

# AN MSI 500 MHz FREQUENCY COUNTER USING MECL AND MTTL

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The design of a MSI 8-digit LED read-out 500 MHz counter using MECL III, MECL 10,000 and TTL is discussed. Described are two prescalers using MECL, along with the designs for two input amplifiers. A unique time-base controller is also shown for providing a multiphase clock to the counter.

### BASIC 8-DIGIT LED TTL COUNTER

The basic counter system uses the MC4021 counter-latch 7-segment display output, automatic leading-zero blanking, and a

The 500 MHz prescaler uses the MC1090 flip-flop from the MECL III family. Also used in the binary section of the MC1078 decade counter. Two input amplifiers are provided to furnish either a 50-ohm 500 MHz input or a high impedance 150 MHz input. The 500 MHz amplifier uses Micro-T\* transistors and the 150 MHz amplifier uses the MC1011B triple differential amplifier along with an FET input stage.

The discussion is broken down into three sections explaining each of the following parts: the basic 8-bit TTL counter board and LED readout, the 500 MHz amplifier/prescaler, and the 150 MHz amplifier/prescaler.

\*Micro-T - Trademark of Motorola Inc.



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### INTRODUCTION

As analog and digital signals continue to increase in both frequency and data rate, the means must be provided within the instrument market to measure these frequencies. This article describes one such instrument which uses high speed integrated circuits from the Motorola MECL III and MECL 10,000 Series to measure frequencies in excess of 500 MHz.

This counter design also illustrates techniques used with integrated circuits to obtain operation of digital devices up to frequencies of 500 MHz.

The basic eight digit counter uses TTL MSI (including the MC4051 counter-latch-decoder) and operates to 35 MHz. Also within this TTL time-base circuit is a controller which provides the correct sequence of events to operate the counter. This time-base clock-phase generator is based upon computer design techniques and provides the necessary pulse sequence while using only one monostable device.

The 500 MHz prescaler uses the MC1690 flip-flop from the MECL III family. Also used is the quinary section of the MC1678 decade counter. Two input amplifiers are provided to furnish either a 50-ohm 500 MHz input or a high impedance 150 MHz input. The 500 MHz amplifier uses Micro-T\* transistors and the 150 MHz amplifier uses the MC10116 triple differential amplifier along with an FET input stage.

The discussion is broken down into three sections explaining each of the following parts: the basic 8-bit TTL counter board and LED readout; the 500 MHz amplifier/prescaler; and the 150 MHz amplifier/prescaler.

### BASIC 8-DIGIT LED TTL COUNTER

The basic counter system uses the MC4051 counter-latch 7-segment decoder. The MC4051 features a 7-segment display output, automatic leading-zero blanking, and a

capability for fully synchronous counter display — all in a 16-pin package. Using this MSI device within the counter system as a functional base permits streamlining the overall design of a numeric display instrument. Savings to the designer result from lower assembly cost due to reduced package count, lower overall size, lowered power consumption, and greater device flexibility.

The counter system has the last seven counter digits operating in a synchronous mode, with the least significant counter digit being ripple-through. This allows the basic counter (shown in Figure 1) to operate up to 35 MHz typically. The counter enable control on the least significant digit, gates the clock input according to the time-base input signal without regard to the state of the clock and without introducing false counter transitions.

The time base, control section, and oscillator are shown at the top of Figure 1. The oscillator uses a MECL MC1004P dual gate operating at +5 volts with a 1 MHz crystal in the feedback path to form a stable self-starting oscillator. A 2N3906 PNP transistor is used to convert the MECL logic levels to TTL levels for the time-base divider-control section that follows. Provision is also made for an external 1 MHz oscillator.

The control section uses the time-base clock to generate a multiphase control clock to provide the sequence of events shown in Figure 2. After a count gate pulse, the latch is strobed, the counter chain is reset, then the time-base is reset.

The display time or sample time is adjustable by means of the MC8601 monostable multivibrator. With the  $R_X C_X$  given, the sample time is adjustable between 0.4 and 10 seconds. If other times are required  $C_X$  must be changed in accord with information available on the MC8601 data sheet. The time-base gate intervals are 100  $\mu$ s, 1 ms, 10 ms, 100 ms, 1 second and 10 seconds.

The seven-segment 8-digit readout devices operate at 7 mA per segment. The readout also provides a decimal point whose control line is available at the edge connector of the counter mother board.

\*Micro-T — Trademark of Motorola Inc.

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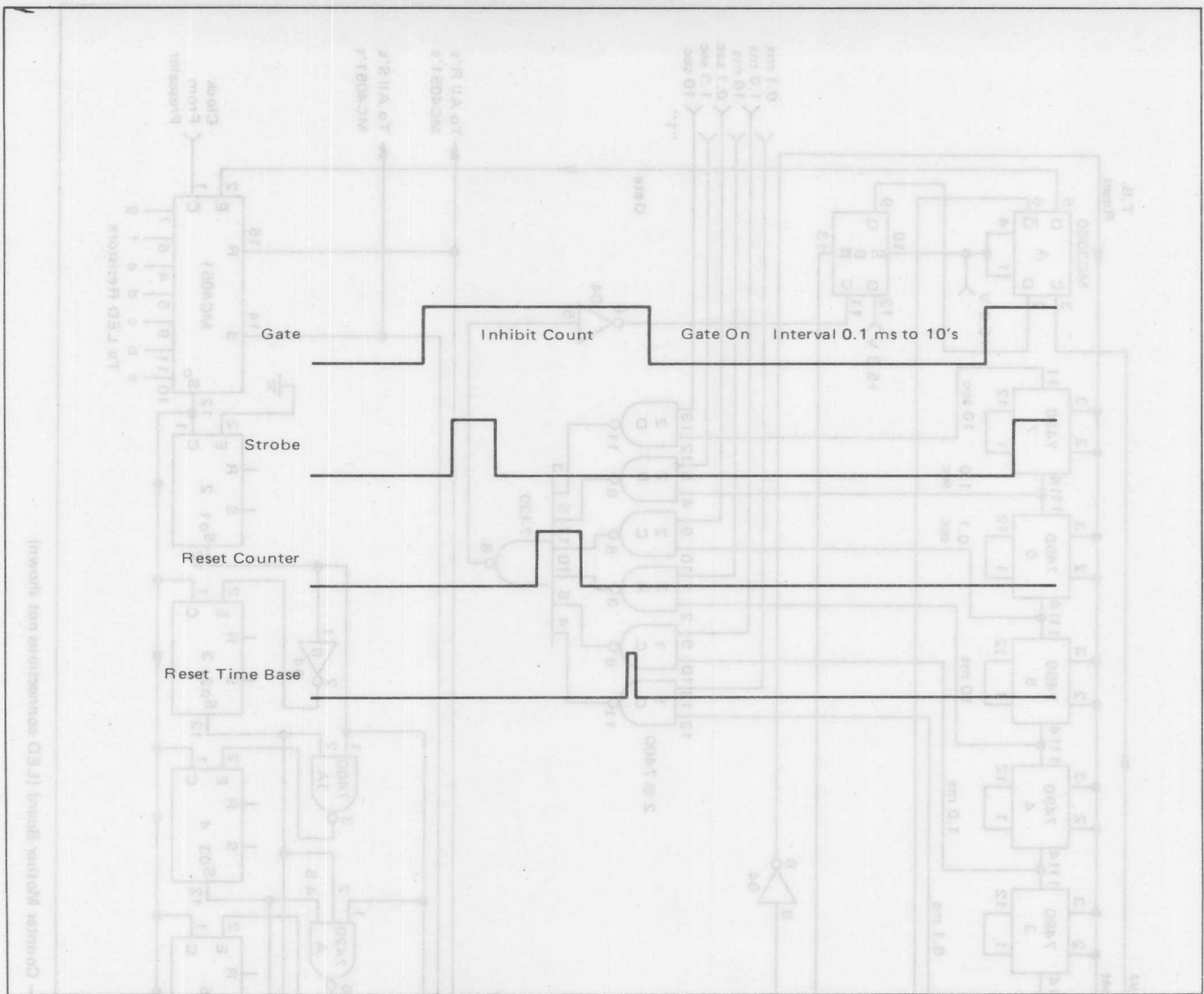


FIGURE 2 — Multiphase Control Clock Signals

## MECL PRESCALER BOARD

### 500 MHz Amplifier

The circuit design of the amplifier section illustrated in the upper left of Figure 3 is ECL and uses MMT3960A Micro-T transistors in a cascaded differential amplifier exhibiting typically 14 dB gain at 500 MHz. The ECL amplifier is dc level compatible with the MC1690 500 MHz flip-flop. The input has an impedance of 50 ohms with Schottky diode clamp protection and is ac coupled to the amplifier section.

The input trigger sensitivity is adjusted by R1 to provide maximum bandwidth for the counter system. Once R1 is set for 500 MHz or higher, the counter will trigger at lower frequencies. The frequency response curves for the 500 MHz amplifier are shown in Figure 4. If this input is to be

used below 10 MHz, then a Schmitt trigger stage will have to be added to the amplifier to shape the input signal prior to the counter. A Schmitt trigger may be added after the second amplifier as shown in Figure 5.

If less gain above 200 MHz can be tolerated then using the MC1692 as an input amplifier/Schmitt trigger (Figure 6) will eliminate the need for the Micro-T transistors.

The important parameters to remember at the interface with the MC1690 or any other MECL flip-flop, are the physical dc levels and the threshold required for successful toggling. Also the  $V_{BB}$  (threshold) supply for an ac coupled flip-flop or amplifier should temperature-track to maintain successful toggling over the full temperature range. It is suggested that design rules covered in the MECL System Design Handbook (reference 1) be employed along with reference to the printed circuit layouts shown in the Appendix.



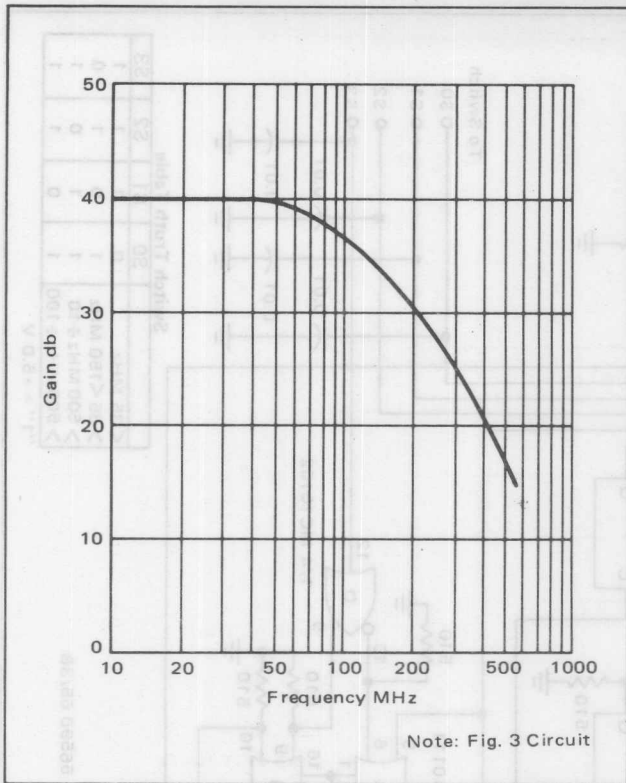


FIGURE 4 - 500 MHz  $\mu$ T Amplifier Gain Bandwidth

### 150/200 MHz Amplifier-Prescaler and Control

This amplifier-prescaler-control section is designed with either MECL 10,100 Series or MECL 10,200 high speed logic, dependent upon whether 150 or 200 MHz input capability is required. The control section shown to the right of Figure 3 determines the amplifier prescaler combinations used. For instance the high speed 500 MHz 50-ohm input can be selected with either prescaling by 10 or by 100, whereas the high impedance input can be selected as an amplifier only (divide-by-1), or prescaled by 10.

The high impedance input section, lower left of Figure 3, is operational to greater than 150 MHz typically, with an MC10116 amplifier/Schmitt trigger, MC10131 counter, and MC10111 clock driver. By substituting MECL 10,200 pin-compatible parts, the MC10216, MC10231, and MC10211, into the equivalent MC10,100 sockets, the high impedance input section will operate at input frequencies greater than 200 MHz.

The amplifier consists of a FET input Micro-T device (MMT3823) followed by an emitter follower (MMT2857), which in turn drives the MECL 10,000 amplifier/Schmitt trigger. The curves shown in Figure 7 illustrate the excellent gain-bandwidth of the MECL 10,100 devices. The MC10102 output device drives an 2N3906 with an MBD102 Schottky diode clamp to convert the MECL signal levels to TTL levels for driving the MC4051 counter chain.

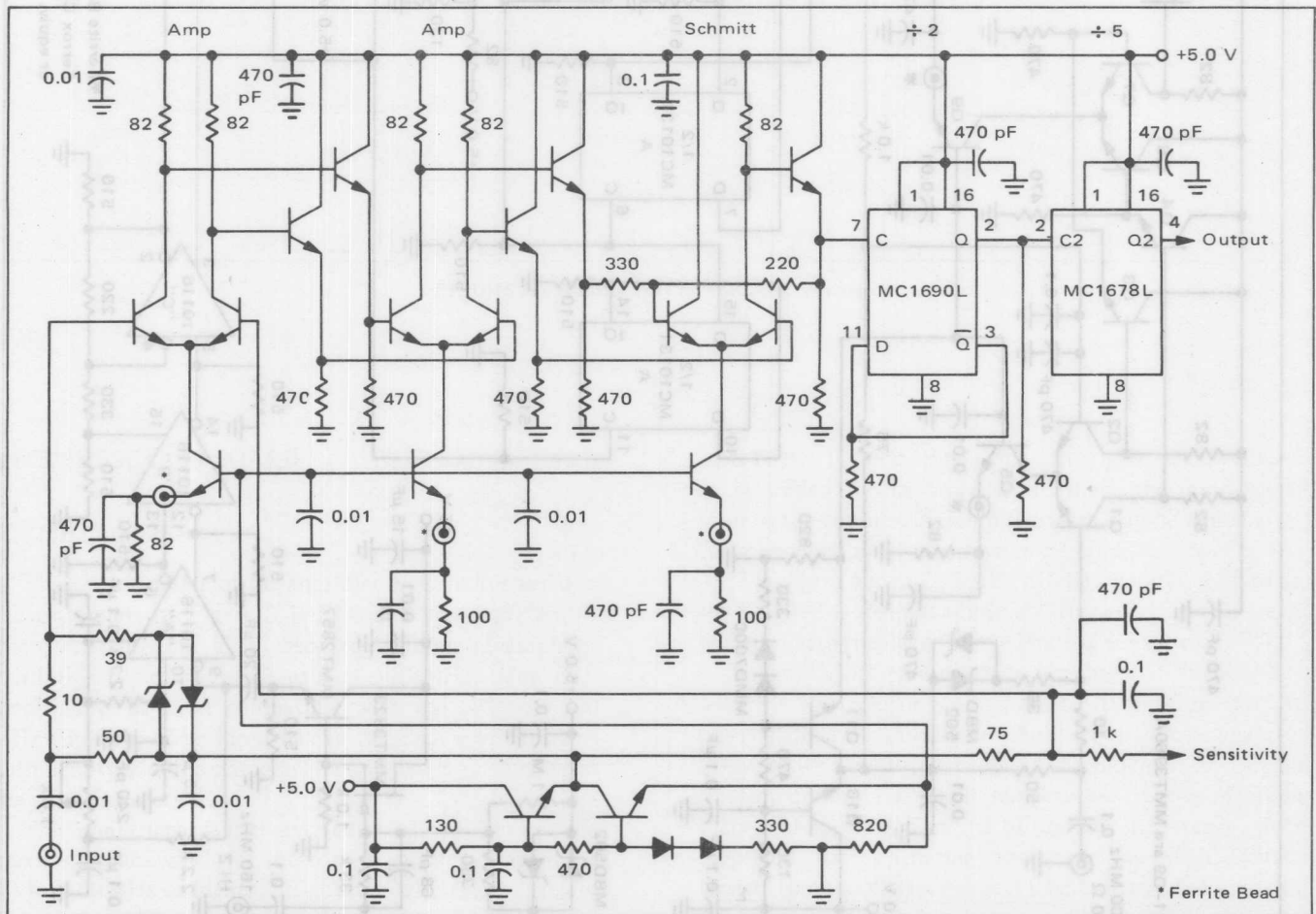


FIGURE 5 - 500 MHz Amplifier - Schmitt Trigger

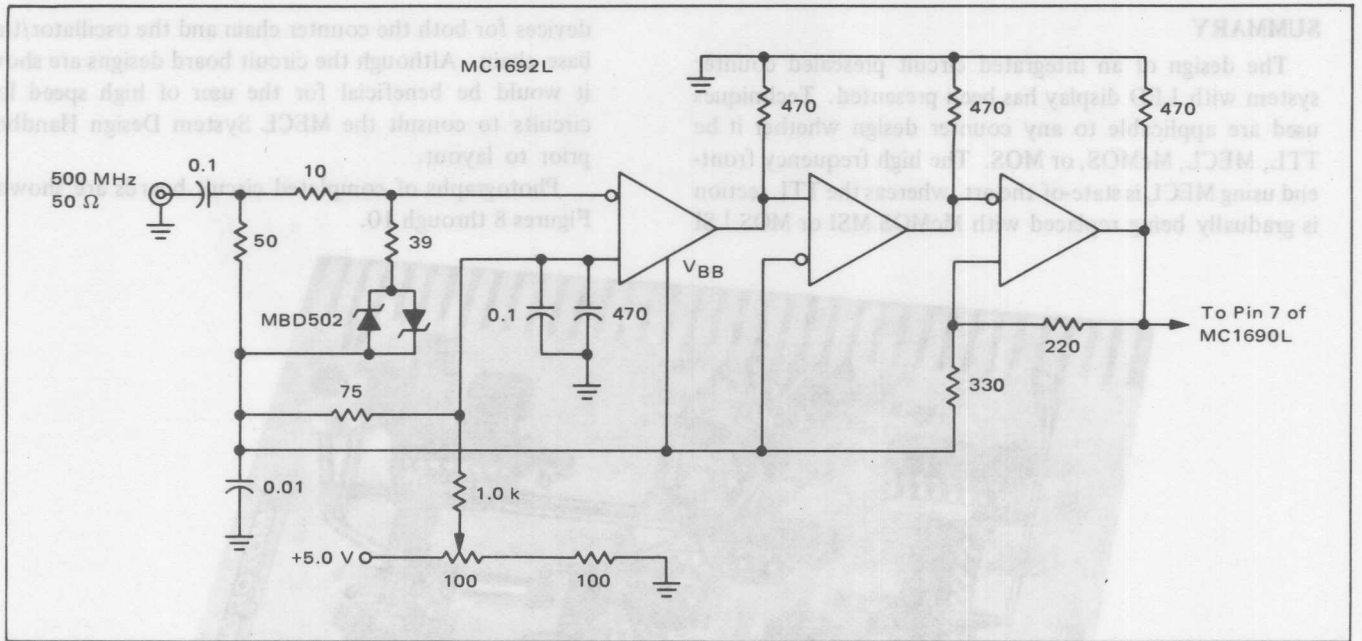
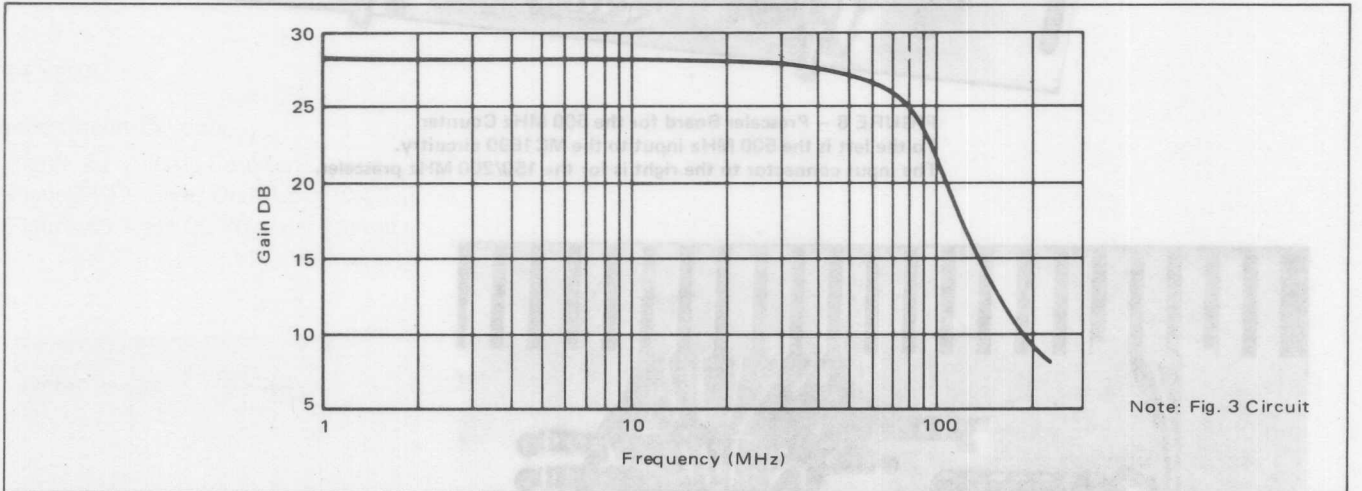
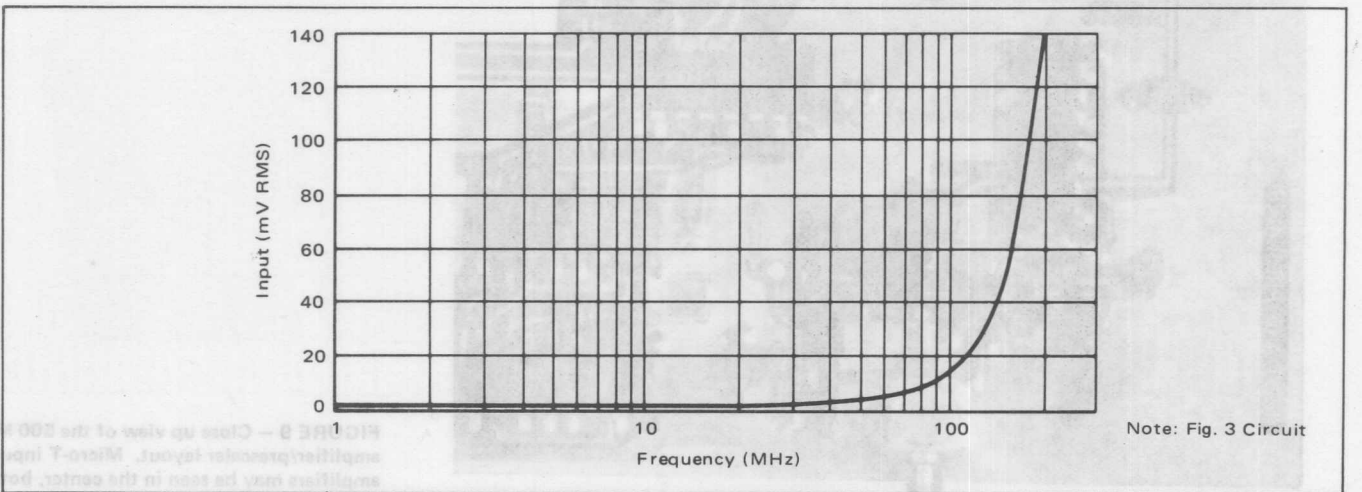


FIGURE 6 – IC 500 MHz Input Amplifier



Note: Fig. 3 Circuit

FIGURE 7A – Gain vs Frequency, 150 MHz Amplifier



Note: Fig. 3 Circuit

FIGURE 7B – Sensitivity vs Frequency, 150 MHz Amplifier

## SUMMARY

The design of an integrated circuit prescaled counter system with LED display has been presented. Techniques used are applicable to any counter design whether it be TTL, MECL, CMOS, or MOS. The high frequency front-end using MECL is state-of-the-art, whereas the TTL section is gradually being replaced with CMOS MSI or MOS LSI

devices for both the counter chain and the oscillator/time-base chain. Although the circuit board designs are shown, it would be beneficial for the user of high speed logic circuits to consult the MECL System Design Handbook prior to layout.

Photographs of completed circuit boards are shown in Figures 8 through 10.

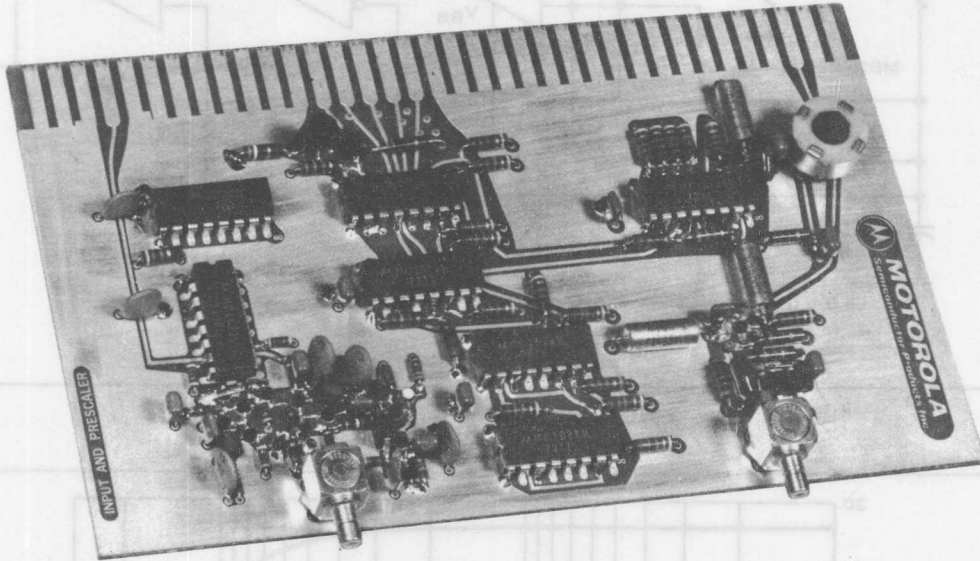


FIGURE 8 - Prescaler Board for the 500 MHz Counter. To the left is the 500 MHz input to the MC 1690 circuitry. The input connector to the right is for the 150/200 MHz prescaler.

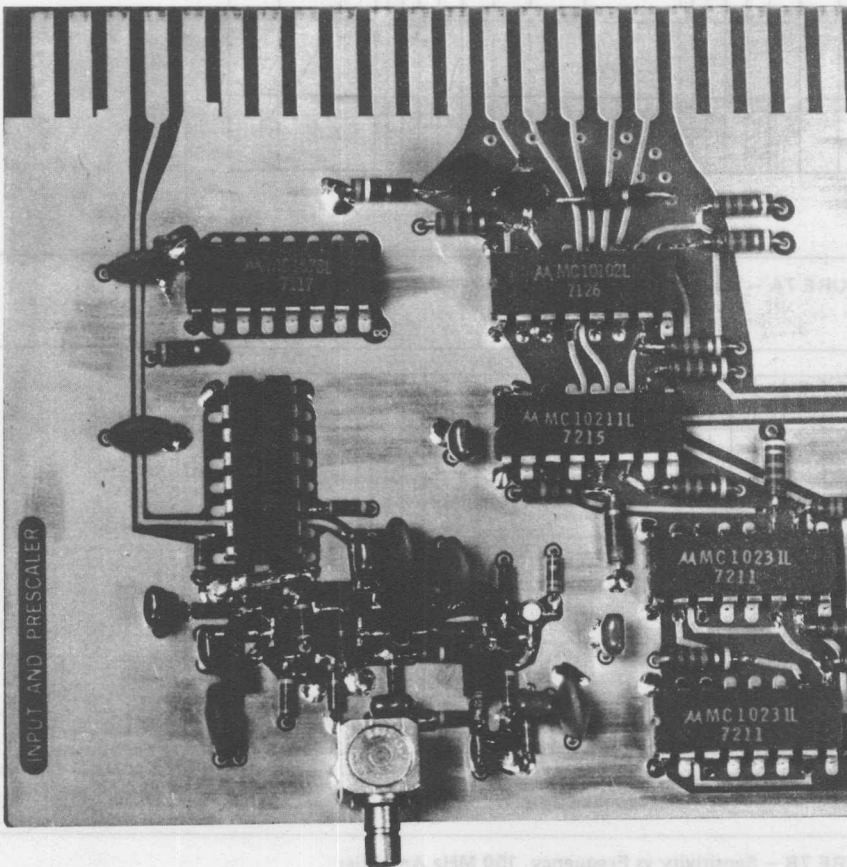


FIGURE 9 - Close up view of the 500 MHz amplifier/prescaler layout. Micro-T input amplifiers may be seen in the center, bottom.



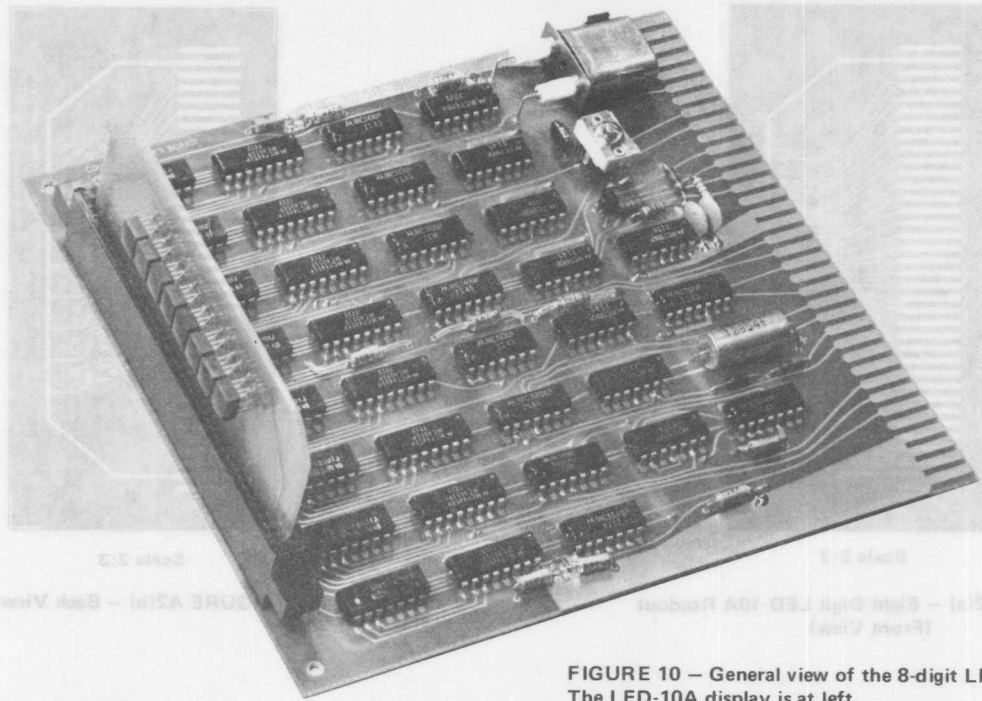
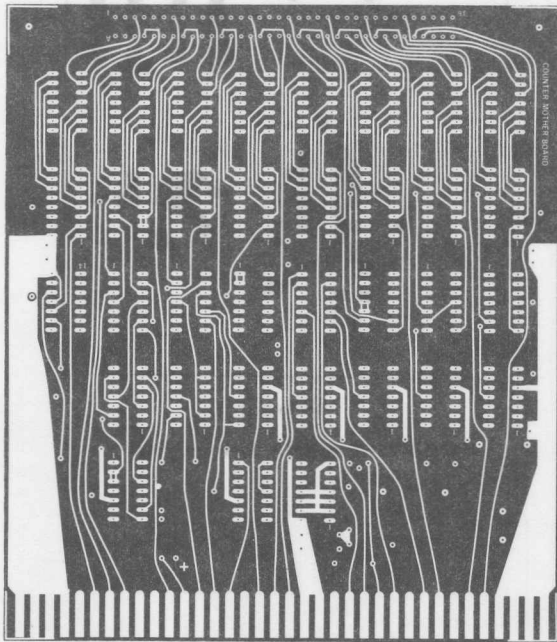


FIGURE 10 – General view of the 8-digit LED TTL counter. The LED-10A display is at left.

## APPENDIX

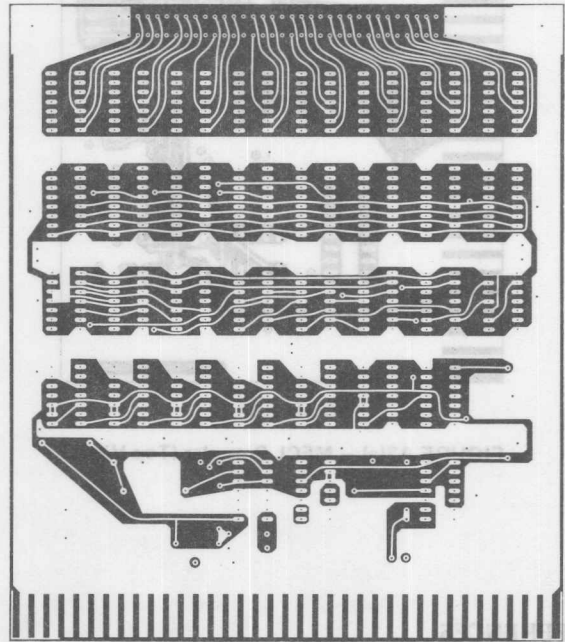
### Printed Circuit Layouts

- Figure A1 – Basic Counter Layout
- Figure A2 – Eight Digit LED-10A Layout
- Figure A3 – MECL Prescaler Layout



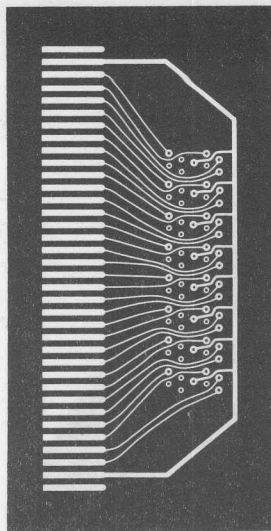
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FIGURE A1(a) – Basic TTL Counter (Top View)



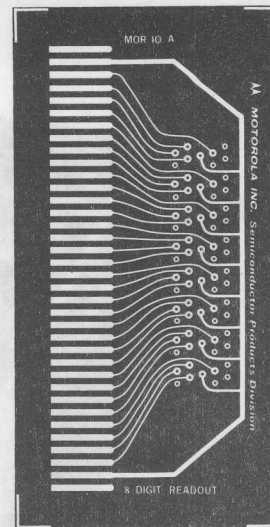
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FIGURE A1(b) – Bottom View



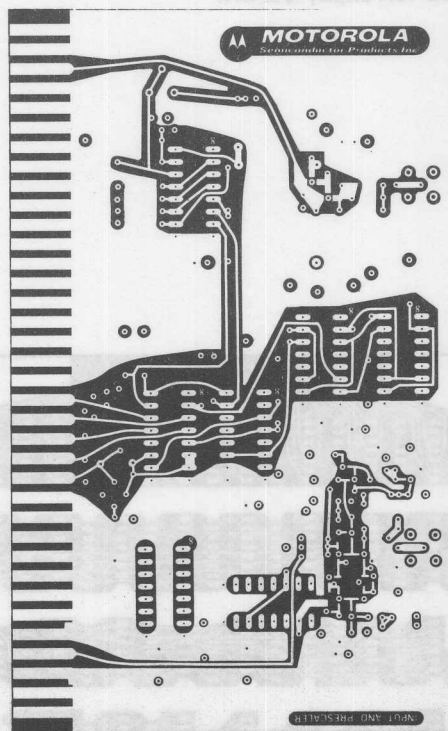
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FIGURE A2(a) – Eight Digit LED-10A Readout (Front View)



Scale 2:3

FIGURE A2(b) – Back View



Scale 2:3

FIGURE A3(a) – MECL Prescaler (Top View)



Scale 2:3

FIGURE A3(b) – Bottom View

**REFERENCES:**

1. "MECL System Design Handbook", Motorola Inc., 1971
2. "MECL Integrated Circuits Data Book", Motorola Inc.



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