Electronics

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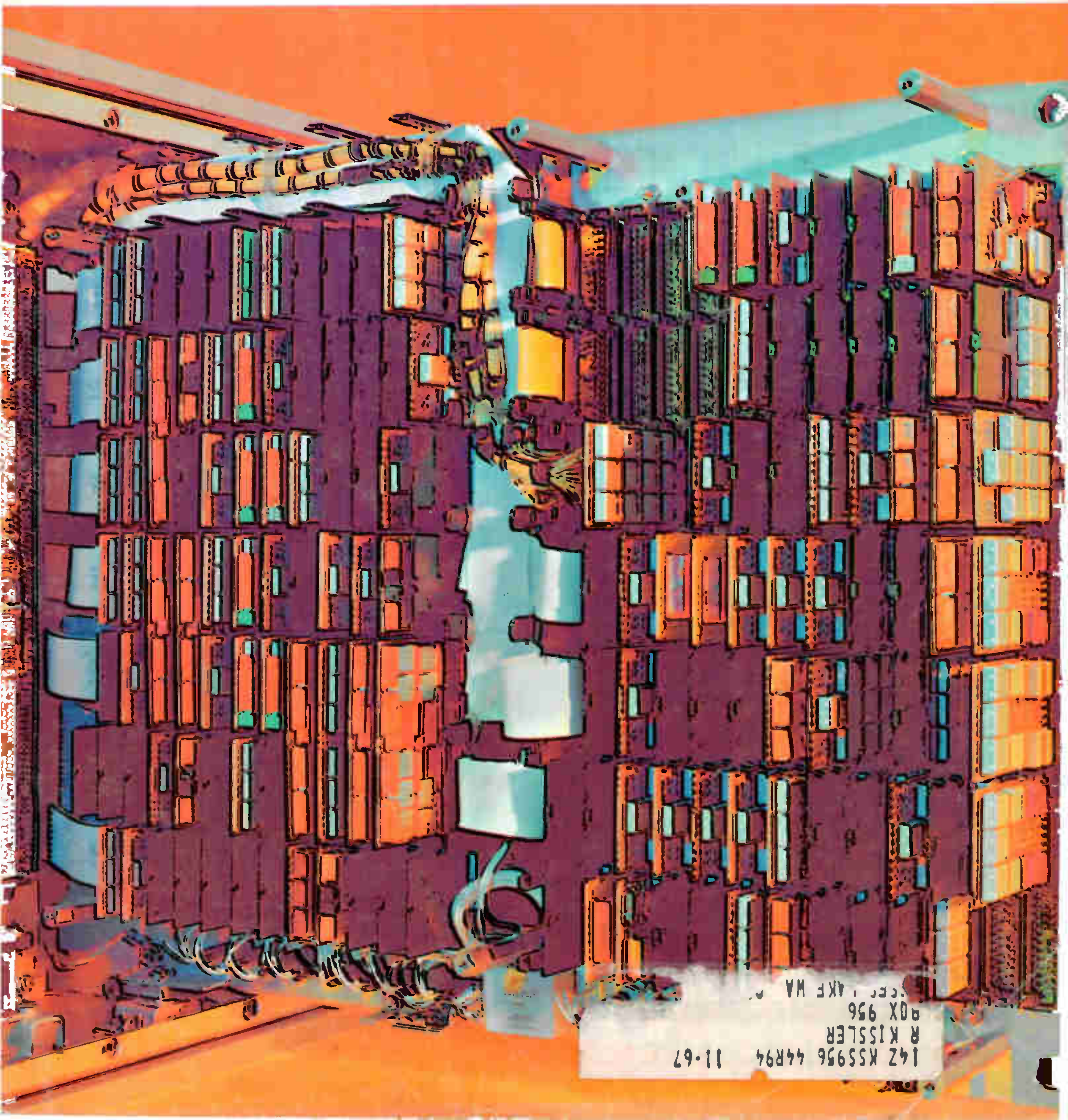
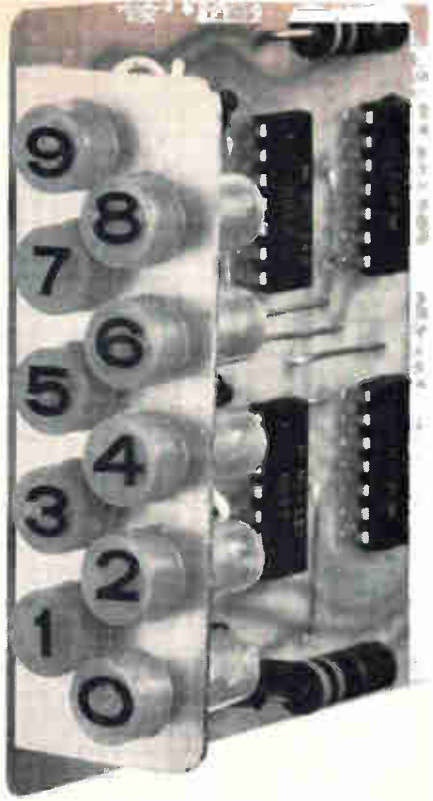


For low cost, count on RTL



Although slower than logic schemes currently favored by designers, resistor-transistor logic modules cut per-decade price of digital instruments

By Donald E. Lancaster
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Progress is the name of the game in electronics, and the advent of diode-transistor and transistor-transistor integrated circuit logic schemes has caused many engineers to write off the older resistor-transistor logic. But by taking a step backward—reverting to resistor-transistor logic integrated circuits and older counter techniques—a decade's worth of counting, decoding, and readout can be achieved for as little as $10.

With RTL decades, any electronics engineer or technician can build a two-digit with overranging voltmeter for $45 or a universal counter for $65. Even a tv repairman would like a digital voltmeter and, with the RTL decades, the price would be right.

RTL counting decades operate from d-c to 8 megahertz. Displays are visible under any ambient lighting conditions and require only low-voltage power sources.

To do the same thing with DTL or TTL would cost at least three times as much in parts alone.

Conventional integrated-circuit decimal counter-decoder-driver-readout assemblies cost between $60 and $100. The parts cost alone of a decimal counter built with diode-transistor logic costs about $10; the associated decoder module, $15, and a Nixie indicator, $8.

But only $4 worth of RTL flip-flops buys 8-Mhz worth of divide-by-10, and all that is needed is to pick the right code, a good decoding method, and a suitable readout.

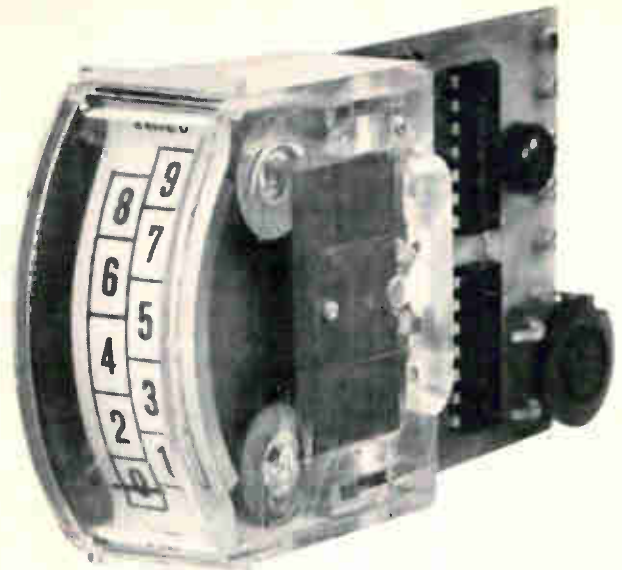
The best code turns out to be biquinary, weighted 1-2-2-4. Biquinary weighted counting is essential for minimum cost decoding and readout. With this code, it's possible to directly drive a vertical meter readout without any decoding or, because of three states already available in the counter, to build an in-line incandescent numerical array by adding only three decodings and seven drive transistors.

Of the eight possible biquinary 1-2-2-4 codes, the one that works best with the desired decoding techniques and readout, and is realizable with RTL modules, is shown on page 75.

Two dual J-K flip-flops and two gates are needed. The counter has some characteristics that help make possible excellent circuit economy. Since each output is weighted—it can be converted directly to a corresponding constant current—the outputs can be summed in a meter readout to indicate total

How they compare

Readout	Vertical meter	In-line incandescent
Parts cost, single quantity	$10	$12
Frequency response	d-c to 8 Mhz	d-c to 8 Mhz
Inputs	COUNT RESET	COUNT RESET
Outputs	CARRY	CARRY
Calibration needed?	YES	NO
Power supply	3.6 vdc at 100 ma 18 vdc at 10 ma	3.6 vdc at 100 ma 6 vdc at 250 ma
Dissipation	.54 watts	1.9 watts
Total IC's	3	4
Transistors	4	7
Resistors	9	6
Jumpers	3	8
Display area	⅜ in. x 1½ in.	¾ in. x 2¾ in.



$10 per decade. Digital displays built with milliammeter or incandescent bulbs and RTL circuits. In-line decades are easier to read and look better but meter version costs less and consumes less power.

The best code					
N		**1**	**2**	**2**	**4**
0	=	0	0	0	0
1	=	1	0	0	0
2	=	0	1	0	0
3	=	1	1	0	0
4	=	0	1	1	0
5	=	1	1	1	0
6	=	0	1	0	1
7	=	1	1	0	1
8	=	0	1	1	1
9	=	1	1	1	1

counts. Few practical counter codes allow this. This design also provides the EVEN or ODD, 0 or 1, and 8 or 9 biquinary output functions needed for an incandescent array and, therefore, takes only three additional gates to obtain the remaining 2 or 3, 4 or 5, and 6 or 7 outputs.

Furthermore, the counter circuit is free from any sudden double transitions of a flip-flop or gate. This is the result of using the transition time of an entire flip-flop to buffer both possible premature coincidences (counts 2 or 6). Such coincidences are unwanted outputs from a gate during the settling times of its inputs.

Each counter flip-flop remains in a particular state for an entire interval. An important advantage of this feature is that a noise-free CARRY output is readily available for direct coupling to the next stage. This output triggers the next higher decade.

Striving for low cost permits only two possible readouts: a meter or a row of 10 light bulbs. While not as attractive as some of the fancier, or single numeral readouts, either is almost as legible and as easy to use, and costs about $2.50, roughly one-third the cost of a Nixie tube.

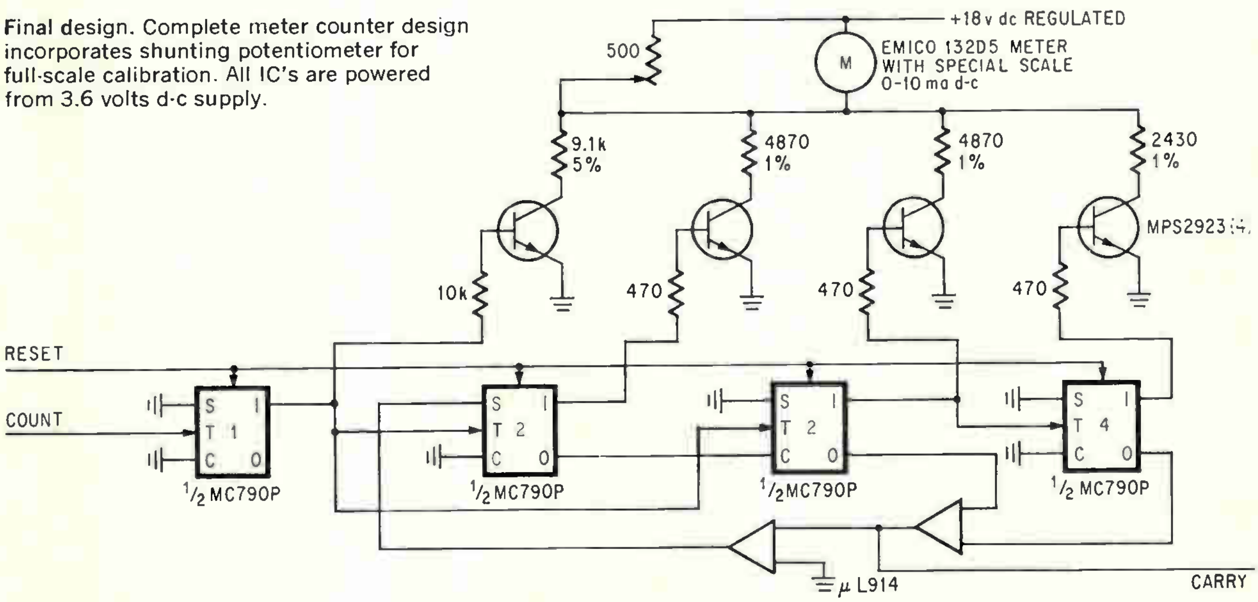
The meter readout is a vertical scale, 0-10 ma, d-c ammeter with a special boxed 0 to 9 readout scale. The total meter current is the sum of the currents produced by the weighted outputs.

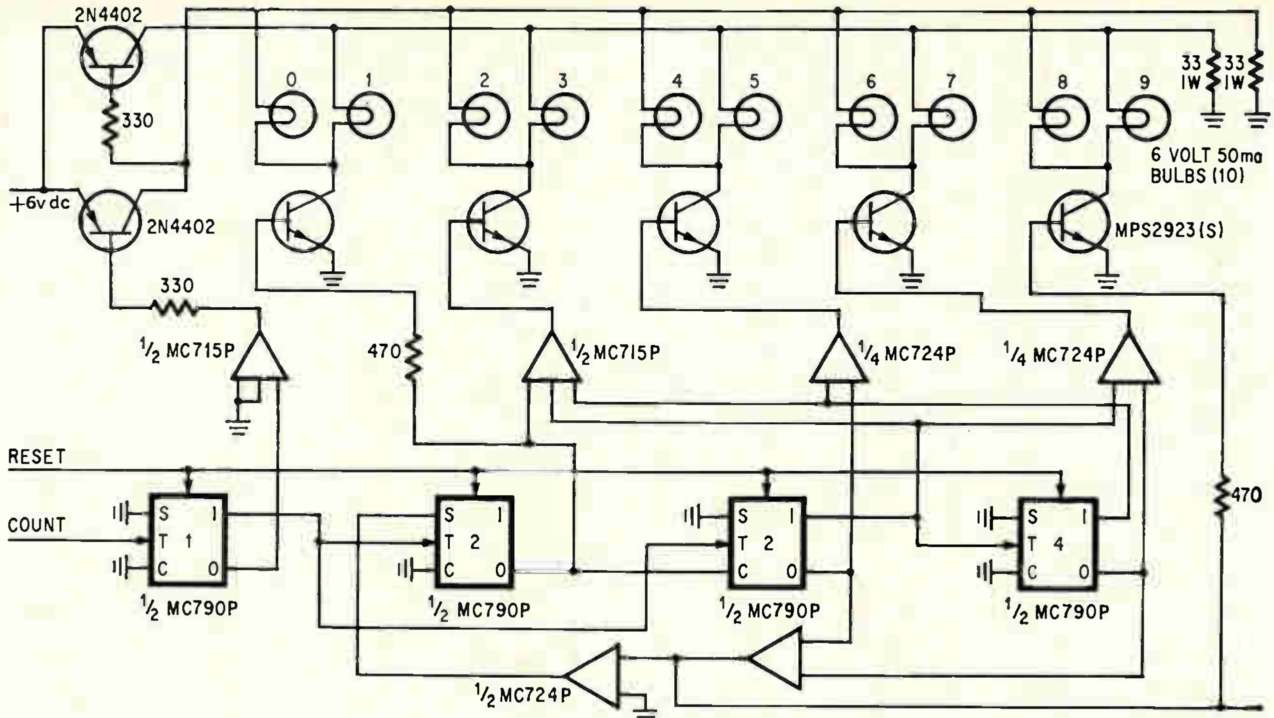
Difficulties exist

However, there are problems. The RTL output voltage is too low and too temperature-dependent to be used as a dependable constant-current source. Isolating driver transistors are used to overcome these difficulties and produce a constant current independent of the flip-flop output voltages and voltage variations.

The summed meter current must be held to 10 distinct values. If the current drifts more than ±5%, the meter's pointer will drift from box to box or fall between two numbers. This requires a regulated meter supply with an output impedance low enough to prevent adjacent meters from in-

Final design. Complete meter counter design incorporates shunting potentiometer for full-scale calibration. All IC's are powered from 3.6 volts d-c supply.





Incandescent display. Bulbs are grounded in pairs by one section of counter while other section supplies power to odd or even groups. Two 33-ohm resistors solve problem of sneak current paths. All the IC's except the MC 715P are powered from the 3.6 v d-c supply. The MC 715P uses 6 v d-c power. Special 6.2 volt, 50 ma bulbs are used.

teracting. The no-load to full-load regulation of the supply should be better than 2%. For four 10-ma meters, this implies an internal supply impedance less than 9 ohms. Also, 18 volts is the lowest voltage that permits neglecting the effects of the internal voltage drop across a low-cost meter.

In addition, 1% resistors are needed on the 2, 2, and 4 outputs, since the meter's nonlinearity uses up a substantial percentage of the allowable tolerances.

The meter's mechanical zero set adjusts the 0 output, while a shunting potentiometer provides a full-scale calibration adjustment. The complete schematic of the meter counter is on page 75.

Direct digital readout

Several novel design techniques keep down the costs of the in-line incandescent readout. The EVEN-ODD output, or the "bi" part of the counter provides B+ either to bulbs 0, 2, 4, 6, 8 or 1, 3, 5, 7, 9 while the quinary part of the counter grounds one pair of bulbs at a time. For example, on count 6, the "bi" part of the counter powers the even buss and quinary part grounds bulbs 6 and 7. Bulb 6 should light.

However, because an attempt is being made to control 10 bulbs with only seven switches, there are some sneak current paths. All the bulbs light all the time. While most are very dim, bulb 7 will be almost as bright as bulb 6.

To avoid this problem, two balancing resistors are added, allowing one-third of the supply voltage to appear across each off bulb and the full supply voltage across the on bulb. All the off bulbs then will be barely visible because of the extreme nonlinearity of small incandescent bulbs. Ten diodes also would have solved this problem but two resistors are more economical.

However, one price paid is the extra power required. The resistors take four times more current than the light bulbs. About 1.9 watts per decade, including the counter, are needed.

A comparison

As with any electronic counter, inputs must be noise-free and have an abrupt fall-time, particularly when utilizing mechanical contacts where the chief noise source is contact bounce. The best trigger fall-time is 100 nanoseconds. An electronic circuit for conditioning the input, absolutely essential for either the meter or in-line design, can be built with conventional RTL IC's for less than one dollar.

From a cost/performance standpoint (see table on page 74), the in-line counter design seems superior to the meter readout in terms of readability, over-all readout appearance, and user acceptance. But the meter design costs less, is smaller, and consumes less power.

The author

Donald E. Lancaster is an electronics design engineer for a major aerospace firm and author of a forthcoming book on RTL. He has written some 200 technical articles on electronics.