should be made as indicated in figure 3 and connected to both boards as shown on the parts overlay.

Having completed both printed circuit boards, the rotary switch can be wired. Initially it should be tested with an ohmmeter to verify that each position of

Table 1

Wire Number	Switch Location
1	d-0
2	e-2, e-5
3	a-6
4	e-1, e-4
5	a-1,a-2,a-3,a-4,a-5
6	e-3, e-6
7	d-1
8	e-0
9	d-2, d-3, d-4
10	c-3, c-4, c-5, c-6
11	d-5, d-6
12	c-1, c-2
13	c-0
14	b-0
15	b-1, b-2, b-3
16	a-0, b-4, b-5, b-6

Table 1. Wiring table for switch 1.



each pole is operational; this may save considerable time if troubleshooting is required later. Use table 1 to connect an eleven inch piece of ribbon cable to the switch.

At this point in construction the unit can be fully tested. With the rotary switch and the display board connected properly, apply power to the main board. If all is well the display will read '000' or '001' and the leftmost digit will be extinguished. If there is a problem, refer to the troubleshooting section, otherwise continue testing. Apply about a 2V peak to peak signal to the input for each of the six ranges; in each case the display should read out the correct frequency. For frequencies above approximately 200 KHz, a TTL equivalent signal should be applied to J17, bypassing the input circuit since it only responds to signals below this frequency. With a signal applied to J17, the frequency counter should read signals up to 9.999 MHz. Also check that the leftmost digit is extinguished when it is zero, and that the decimal point moves according to the rotary switch position. If all ranges work properly, continue construction by mounting all parts inside the cabinet.

The front and back panels which come with the cabinet are over three inches high and should both be cut down to the two inch mark and appropriate holes drilled. The display board and bezel can be mounted to the front panel followed by

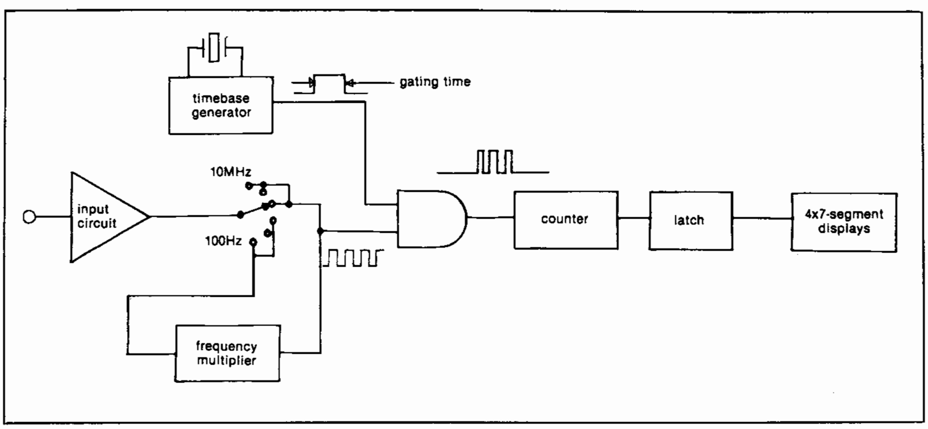
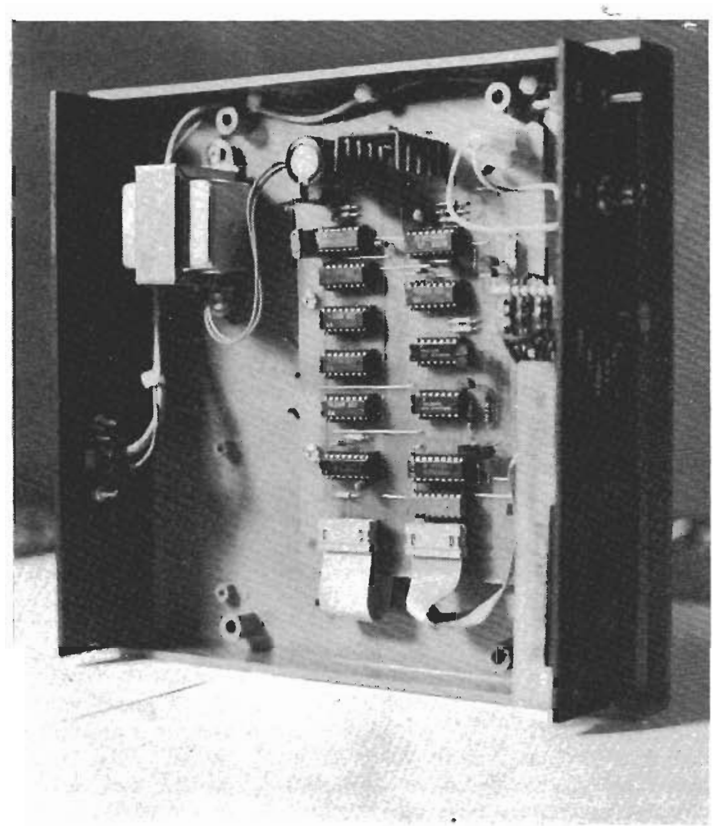


Figure 1. Frequency counter block diagram.

Problem	Area of Problem	Possible Cause of the Problem
all four digits extinguished	display driver circuitry	- DISP1-DISP4 properly oriented - ribbon cable connected properly - DIP resistor in place - IC11 properly inserted - Q6,Q7,Q8 properly inserted
leftmost digit always extinguished	first-digit blanking circuitry	- Q3,Q4,Q5 correctly in place - R8-R11 proper values - proper insertion of IC9,IC10
decimal point not on	decimal point switching circuitry	- proper connection of ribbon cable - wiring of switch 1, pole 'e' - R19 (DIP resistor) okay
display on, but unit won't count on any range	input circuit or clock circuit or reset circuit	- input BNC connector - input circuitry (Q1,Q2) - wiring of switch 1 poles 'a', 'b' and 'd' - R3,C3,R4,C4 proper values - IC6 inserted correctly - operaton of the clock and clock divider circuitry (IC1-IC5) - proper insertion of IC9-IC11
operational on all but the lower three ranges	input frequency multiplier	- switch 1, pole 'c' - all parts associated with IC7 and IC8
operational on all but the 10 MHz range	input frequency divider	- switch 1, pole 'a' - proper wiring of IC5b

Table 2. Troubleshooting guide.



the rotary switch, BNC connector and the power switch. The back panel only has the power connection. The main board is mounted inside the cabinet with the input molex connector adjacent to the BNC connector. Mount the transformer and wire the power switch followed by the BNC and power connectors. Finally, plug the two 16 pin headers into the appropriate sockets.

The frequency counter is now complete and should be tested again. If input signals greater than 200 KHz are frequently going to be measured, the input circuit should be redesigned to respond to signals up to 10 MHz. Alternatively, a switch could be used to take the input circuit out of the signal path in which case the input signal would have to be TTL compatible.

Use

The frequency counter is very easy to use. An appropriate signal is applied to the input BNC connector, and the corresponding frequency is read off the display. If the recommended input circuit is used, the input signal should be less than 200 KHz with an amplitude greater than two volts peak to peak. When taking a reading, the highest range should be selected first and lower ranges selected until the left display is lit; this avoids misreading the counter when there is an overflow. The lower three ranges of the counter may take a few seconds to stabilize after a signal is applied while the phase-locked loop locks onto the input signal. On all but the 100 Hz range, the display is updated about once every 300 ms; the 100 Hz range, having a gating time of one second, is updated once every 1.3 s or so.

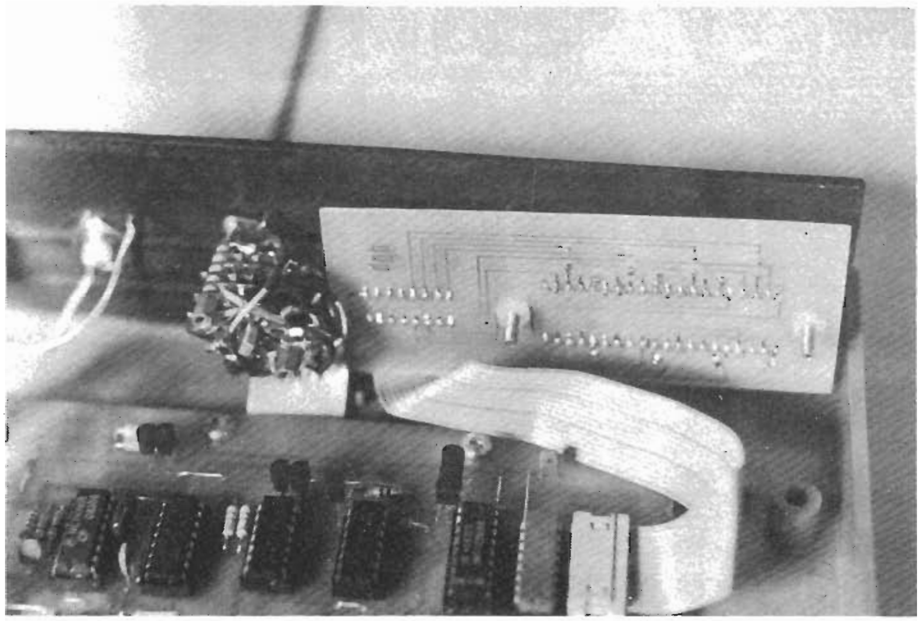


Figure 2. The display board.

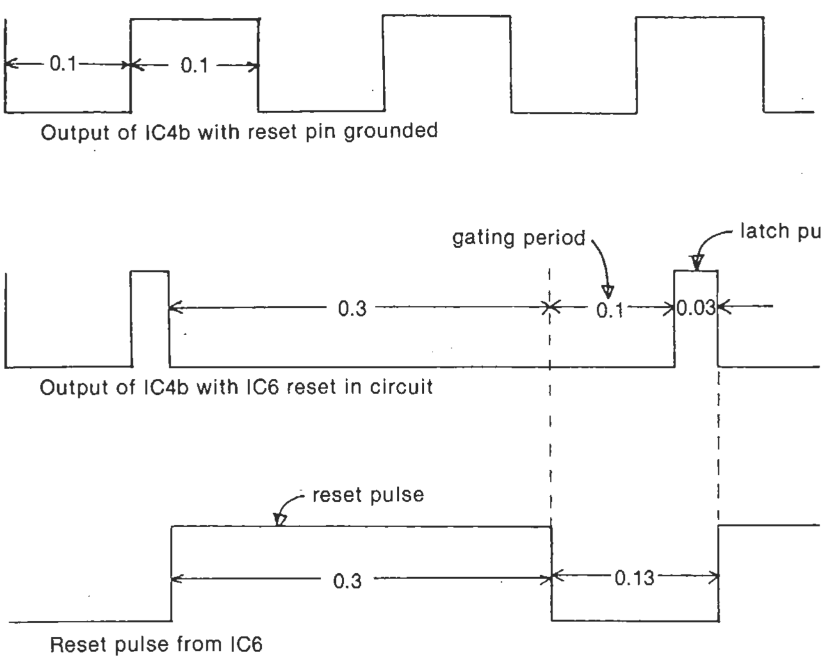


Figure 3. Timing diagrams.

Troubleshooting

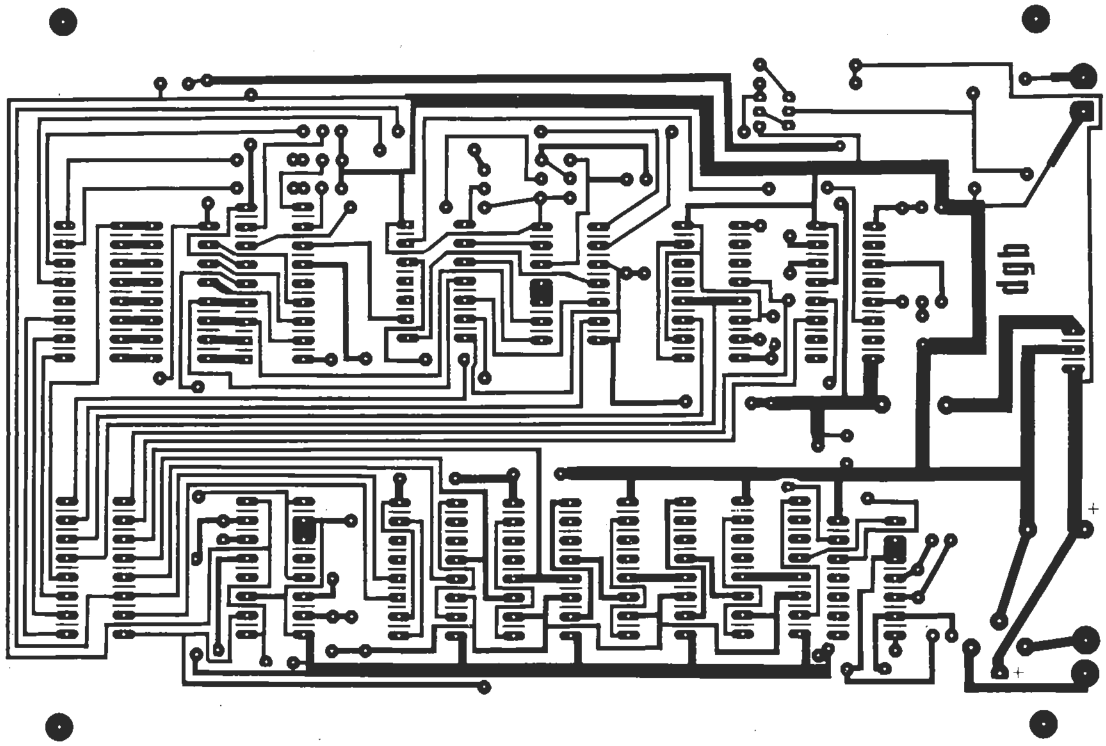
If the frequency counter does not function properly, first check the power supply for +5V. Both circuit boards should be inspected for solder bridges and all IC leads should be checked for proper insertion. If the problem(s) still persist, use table 2 as a guide in troubleshooting the unit.

PARTS LIST

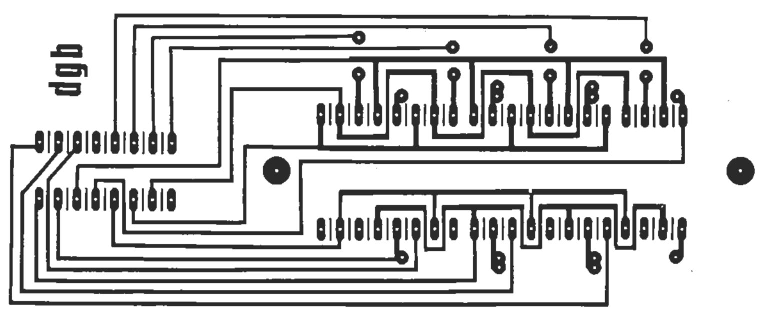
Resistors (all ¼W 5% unless otherwise specified)	
R1,2	270R
R3,8,9,20	4k7
R4	390k
R5	18k
R6	47k
R7	10k
R10	1k
R11	10R
R12-19	33R DIP resistor (Bourns 4116R-001-330 or equiv.) *
R21	4M7
Capacitors	
C1	2200*u* 25 V electrolytic
C2	10n ceramic
C3,8,9,10,11	100n ceramic
C4	1*u* tantalum
C5	4*u*7 tantalum
C6	50p silver mica
C7	2*u*2 tantalum
Semiconductors	
Q1-Q8	2N3904 or equiv.
D1	1N4148 or equiv.
BR1	1.5A, 200 V bridge rectifier with heatsink (W02M or equiv.)
REG1	5V, 1A regulator with heatsink (LM7805)
IC1,10	74LS04
IC2,3,4,5,8	74LS390
IC6	74LS221
IC7	MC14046B
IC9	74LS132
IC11	74C926 (National)

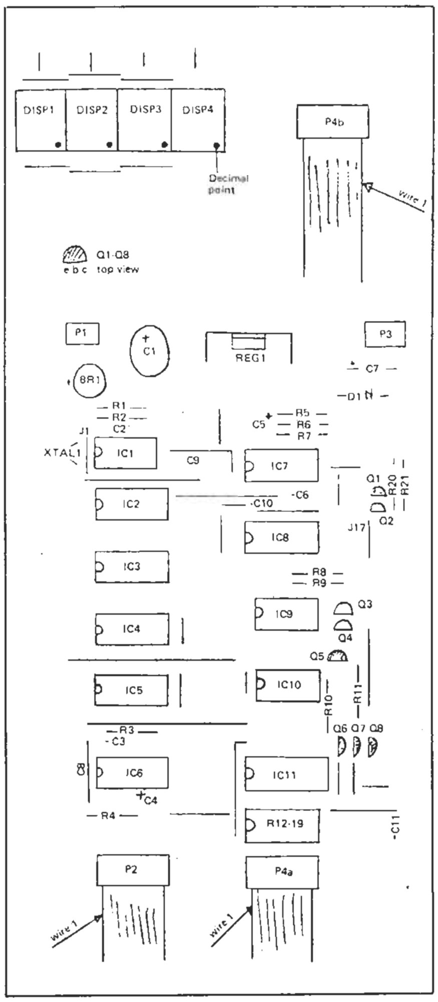
** These parts are available at Newark Electronics, 271 Attwell Drive, Rexdale, Ontario, M9W 5B9.*

The 74C926 is a National part available at Zentronics and other National distributors.



The printed circuit layouts for the main board and display.





Parts overlay for the frequency counter.

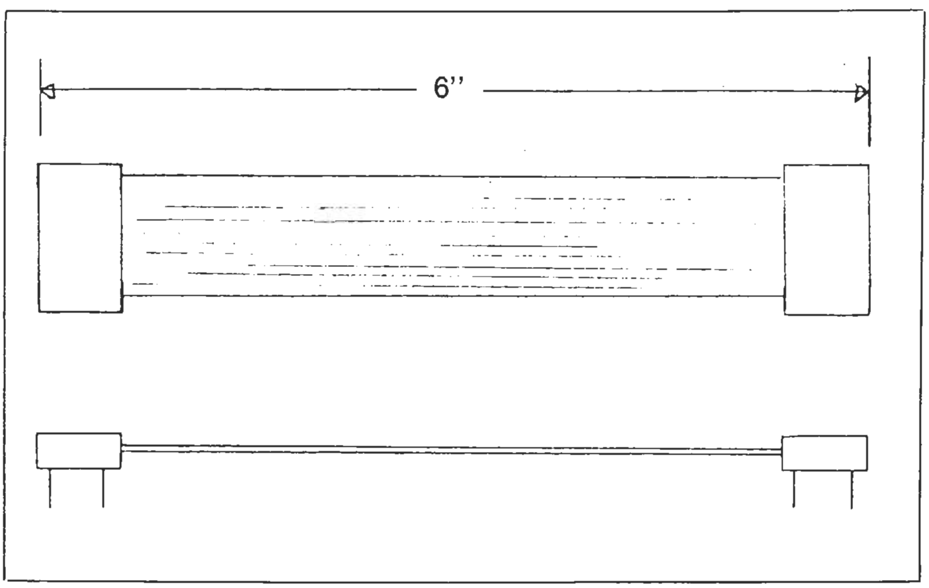


Figure 4. Header cable diagram.

HOW IT WORKS

The frequency counter can best be understood if it is broken down into five separate sections: the power supply, the input circuit, the frequency multiplier, the clock generator and divider, and the counter/display driver.

Power Supply
The secondary voltage from the transformer is full wave rectified by BR1 and filtered by C1; it is then fed to the regulator where it is regulated down to 5 VDC. The output of the regulator is used to drive all of the ICs and the unregulated 12 VDC (or so) is used in the input circuitry. C9 improves the stability of the regulator.

Input Circuit
Input signals are fed to the main board via the BNC connector on the front panel. C7 removes any DC component from the input signal, and D1 clips off the negative half of the signal. Q1 and Q2 amplify the input to a square wave which is fed to the input of IC9a; the output is connected to both a decade divider (IC5b) and switch 1 pole 'a'. While on the 10 MHz range the divided signal from pin 3 of IC5 is used; on all other ranges the direct output from IC9a is used. The output from S1a feeds both switch 1 pole 'b' and the frequency multiplier.

Frequency Multiplier
An MC14046B phase-locked loop (PLL) is configured to multiply the input frequency by 10 on the 10 KHz range and by 100 on the 100 Hz and the 1 KHz range. The signal from S1a is buffered and inverted by IC10a and is fed to the input of the PLL (pin 14). This input signal is compared to the output of the decade dividers IC8a and b, and a comparison signal is generated at pin 13; this signal is filtered by C5, R6, and R7 and drives the voltage controlled oscillator input (pin 9). The VCO output at pin 4 is buffered and inverted by IC1d and drives both the decade dividers and the input of IC9b. The VCO adjusts its frequency until the input signal and the comparison signal from the decade dividers are equal. At this point the PLL is locked, and the output frequency is either 10 or 100 times the frequency at pin 14, depending on the position of the rotary switch.

Clock Generator and Divider
IC1a, b, c, and the crystal are configured to oscillate at a frequency of 5 MHz. The 74LS390 decade dividers reduce this frequency to produce the required gating times of 0.01s, 0.1s, and 1.0s. Switch 1 pole 'd' selects which of the gating times will be used; the following explanation assumes a gating time of 0.1s. At the end of the 0.1s, the output of IC4b will swing from low to high, triggering one half of IC6 (a dual one-shot timer). This one-shot generates a 'high' pulse approximately 300us wide (determined by the time constant of R3 and C3) at pin 13. This pulse transfers the output of the counter into a latch and triggers the second one-shot. A 300ms pulse is produced at pin 5, resetting both the decade dividers and the counter, but not the contents of the latch. With the decade dividers reset, another gating pulse is generated and the contents of the latch are updated. The gating pulses from S1d are inverted and 'anded' with the conditioned input signal to produce the 'count' signal. A timing diagram showing the clock signals is given in figure 4.

Counter/Display Driver
The 74C926 is a complete counter, latch, and display driver. The count, latch, and reset signals are connected to IC11 and the appropriate display signals are generated. R12-R18 limit the current to the displays and Q6, Q7, and Q8 drive the common cathode of DISP4, DISP3, and DISP2 respectively. DISP1 is blanked when it is zero, and therefore requires some extra circuitry. Note that DISP1 is zero when segment 'f' is on and segment 'g' is off. Q3, Q4, IC10d and e, and IC9c and d decode this condition and blank the display. Switch 1 pole 'e' selects the proper decimal point to light.