A 200-MHz Counter Prescaler

An add-on unit to extend frequency measurement

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Direct digital frequency measurement has come well within the amateur's price range this last year due to the introduction of ultra fast logic intended for high volume computer applications. As these circuits are produced by several manufacturers, price competition has resulted in savings for the amateur too. With only £5 worth of integrated circuits, it is possible to build a prescaler which combines 2mV low-frequency sensitivity with a 200MHz measurement ability. Here such a prescaler is described and there are three possibilities for its use:

- As an add-on unit for heterodyne or similar frequency meters, where the indicated readings are multiplied by four to obtain the true frequency.
- As an additional unit for a home-built frequency counter, where the timebase can be modified to include a scaling factor of four.[1]
- With an additional divide-by 25 circuit (not described here) so that the net frequency division is by 100 times. As the output frequency does not exceed 2MHz, this would be suitable for direct reading with an older vintage of counter.

The range of i.cs which form the basis of the described design, is the Motorola MECL 10000. This is an e.c.l. (emitter coupled logic) family introduced in 1971 which uses current steering rather than saturated transistor switching. This technique avoids the delays normally associated with transistor charge-storage mechanisms.[2]

Current steering logic has various advantages:

- It can drive 50Ω lines directly.
- It generates fewer supply line transients because of the balanced nature of the circuit.
- Each gate consists of a differential amplifier, which makes interfacing to analogue signals easier than with t.t.l.

The price to be paid for these advantages is a higher power consumption noticeably in the "pull-down" resistors required on the emitter follower outputs.[3] However, the basic gate has a power-speed product (a parameter used by semiconductor manufacturers to sell their devices) second only to that of low-power Schottky t.t.l. which is very much more expensive at this time and availability is poor. Practical advantages of the MECL 10000 series are, the fastest operating speed per pound, ease of electrical operation, and good availability.

Using only two i.cs this prescaler simply takes a low-level sinewave signal, amplifies it to the levels required by the logic circuit which then divides the frequency by four.

Pre-amplifier, limiter and divider

The MC10116 (IC_1, Fig. 1) is a triple line-receiver which consists of three wideband differential amplifiers, each having a voltage gain of 16 (differential input to output). A possible way to use this device is as a pre-amplifier (two stages) and a Schmitt trigger. However, this results in a poorer low-frequency sensitivity and a lower high-frequency limit than can be achieved. A better way to use this i.c. is as a broad-band limiting amplifier, using differential interconnection between the stages. In this way a sensitivity of a few millivolts at 10MHz and about 100mV at 200MHz can be achieved.

The MC10131 (IC_2, Fig. 1) is a dual D-type flip-flop which in this circuit is used as a toggle-bistable to give a frequency division of four times. It can drive loads directly and is guaranteed to toggle at 150MHz.

At the time of writing the following one-off prices were quoted MC10116 – £1.12, MC10131 – £3.93, making the total semiconductor cost £5.05.

Circuit details

The input has been designed to match either 50 or 75Ω, the expected source being a small search coil which can couple to the apparatus under test. As will be seen from the circuit diagram this is achieved by altering one resistor R_1, which is 82Ω for 75Ω input and 56Ω for 50Ω input. The off-set voltage produced across this resistor serves to prevent the prescaler being too sensitive at low frequencies, where noise and external signal pick-up may become a problem.

The intermediate amplifiers are termin-

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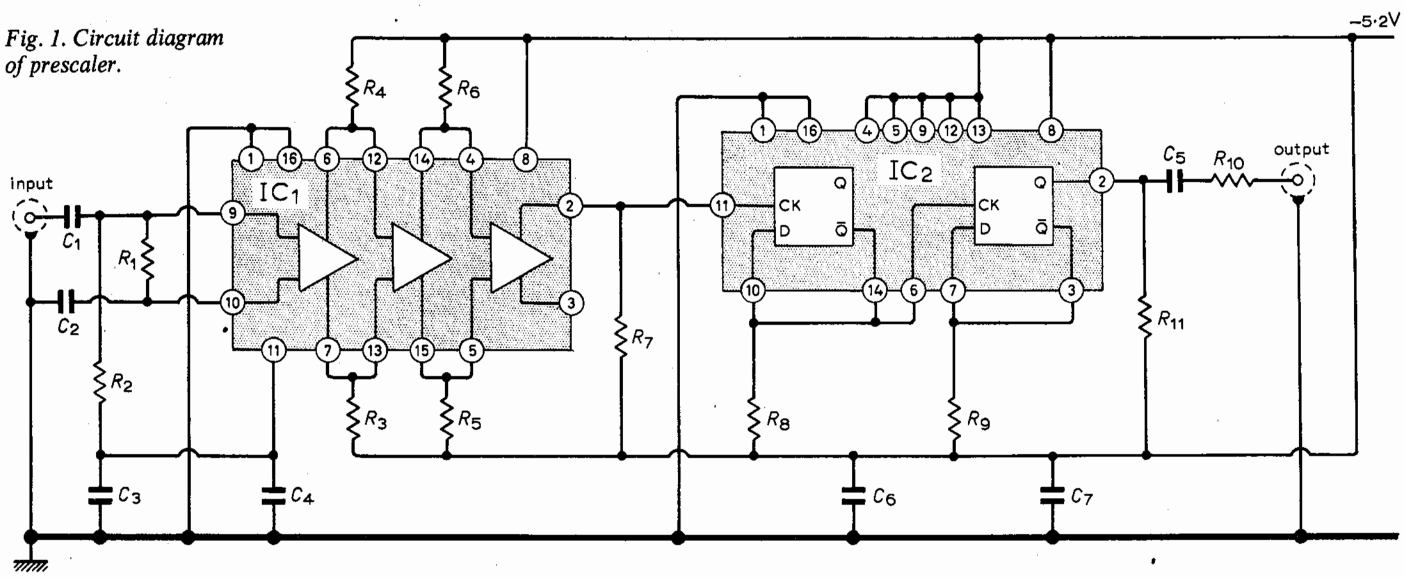
Fig. 1. Circuit diagram of prescaler.



ated by 680Ω resistors to the negative supply, this value of resistor giving adequate bandwidth. The final stage uses a lower value resistor (R_7), as experiments have shown that this triggers the divider more satisfactorily and makes the waveform at that point easier to monitor.

The toggle speed is limited by the first bistable and not the bandwidth of the preamplifier which only determines the input sensitivity. The bistable itself uses a similar low value of termination resistor (R_8) for the first stage which is speed critical. Note that the complementary output $\bar{Q}$, does not need a terminating resistor for bistable operation as an extra emitter follower is included inside the device for feedback.

The output can feed either terminated or unterminated lines. If a terminated line is used, the matching resistor R_{10} should not be included and R_{11} should be decreased to 220Ω. The output will be about 800mV peak-to-peak. For unterminated lines, R_{10} absorbs the reflection produced by the open circuit, and the voltage at the open circuit is also about 800mV peak-to-peak. However, this voltage level will no longer be suitable for driving further e.c.l. circuits, as it consists of both forward and reflected waves.

The input stage of the prescaler is not protected against transients, but back-to-back Schottky-barrier diodes, MBD101 or similar, could be connected across R_1 if required.

Components List

R_1	56Ω	C_1	10nF
R_2	1k	C_2	10nF
R_3	680Ω	C_3	47nF
R_4	680Ω	C_4	100pF
R_5	680Ω	C_5	10nF
R_6	680Ω	C_6	47nF
R_7	270Ω	C_7	100pF
R_8	270Ω		
R_9	1.5k	IC_1	MC10116
R_{10}	43	IC_2	MC10131
R_{11}	680 or 220Ω		

Construction

As with any circuit operating at 200MHz, lead lengths should be kept as short as possible. In the prototype this was achieved by using the lid of a tobacco tin as a ground plane and mounting the devices, pins uppermost, directly against the metal surface. This also gave some degree of heat-sinking. A photograph of this prototype is shown in Fig. 2. The layout was kept as simple as possible, with the decoupling capacitors having as short a lead length as could be reasonably achieved.

The MECL 10000 series are designed to work with positive earth and have two V_{CC} pins, 1 and 16 in this case. These are grounded as close to the package as possible. The prescaler is envisaged as a small accessory unit and the use of an insulated case in which the unit will fit, will remove any problems of earth polarity incompatibility.

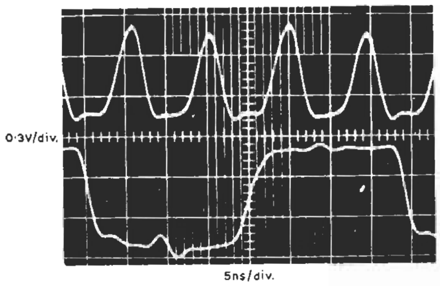


Fig. 4. 100MHz oscilloscope traces: top, pin 2, IC_1; bottom, pin 2, IC_2. Input level 16mV, h.t. 5V.

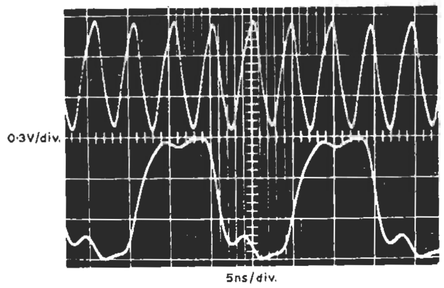


Fig. 5. 200MHz oscilloscope traces: top, pin 2, IC_1; bottom, pin 2, IC_2. Input level 125mV, h.t. 5.5V.

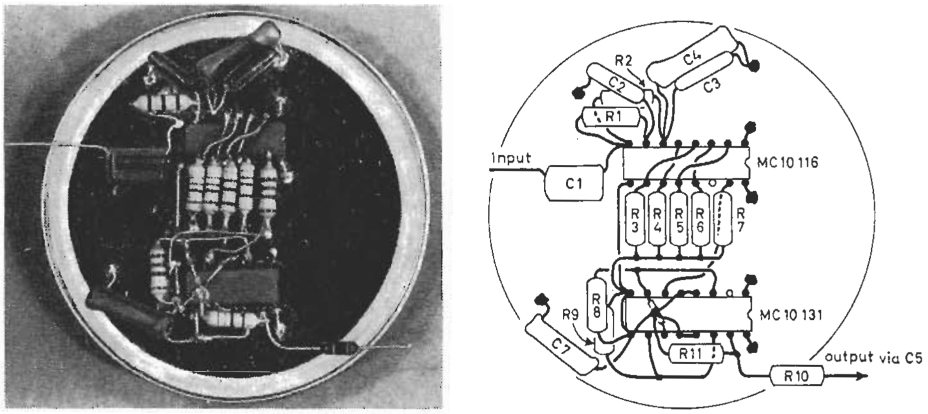


Fig. 2. Prototype construction technique showing component positions.

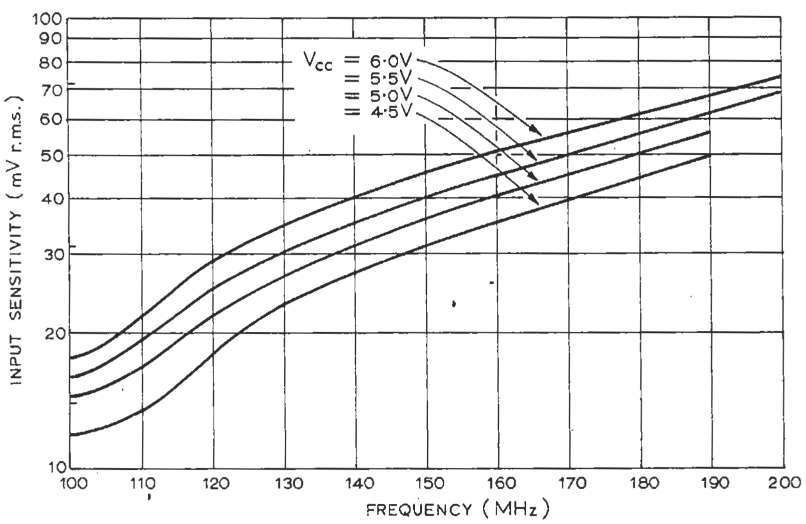


Fig. 3. Measured sensitivity for input frequency.

Performance

An r.f. signal generator, Marconi TF995A/2M, was fed into the input, providing excitation between 10 and 200MHz. Voltages at pin 2 of each i.c. were monitored with a Tektronix sampling oscilloscope, model 661, with a × 10, type P6032 probe.

Fig. 3 shows the minimum voltage to provide satisfactory triggering against frequency over the range 100 to 200MHz with various d.c. supply voltages as a parameter. Signal input voltages are source e.m.f., so that 100mV plotted means 50mV p.d. or 140mV peak-to-peak. Over the range covered, higher supply voltages produced slightly faster toggling but reduced the sensitivity slightly. However, performance is largely independent of supply voltage. At 145MHz, between 28 and 45mV were required, an e.m.f. easily bled-off even a low power transmitter (45mV e.m.f. corresponds to a power requirement of 10μW when referred to 50Ω).

Waveforms for operation at 100MHz and 200MHz, are shown in Fig. 4 and Fig. 5 respectively with horizontal scale of 5ns/div and vertical scale of 0.3V/div. The sub-harmonic is clearly visible on the 100MHz trace, this being a generator imperfection. The distortion on the output waveforms is due to coupling between the two halves of the dual flip-flop package.

References

1. 'Some Improvements in Digital Frequency Measurement Techniques', D. J. Taylor, *Radio Communication*, May 1972, p. 288.
2. 'Electronic Devices & Circuits', Millman & Halkias, McGraw-Hill, 1967, p. 259.
3. 'General Information MECL 10000 Series', Motorola Inc., 1971, sheet O.3–4.
4. 'A 5V Logic Power supply', D. J. Taylor, *Wireless World*, March 1972.