

Build Numeric Glow Tube DCU

Nixie Readout at \$15 per Decade

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Now IT IS possible to build a highspeed, decimal counter module (complete with logic and Nixie[®] tube readout) at a cost of \$14.90 per decade. This counter, with speeds from d.c. to either 8 or 12 MHz (depending on the type of logic used), can be built with 2½ decades (0-199), 3½ decades (0-1999), or 4½ decades (0-19999) using a single printed circuit board. No mounting or front brackets are needed and there is a minimum of interconnections to be made.

The design provides an overflow indicator and latch which operate when full scale is exceeded. This function is useful for overrange indication or as a "turnaround" command on dual-slope DVM designs. Display blanking, in which the readout can be turned off or on by an external 0-2-volt d.c. control signal is also available. This feature eliminates display bobble or blur and back-andforth numeral motion during rapid counting.

There is also a self-contained "gate" input that permits turning the counters on and off and is useful for period or frequency measurements. This feature eliminates quite a bit of external circuitry.

You have a choice of the type of logic you use in building the DCU. If RTL is used, the unit is fully compatible with previous POPULAR ELECTRONICS projects. Or you can use Utilogic (Signetics Corp.), a faster type of logic with a higher voltage swing that is compatible with industrial TTL and DTL circuits. Both types of logic cost the same.

The IC counters are "weighted" in the industrial 1-2-4-8 manner to provide electrical as well as visual outputs if de-

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Fig. 1. The schematic for one decade counter. As many decades as desired can be built using this same schematic. The readout is a conventional Nixie tube with a glowing numerical-shaped display.

The 21/2-decade board. Each Nixie indicates up to 9, and at the 100th count, both Nixies indicate zero while the special "1" neon lamp comes on. The combination indicates to 199. At 200th count, a special overrange neon lamp (not shown) glows indicating that counter has progressed beyond its limits.



sired. A simple modification and an external adapter can be used to convert the RTL version of the DCU into an "add-subtract" counter which operates in either direction. The units are useful in computers, calculators, and positional controls.

When RTL is used in this new DCU, the unit can be used in POPULAR ELEC-TRONICS projects such as the "Digital Voltohmmeter," the "Universal Frequency Counter," the "Sports Timer," and the "Electronic Stopwatch." In fact, with a few mechanical changes, the new 21/2digit assembly can be dropped into the "Digital Voltohmmeter" without adding any new parts. This makes a DVM that looks like the industrial models that cost many times as much.

PARTS LIST DECADE COUNTER

IC1, IC2-MRTL dual JK Rip-Rop (Motorola MC791P

1C3-MRTL quad two-input gate (Motorola MC724P)

Q1-Q10-2N3877 transistor (Allied Electronics 49D30 2N3877 SfR, no substitute) Q11-Q13—Transistor (National Semiconductor

2N5129)

R1,R4,R5—470-ohm, ¼-wall resistor R2,R3—330-ohm, ¼-wall resistor

R6-15,000-ohm, ½-walt resistor V 1-Nixie tube (Burroughs B5750,

Misc .- #24 wire insupers. insulated sleeving, solder, spacers, mounting hardware, etc. Note-The following are available from South-

west Technical Products, Box 16297, San Antonio, Texas 78216: Etched and drilled PC boards-2½-digit, \$4.00; 3½-digit, \$5.75; 4½-digit, \$7.50. Complete kit of all parts-2½-digit, \$4.50; 3½-digit, \$59.50; 4½-digit, \$75.00. Write for a complete list of related circuits, kits, and instruments. All prices postpaid in U.S.A.

Because of space limitations, construction details are given here for the RTL counter only. Complete information, including PC layouts, for the Utilogic version is available without cost from the source given in the box.

In deciding whether you want to use RTL or Utilogic in your DCU, consult the Table.

The circuit for one decade of the DCU is shown in Fig. 1 and that of the overflow counter is shown in Fig. 2. Although these are shown as separate circuits, in practice, one overflow counter and as many decades as are necessary are mounted on one PC board. Interconnections for the units are shown in Fig. 3. Note that the Gate connections of all decades except the first are grounded. In this way, if the input (units) decade is turned on or inhibited, the counter operates or not accordingly.



Overall view of the 21/2-decade board. When mounted in enclosure, only the readouts will be visible.

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Construction. Decimal counting units can be built in a number of configurations: $1\frac{1}{2}$ (counting to 19), $2\frac{1}{2}$ (to 199), $3\frac{1}{2}$ (to 1999), $4\frac{1}{2}$ (to 19999), etc. In each case the $\frac{1}{2}$ stands for the "1" of the overflow counter, while the whole number stands for the number of decade counters (each counting to 9).

Construction details are given here for the popular 2½-digit assembly. Because of the complexity of the circuit, a printed board is mandatory. A board is shown actual-size in Fig. 4. A commer-

General view of a portion of a 2½-decade board. This view shows the correct way to install the ten switching transistors for the Nixie drive.



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Fig. 3. Interconnection of decades, overflow, overrange indicator and decimal-point selector. Note that all decade gate inputs, other than the first one, are grounded. First gate is used to start and stop counting.

cially made board is available (see Parts List for Fig. 1). If you prefer to make your own, it is recommended that you use the better-grade, G-10 fiberglass.

Besides drilling details, Fig. 5 shows the location of the 32 jumpers located on the component side of the board. In addition, there are four jumpers that are "sewn" through the board, so that they alternate from one side to the other and pick up five connections each. Details of this are also shown in Fig. 5. The long bare jumper is soldered at one end and then threaded through the holes in the board. Use insulated sleeving over the exposed parts to prevent shorts to the transistor leads.

Once the various jumpers have been installed, the components are inserted in accordance with the layout shown in Fig. 6. Use a low-power (40-watt) soldering iron and thin solder to make all connections. The IC's are identified by a notch and dot code for positioning. To insert the 20 driver transistors, hold them with the flat facing away from the readout tubes. Then bend the center lead back toward the tubes and insert as shown.

In inserting the Nixie tubes, put the leads in two at a time. Before soldering, make sure that all leads are tight, none are doubled over or shorted to each other and the viewing face of the tube is aimed in the correct direction. Also be certain the tube is vertical.

Mount the neon lamp (for numeral 1) so that the metal rods within the tall narrow bulb are at the same height as the numerals in the Nixie tubes.

Underside view of the PC board showing how some jumpers are connected. These below-board jumpers must all be insulated.





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Fig. 6. Component installation of 21/2-decade board. Other than placement of R6, both decades are similar. This illustration shows external connections needed.

Use. The 21/2-digit module can be used in any one of a variety of chassis styles -as long as it has a rectangular frontpanel cutout for the two Nixie readout tubes and the neon light. A special polarized optical filter is available (see Parts List for Fig. 1) to improve readout visibility. This filter should be oriented to produce the blackest instrument interior when viewed and illuminated through the filter. Once the correct orientation

has been found, glue the filter in place behind the front-panel cutout.

External connections to the module are shown in Fig. 6. The 21/2-digit module requires +175 volts at 5 mA for the readouts, and +3.6 volts at 340 mA for the remainder of the circuit. A power supply (such as the one shown in Fig. 7) is required. It has low ripple with highfrequency bypassing-an essential.

Ground leads should be short and of

PARTS LIST POWER SUPPLY

- C1-100-µF. 250-volt electrolytic capacitor
- C2--6000-µF, 10-volt electrolytic capacitor C3--200-µF, 6-volt electrolytic capacitor C4--0.1-µF, 10-volt disc ceramic capacitor
- D1,D2-1-ampere, 600-volt silicon diode
- (1N4005 or similar) D3—1-ampere, 50-volt silicon diode (1N4001 or similar)
- D4-4.2-volt (RTL) or 5.6-volt (Utilogic) 1-woll sener diode
- F1-0.5-ampere juse and fuse holder
- -2N5190 transistor and snitable heatsink 01-S1-Power switch (usually a pari of other instru-
- ment or circuit switching) T'1-Power transformer; secondary 135-0-135 V at 50 mA, 6.3 VCT at 1 A (Southwest Tech-nical \neq TR-DVM or similar)*
- Misc .- Mounting spacers, hardware, wire, solder, terminals, line cord and strain relief.
- *Available at \$6.30 plus 4 lb postage from South-west Technical Products, Box 16297, San Antonio, Texas 78216.

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Fig. 7. Low-ripple power supply for the 21/2. decade board. By changing D4, the supply can be used for either RTL or Utilogic circuits.

FOR UTILOGIC DCU DETAILS

Complete construction information, including full-size PC layout replicas and all other details, is available free upon request from: Alvin R. Smith, Section Head Digital Design Group Southwest Technical Products, Inc. Box 16297 San Antonio, Texas 78216 Please limit free requests to single copies.

heavy gauge wire (at least #16). The "Out" terminal on the board is used only in some special DVM circuits and is normally left unconnected. The terminals along the rear of the board are for use in the future with an add-subtract adapter and are also left unconnected for routine applications.

The "Gate" input, if used, goes to an RTL-derived signal that is positive when the counter is to be inhibited and ground when the counter is to count. If you are not going to gate the assembly, the Gate terminal should be connected to the ground terminal.

To provide a blanking feature, connect the "Unblank" terminal to an RTL-derived signal that is positive when you want the display to light and ground when you want it off. Remember that the Unblank input does not stop the

CHOOSING THE RIGHT LOGIC FAMILY	
RTL	UTILOGIC
Supply: 3.6 volts. Compatible with all previous POPULAR ELECTRONICS pro- jects.	Supply: 5 volts. Compatible with in- dustrial DTL and TTL circuits.
Typical maximum speed: 8 MHz. Grounding and supply leads relatively critical. May be converted to an add-subtract counter assembly.	Typical maximum speed: 12 MHz. Grounding and supply leads less critical. Conversion difficult.
Input toggle must be bounceless and fall faster than 200 nanoseconds.	Input toggle must be bounceless, but may have consider- ably longer fall time.
External monostables, astables. crystal oscillators using RTL easy and cheap. Recommended for stu- dent and home experimenter.	External circuitry often much more complex and expensive. Recommended for in- dustrial technician or engineer.

HOW IT WORKS DECADE COUNTER

One decade counter can be divided into four sections: the actual counter, the decoder, the readout driver, and the readout.

The counting portion (at hottom of diagram) consists of four JK flip-flops arranged to count to 9 before reverting back to zero and simultaneously delivering a "Carry" output to the next decade. To force the counter to count only to 9, an inverter in a feedback loop is used. The voltage levels, which are unique for each count, are taken from the Q and \overline{Q} outputs of each flipflop for use in the decoder. The flip-flop outputs are in the common 1-2-4-8 code. If more than one module is to be used in an instrument, the "Gate" input terminal of the counter is connected to ground in all but the first counter. When the gate is grounded, the counter operates normally. When it is made positive, the counter is inhibited. In this way, an externally generated signal can be used to determine when the counter is to operate.

In the decoder, consisting of four gates and two discrete transistors, the $1-2\cdot4\cdot8$ output of the counter is converted into a biquinary (divide by 2, then by S) code. It has seven outputs: even, odd, 0 and 1, 2 and 3, 4 and 5, 6 and 7, 8 and 9. These form the input to the readout drivers.

The readout (Nixie tube) is a gas filled tube with one common anode and 10 discrete metal cathodes, each formed into the shape of a number (from 0 to 9). When B + is applied to the common anode and any of the cathodes is grounded, the gas around that particular piece of shaped metal glows causing a number to appear in the viewing plane.

The readout drive consists of 10 high voltage transistors, driven in pairs by the decoder outputs. The transistor collectors are connected to the 10 cathodes of the Nixie tube. The emitters of all of the odd-numbered transistors are connected together and to the "odd" buss, while the even-numbered transistors have their common emitters connected to the "even" buss. The even and odd busses are driven by the two transistors in the decoder.

The system can be considered to operate like a switching network. When, for example, the even transistor in the decoder is saturated (with its emitter grounded), the even buss is essentially at ground. Then, if a signal is applied to the bases of one pair of driver transistors, only the one whose emitter is connected to the even buss saturates and acts as a switch to close the circuit to the appropriate cathode on the readout. Suppose, for instance, that the count is 7. Since 7 is an odd number, the odd decoder transistor is saturated and the odd buss is grounded. Simultaneously, the 6 and 7 driver transistors. Because only the 7 transistor is connected to the grounded odd buss, only the 7 transistor saturates, causing the number 7 to glow in the readout. Note that we said previously that the odd or

Note that we said previously that the odd or even buss must be krounded for the decoder transistors to work. The grounding is made external to the counter through a connection to the "Blanking Input" terminal. A circuit in the overflow counter determines when this terminal is grounded for display viewing. In this way, rather than have a blur of numbers while the counter is counting, the blanking input keeps the display off until the counting is complete. Then a steady display is shown.



HOW IT WORKS OVERFLOW COUNTER

The overflow counter consists of a counting section, a display driver, and a display. The counter contains two JK flip-flops the first

of which is a divide-by-two and the second a latch. The latch flips positive and stays positive when there is an overflow. Resetting the counter resets the latch. The outputs of the flip-flops drive high-voltage transistors which act as switches in series with special neon lamps. The first flip-flop and its transistor energize the noon lamp that displays a 1 which is similar to the 1 displayed by the Nixie tube. The land driven by the second flip-flop and its transistor is a standard neon lamp on the front panel and it indicates "Overrange." Resistors in the B+ circuit of the neon lamps provide for differences in breakdown voltages.

The emitters of both driver transistors are con-nected together and to the "Unblank Input" through a switching transistor. A positive input to this terminal saturates the switching transistor and causes the display to turn on. The switched signal is supplied to the decimal counters through the "Blanking Output" terminal.

Remember that counting continues whether or not the display is lit. The blanking merely contrels whether or not the display is on.

The overflow counter also contains a bypass capacitor for the supply, resistive loading for the reset buss, and a decimal point resistor. These elements are connected to their respective circuits through the instrument wiring.



counter from working-it just determines whether or not the display can be seen. If you do not want to turn the display off, connect the Unblank terminal to the +3.6-volt source.

The two terminals marked "X" are connected to a neon overrange indicator (usually mounted in a red holder). If you don't want the overrange indication. leave these two terminals unconnected.

Decimal points are activated by connecting the selected decimal point terminal beside each Nixie tube to the "DP" terminal on the overflow counter through an external switch. Decimal point operation is independent of display blanking.

The "Reset" terminal is normally connected to ground through an external switch. Raising the buss to +3.6 volts momentarily resets the assembly to zero.



General view of the second decade of the counter. Even though the three portions extend across the board, the three readouts are very closely spaced.

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The Reset button need not be bounceless. If you use an electronic reset, a 2-microsecond pulse with a fanout of 30 is required.

Input. The input must be a waveform that changes abruptly from +3.6 volts to ground each time a count must be registered. For the counter to operate properly, the input must be both noiseless and bounceless and have a fall time less than 0.2 microseconds. Thus it is absolutely mandatory that the input be properly conditioned. Four possible signal conditioners are shown in Fig. 8. Circuits (A) and (B) are used for mechanical-contact inputs, while (C) and (D) are for electronic inputs. Circuit (C) is used for input levels of about 2 volts r.m.s. If the input frequency is below 1500 Hz, the capacitor must be included. For higher frequencies, omit the capacitor. Circuit (D) is a Schmitt squaring circuit.

Any of the circuits used in previous POPULAR ELECTRONICS DCU projects have the proper conditioning circuits built in. Thus, if you have built or are considering building the Digital Volt-ohmmeter (December 1968), besides making the mechanical modifications that are necessary to use this new counter module, connect the "Unblank" input to the existing "Gate" terminal on the V/F module in the Voltmeter. Should the brightness of the display be inadequate, the original DVM transformer should be replaced with the one called for in Fig. 7.

Power Supply. A recommended power supply with sufficient regulation is shown in Fig. 7. This supply is wired point-to-point after all parts have been mounted in a suitable chassis.