Discriminator displays first of four responses

by John S. French
Western Electric Co., Inc., Sunnyvale, Calif.

A first-response discriminator, which turns on a light indicating the first switch to close and simultaneously locks out the other switches, can be useful in sports, games, behaviorial learning studies, and experiments in physical science. The circuit shown here indicates which of four switches closes first. It uses three low-drain C-MOS integrated circuits and a 9-volt radio battery.

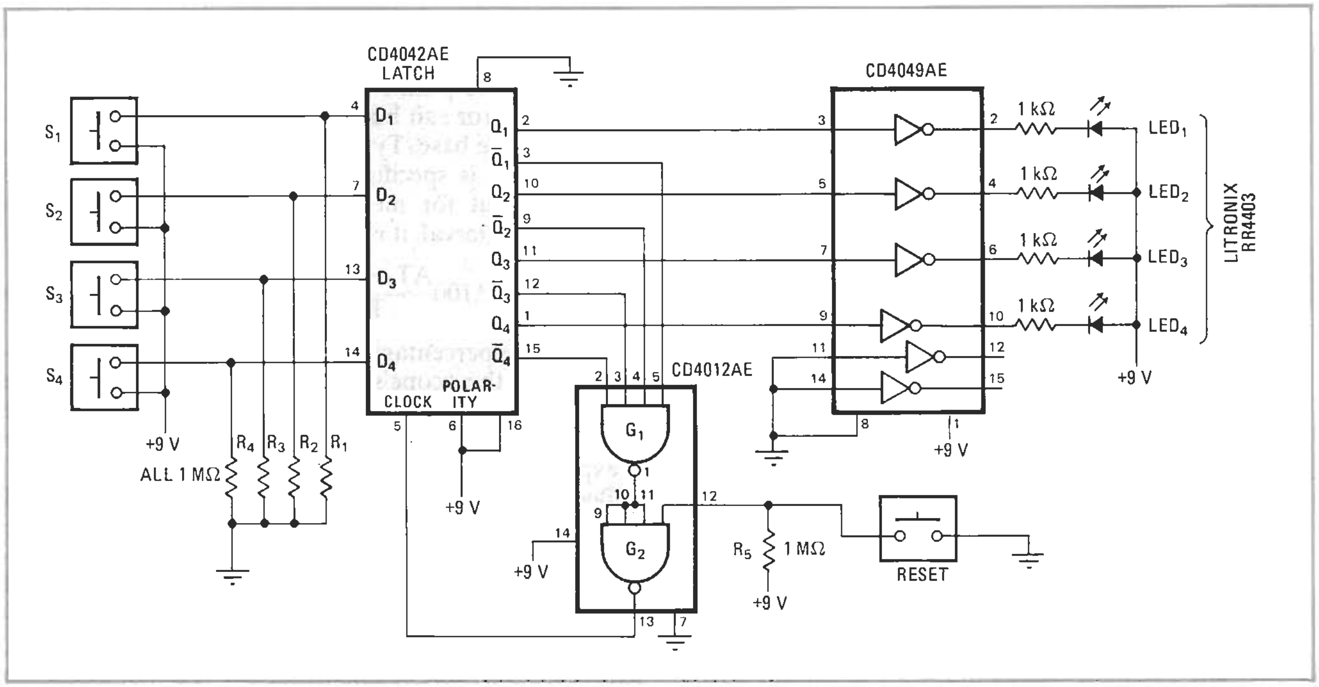
When the push-to-close switches S_1 through S_4 are open, inputs D_1 through D_4 to the 4042 quad latch are low. Therefore outputs Q_1 through Q_4 are low, and $\bar{Q}_1$ through $\bar{Q}_4$ are high. These four high inputs to NAND gate G_1 make G_1 low and G_2 high. The high output from G_2 is applied to the clock input of the latch; with the clock thus enabled, the outputs of the latch can follow the inputs.

If switch S_1 is closed, D_1 goes high and therefore Q_1 goes high, allowing light-emitting diode LED_1 to light. Simultaneously, $\bar{Q}_1$ goes low, sending G_1 high but G_2 and the clock input of the latch low. The clock low locks the latch so that D_2, D_3, and D_4 no longer control Q_2, Q_3, and Q_4. As a result, even if S_2, S_3, or S_4 is closed, the corresponding LED does not light.

The circuit is reset by momentary closing of the reset switch to set G_2 and clock high. If S_1 through S_4 are open, Q_1 through Q_4 go low for the next trial.

Expansion of this circuit to handle N inputs is straightforward. Only two NAND gates are required, but one of them must have N inputs. □

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.



Who's on first? The first switch to close lights up its associated LED, and blocks all other LEDs from lighting if their switches are closed. Circuit can distinguish first-closed switch for time differences as small as 0.05 microsecond. Cost of parts for entire circuit is under $10.

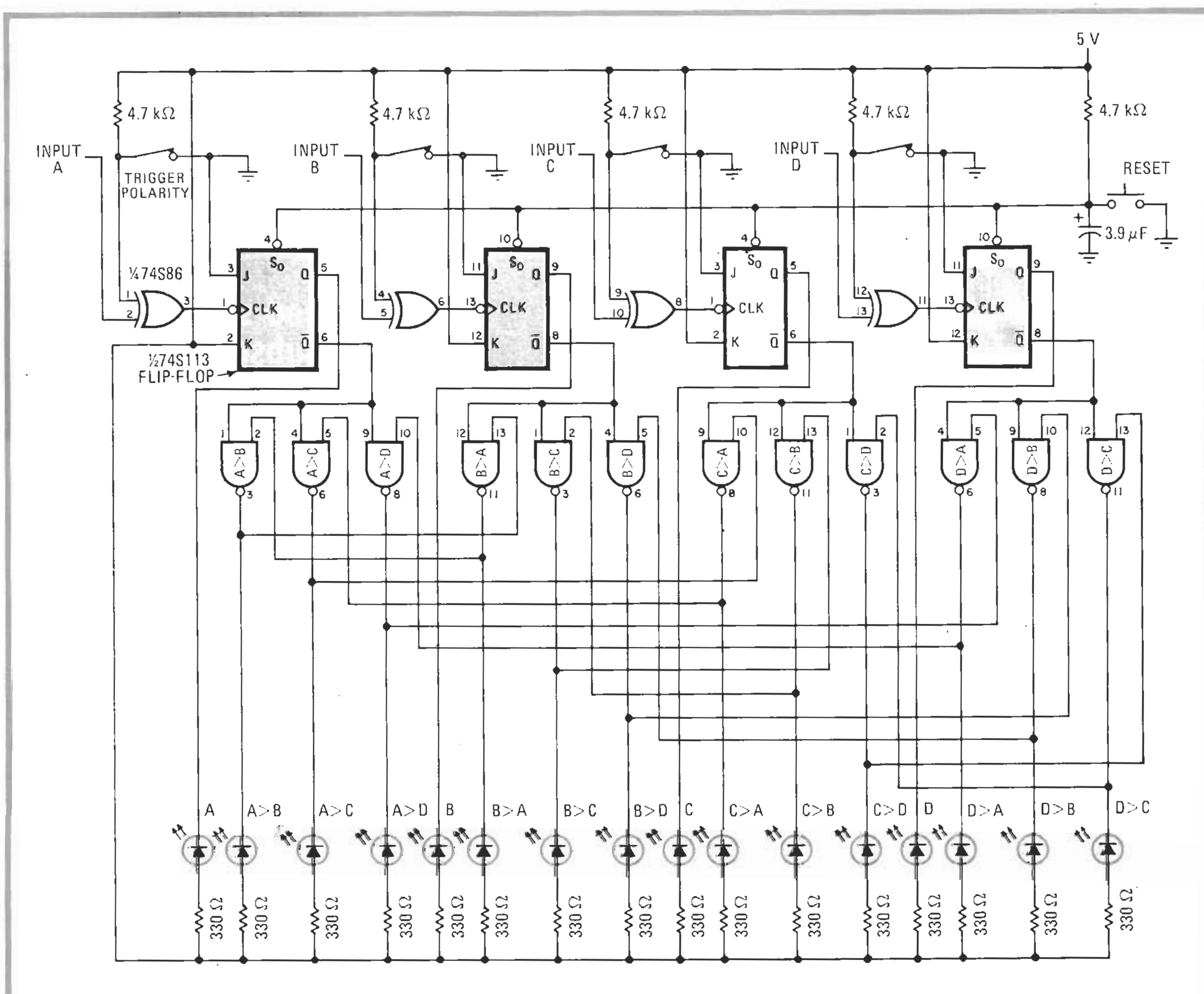
Decoder logs signals' order of arrival

by Claude Haridge
Ottawa, Ontario, Canada

This decoder indicates the sequence of arrival of up to four digital input signals and therefore serves as an excellent priority encoder. Alternatively, it can aid the technician in troubleshooting high-speed circuits. Using Schottky TTL devices to minimize propagation delays, the decoder can resolve two signals only 30 nanoseconds apart.

As shown, one flip-flop, three NAND gates, and four light-emitting diodes per input are needed to capture the corresponding signals and compare their arrival times. There are four such sections. In order to perform the time-difference checks accurately, the gates of each section are cross-coupled as shown in the figure, so that they provide an effective signal-lockout function. Polarity switches at each input enable the user to designate either the rising or falling edge of a signal as a valid gating stimulus.

A system reset brings the Q output of each flip-flop low. At this time, all the LED indicators are off. A valid



Signal sequence. Circuit indicates relative arrival times of four digital signal inputs. Using Schottky TTL, unit resolves any two signals separated by as little as 30 ns. Polarity switches at each input enable detection of signal's rising or falling edges.

trigger input sets its corresponding flip-flop, which then turns on its indicator LED A, B, C, or D. Simultaneously, the gates leading to the remaining three LEDs of the activated section are enabled. These three LEDs are used to indicate the relative arrival of succeeding pulses.

Thus, the lighting of LED A, followed by the LED associated with the A ► C output, indicates that a signal at input A arrived before a pulse at input C. In this case, note that the LEDs connected to the C ► A, B ► A, and D ► A ports are inhibited from turning on until the next system reset. Succeeding pulses reaching the B, C, and D inputs in any order enable the corresponding outputs and lock out the appropriate LEDs until all four inputs have been detected. □

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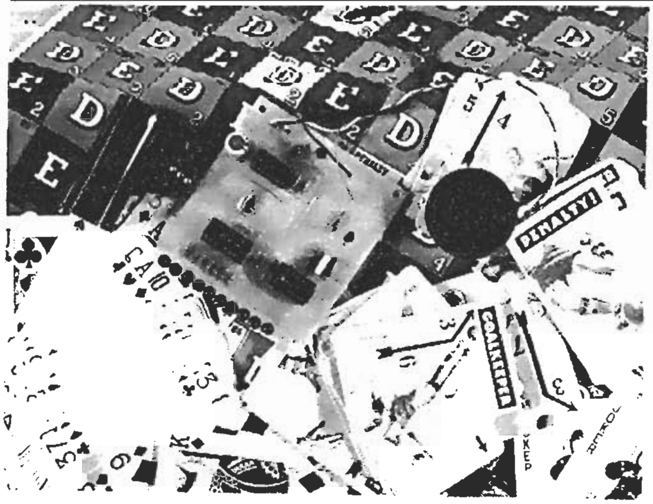
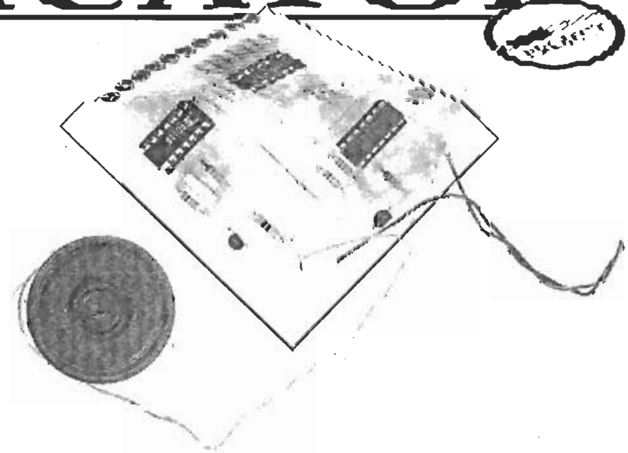
WIN INDICATOR



An inexpensive and easily-built project that is bound to be a winner with all games enthusiasts with ten or fewer arms.



As you can see we have left the choice of a box up to the individual constructor, similarly the LED panel may be used as a separate board for remote applications.

THIS PROJECT IS DESIGNED TO BE USED in those 'first-person-to-press-the-button-wins-the-game' types of activity that are so popular at parties and fund-raising functions. The device enables up to ten contestants to participate in such games and gives a virtually infallible audio-visual indication of the true winner of the game, even when all contestants seem to operate their push-buttons simultaneously.

In this project, each contestant is assigned a numbered push-button, with which an identically numbered LED (light-emitting-diode) is associated. Prior to the start of each game, the game referee presses a RESET button, which causes all LEDs to turn off and causes an electronic scanning circuit to start sequentially inspecting the state of each switch at a rate of several thousand scans per second. The 'game' switch to be subsequently operated causes the scanning action to lock at the switch position and activate a simple memory circuit, which energises an audible alarm and latches on the individual numbered LED that is associated with the winning switch; all subsequent switch operations are ignored by the unit. The alarm and the winning LED remain on until the referee again operates the RESET switch.

The ETI Multi-Input 'Game Won' Indicator circuit is powered from a single 9 volt battery and is an easy and inexpensive project to build. It can be used with any number of GAME switches up to a maximum of ten. Unwanted switches are simply omitted from the circuit.

Construction

All components except the switches and speaker are mounted on a single PCB. Construction should present few problems, provided that normal care is taken to ensure that all components are fitted in the correct polarity. The following minor points should, however, be noted.

(1) The ten indicator LEDs are mounted close to one edge of the board. The LEDs should be given individual funtional checks (by connecting them across a 9 volt supply via a 470R limiting resistor) before soldering them into place.

(2) Five under-board links are used to connect the LEDs to the output of IC1.

(3) Connections to the 'top' terminals of the ten external GAME switches are made via three topboard Veropins and seven under-board connections. The 'bottom' terminals of all ten switches are wired together and taken to R2 via a single Veropin connection.

When construction is complete you can connect the unit to a speaker and a 9 volt battery and give it a simple functional test, as already described. The completed unit can then be fitted into a suitable case of your own choice.

PARTS LIST

RESISTORS

R1,4	27K
R2,3,6	12K
R5	68K
R7	82R

CAPACITORS

C1	180p polystyrene
C2	100u 25 V PCB electrolytic
C3	47n polyester

SEMICONDUCTORS

IC1	4017
IC2	4001
IC3	4011
Q1,2	2N2925
D1,2	1N4148

Led1-10, are standard 0.2in. Red leds

MISCELLANEOUS

PB1-11 are momentary push buttons.

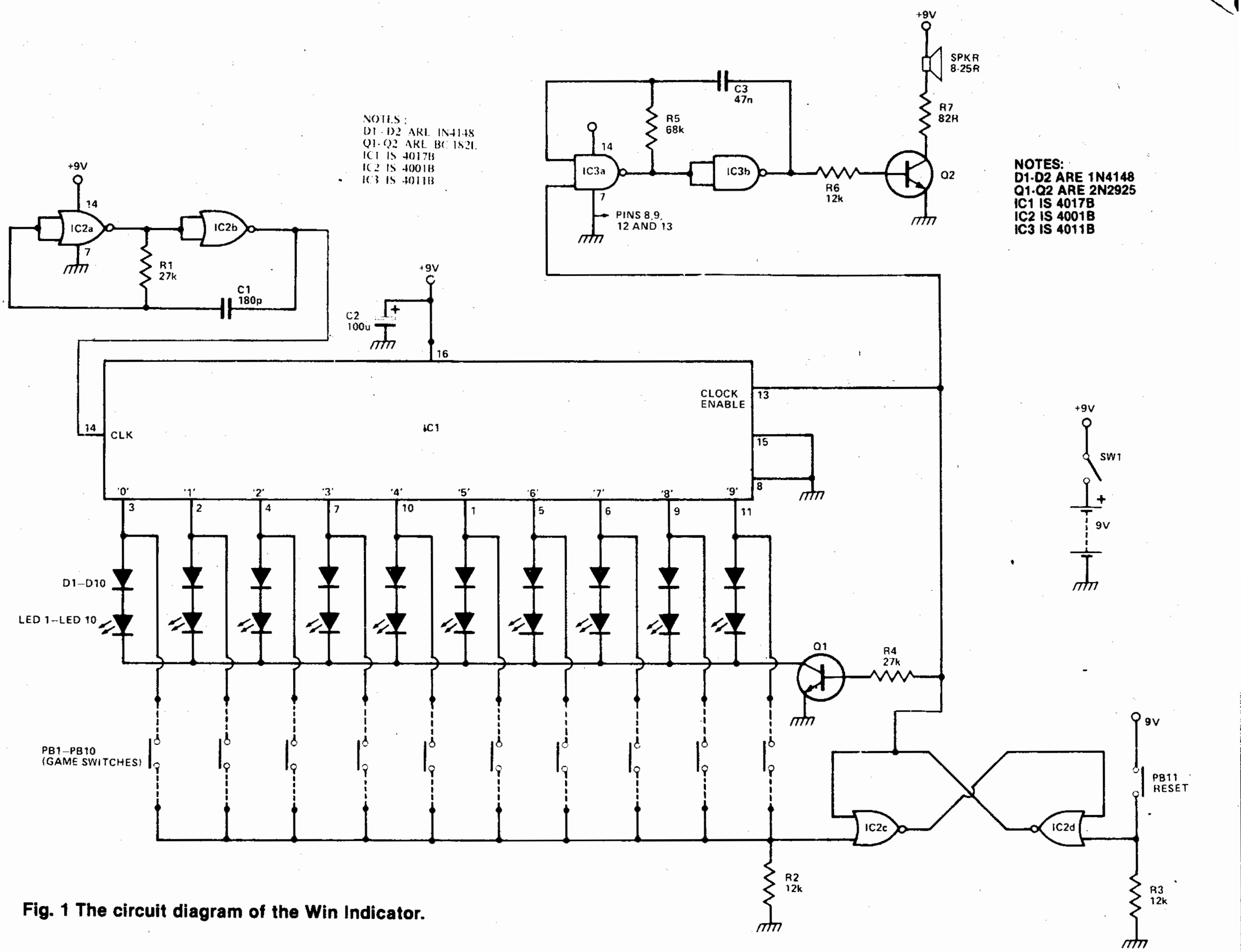


Fig. 1 The circuit diagram of the Win Indicator.

HOW IT WORKS

IC1 is a 4017 'decade-divider-with-ten-decoded-outputs'. When this IC receives clock signals its ten decoded outputs sequentially go high in synchrony with the clock signals, with only one output being high at any given moment of time. An indicator LED is wired between each of these current-limited outputs and ground via switching transistor Q1. IC2a-IC2b are wired as a fast astable 'clock' generator that is permanently operational when on/off switch SW1 is closed. IC2c-IC2d are wired as a simple bistable that can be SET by a brief positive pulse across R2 or RESET via PB11. The output of the bistable is fed to the CLOCK ENABLE terminal of IC1, to the base of Q1 via R4 and to the input of a gated sound generator that is built around IC3 and Q2.

At the start of each 'game' the IC2c-IC2d bistable is reset via PB11. Under this condition IC1 accepts clock signals but Q1 is turned off, so none of the LEDs are operational. The IC3-Q2 sound generator is also turned off. In this mode of operation, sample or 'scanning' pulses are sequentially applied to one side of each of the normally-open game switches at the 'clock' rate.

If any of the PB1-PB10 GAME switches become momentarily closed during this operation the scanning pulse will pass through the switch to the SET position. Under this condition the CLOCK ENABLE terminal of IC1 goes high, causing the IC to lock at that scan position. Simultaneously, Q1 turns on, causing the LED associated witht he winning switch to illuminate and give a visual indication of the game winner. The sound generator also activates at this time, giving an audible indication of the 'game won' state. The audio/visual indication then remains on until the bistable is reset via PB11 or until the circuit is turned off via SW1.

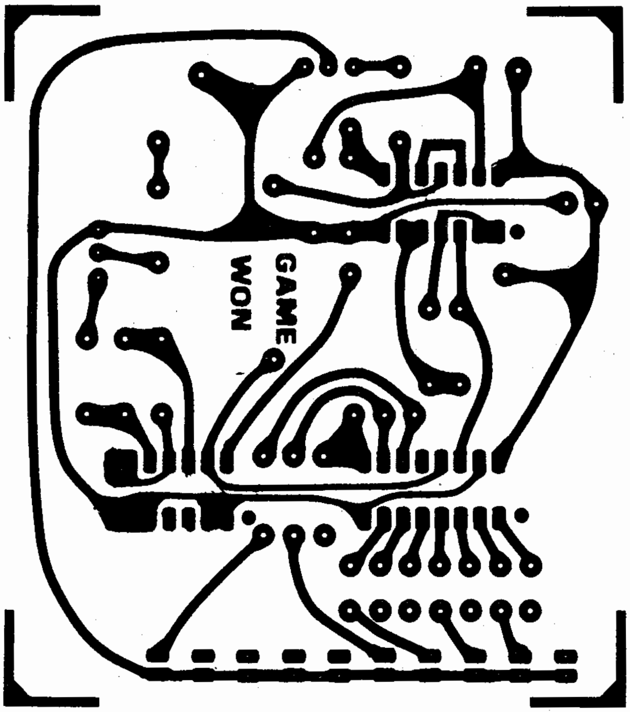


Fig. 2 Left. The PCB foil pattern for the Game Win Indicator. As was mentioned earlier the use of an all-in-one design is purely a matter for personal choice. The unit will function equally well with the LED indicator panel on a separate board.

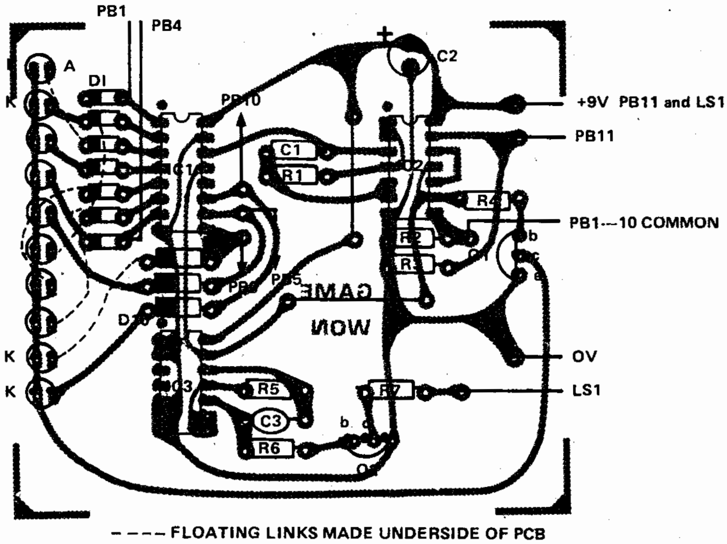


Fig. 3 Overlay diagram, ensure that all polarised components, ie ICs, diodes etc are inserted the right way round. This causes more 'dead' projects than any other factor.

I/O Devices *Continued*

bus should be rigidly defined in both its operation and useage. One of the main reasons that the S100 had a bad name until the IEEE (Institute of Electronic and Electrical Engineers, of course!) got hold of it was its flexibility. This rigid defining process unfortunately takes time.

Special Cases

A brief word must be said at this point about some special cases, namely the IEEE-488 and 20 mA interfaces. The IEEE-488 or General Purpose Interface Bus came to the micro world in a rather mutilated form as the Commodore PET. Designed originally as a high speed data highway it allows multiple talkers (sources) and listeners (acceptors) to communicate along a single eight eight bit data bus. The bus is controlled by a number of signals and can be accessed by any of the devices. The original useage was in the laboratory where various recording instruments were connected to a single event recorder or data logger. In the case of the PET version, the pruning has resulted in one or two headaches among hardware designers, but it can be genuinely useful.

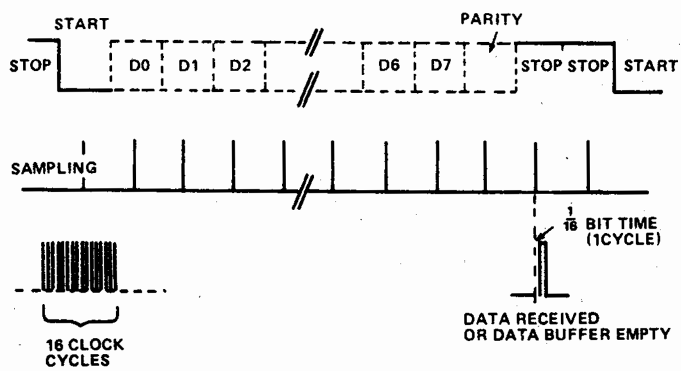


Fig. 4 Serial Transmission timing diagram.

The original serial interfaces were designed around the teleprinter and teletype devices that are mainly built from solenoids. The device which controls these solenoids is a current driven device. The 20 mA interface is built around a closed loop current source where the drive of 20 mA is turned on or off by a transistor which is in turn controlled by an external voltage. This allows the interface to be electrically separated from the device, a considerable benefit as the back EMF generated by the coil of a solenoid could fry modern ICs and transistors if it escaped into the bowels of the computer.

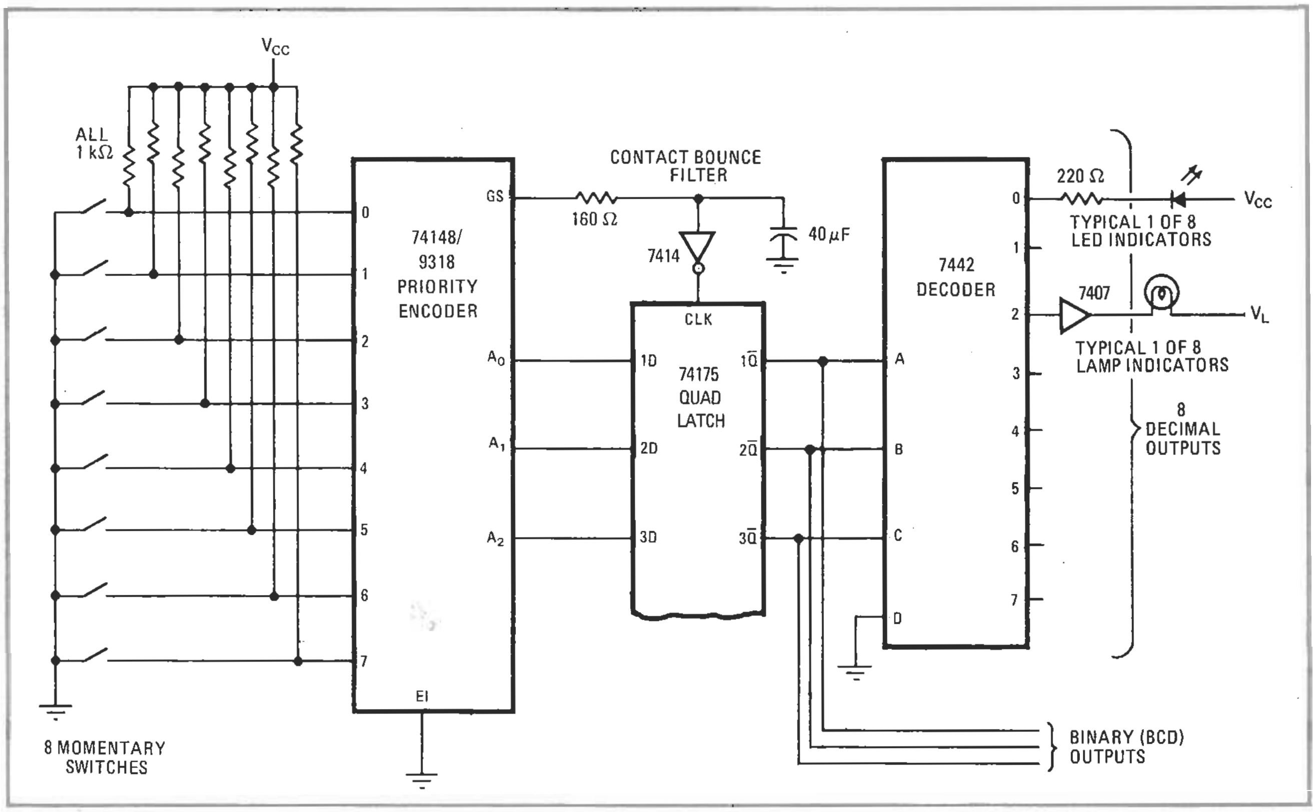
Latch circuits interlock remote switches electrically

by Jack Elias
Honeywell Inc., Fort Washington, Pa.

As many as eight momentary switches can be interlocked electrically even when they are physically separated from one another—an impossible task for mechanical interlocks. The keyboard-type momentary switches provide both binary-coded and individual outputs and are much more reliable than mechanically interlocked switches. The electrical interlock consists of an encoder, decoder and quad switch latch plus a Schmitt trigger and a few passive components.

The switches provide the inputs to a priority encoder, such as a TI 74148 or Fairchild 9318, which translates the identity of any actuated switch into a binary-coded output. The encoder also has an output, termed GS, for group-select, indicating when any one or more inputs are actuated; it provides a clock pulse for a 74175 quad latch, which stores the binary-coded output of the encoder. An RC filter and a Schmitt trigger remove uncertainty caused by switch bounce. The outputs of the flip-flops go to a 7442 decoder, which can drive either light-emitting diodes directly or incandescent lamps through buffers. Of course, the outputs can drive other circuits or systems that require the interlock.

If a second switch is actuated before the first is released, it has no effect because the Schmitt trigger has already generated its clock. Likewise, if the first switch is released while holding the second one down, the first switch's indication will be held until all the switches are released. The circuit can be expanded by cascading the encoders and using a larger decoder. □



Interlock. Momentary switches are interlocked from simultaneous operation by encoding them into a set of latches and then decoding the latch states to drive indicators or other apparatus. Circuit is more reliable than mechanical interlock, and switches can even be remote.

Glitchless TTL arbiter selects first of two inputs

by Yukihiro Mikami
Ottawa, Canada

Failure to differentiate between independently timed asynchronous signals only a few nanoseconds apart can cause glitches in standard transistor-transistor-logic circuits that spell disaster to system operation. Once the glitch is detected, it must be eliminated, so that an arbiter circuit like the one described here is essential in applications like dynamic memory controllers.

As shown in the figure, the 74S02 cross-coupled NOR latch will respond to a signal on request line A or B. The signal arriving first will appear on the corresponding output line. With simultaneous inputs, however, a single-pulse glitch, a sinusoidal oscillation, a metastable-state response (0.8-to-2.1-volt unassigned or guard-band region), or a combination of such responses may occur at each output for an indefinite period before the gate decides to switch into its desired state.

An RC network and Schmitt-trigger buffer eliminate these undesirable responses from the circuit outputs while minimizing the decision time. The amplitude of the glitch or oscillation is essentially filtered or damped, as the case may be, by the RC combination of the 330-ohm resistors and the 22-picofarad capacitor.

The resistors also combine with the 820-Ω resistor at the input of either Schmitt trigger to form a voltage divider. This divider effectively raises the positive-going switching threshold at this point by 0.6 to 2.1 V. Thus there is no spurious response, even for a 3-V glitch, a 1.5-V peak-to-peak oscillation, or a metastable-state response at the NOR gate output. The circuit responds with an output when the transient dies away, as the latch may then decide which signal came first. In the event of the arrival of two truly simultaneous signals, the gate would render an arbitrary decision.

Nonsimultaneous signals appearing at the appropriate output of the NOR gate will pass through the deglitching circuit relatively unaffected. Typical propagation delay of the arbiter is 20 nanoseconds for nonsimultaneous inputs and 25 ns for simultaneous input signals. □

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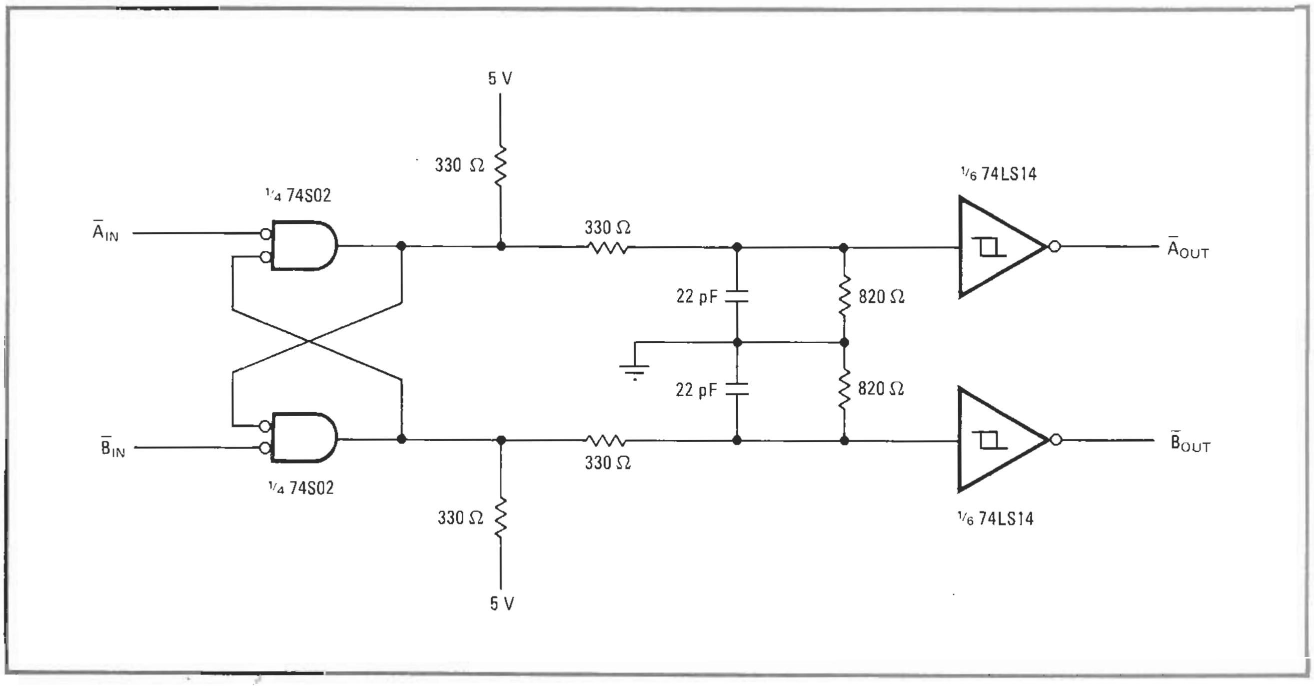


First come, first served. The input signal arriving first passes to an output, while simultaneously arriving signals produce an eventual output but no glitch. The resistor network raises the threshold of the Schmitt trigger, and the RC combination reduces glitch amplitude.

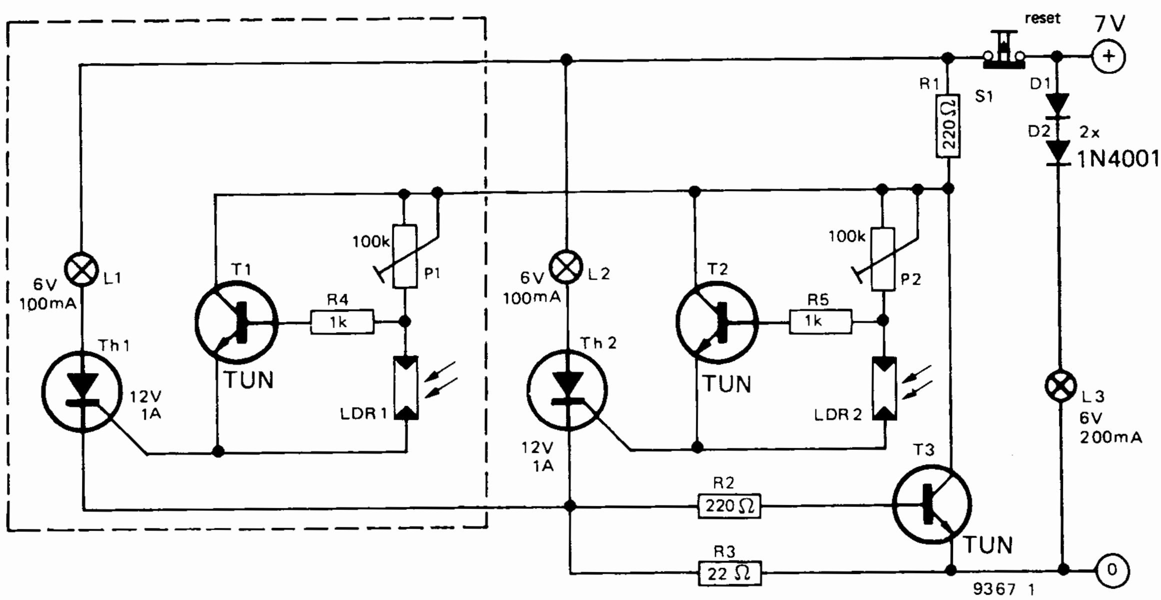
photofinish

F. Ansoms

When several mini racing cars are driven along a number of parallel tracks it is sometimes difficult to spot the winner. Heated discussions about the results of the race can be avoided by using this simple electronic photofinish system.

The circuit is of a quite simple design. The adjustment potentiometer, P1, (figure 1) which together with the LDR controls the base bias of transistor T1 is so adjusted that the transistor is just cut off. When a racing car intercepts the light beam, the resistance of the LDR momentarily increases, so that the base voltage of the transistor also increases, with the result that the latter turns on and lamp L1 lights up. The resulting current causes a voltage drop of about 1 V across resistor R3 so that T3, too, turns on. The collector voltage of T3 is now about 0.3 V, so that the other thyristor cannot fire, since the cathode voltage is higher than the gate voltage. After the final heat, the circuit is reset by briefly interrupting the supply voltage by pushing button S1. If this is often forgotten, automatic resetting after each round can be achieved by fitting a microswitch under the track some distance before the finish line.

1



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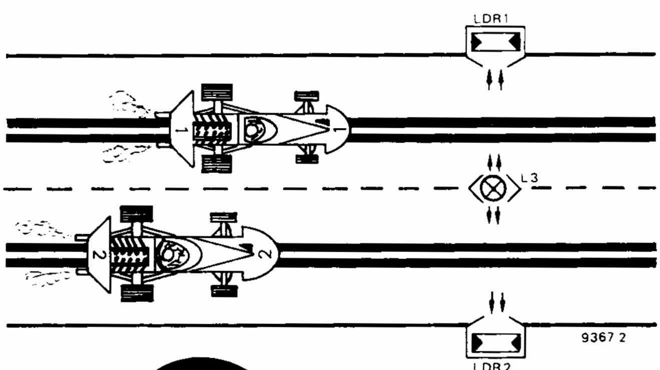

If more than two tracks are used, which makes it more difficult to see who was first, the circuit can easily be extended by parallel connection of the section surrounded by the dashed line. And as a last practical hint: the LDRs and the lamp should be mounted in pieces of PVC tubing. The LDRs are then not influenced by ambient light.
The supply voltage depends on the types of lamp and can be chosen about 1 volt higher than the nominal lamp voltage.

santatronics

ASK R-E

WRITE TO:

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Radio-Electronics
500-B Bi-County Blvd.
Farmingdale, NY 11735

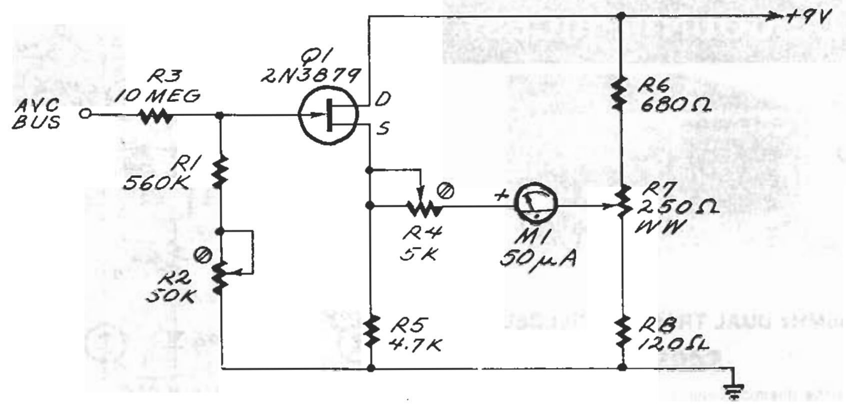


FIG. 1

S-METER AND HEADPHONE JACK

Please show the circuit of a signal-strength meter for an AM radio. Also describe how I can add a headphone jack that will automatically silence the speaker when the phones are plugged in.—J.D., Turnersville, NJ.

I don't know anything about the radio you're modifying, so the best bet for a signal-strength indicator is an FET DC voltmeter (Fig. 1) connected to the set's AGC bus. As shown, the meter reads upward when connected to a positive-going AGC. If the radio uses tubes or has a negative-going AGC, completely isolate the voltmeter's positive and negative leads from the receiver and then reverse the meter movement's connections so it responds to a negative voltage input. Or, do as was often done on communications receivers: Turn the meter upside down so a declining voltage input will cause the meter to appear to read up-scale.

Figure 2 shows how low-impedance headphones can be connected into the audio output circuit of the radio. Inserting the phone plug connects the phones across the audio output while disconnecting the speaker.

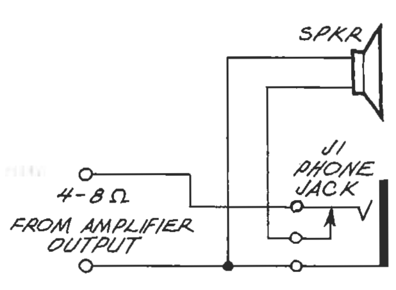


FIG. 2

PRECEDENCE DETECTOR

We are planning to update the indicator system used in our "Scholastic Bowl" events. The present system uses relays and we want to use solid-state circuitry.

The moderator or quiz-master asks a question and the first contestant to believe that he has the answer presses a pushbutton switch that causes his indicator lamp to light, and, at the same time, locks out the indicators of the other contestants. The judge determines the winner and then resets the system.—J.R., Cuba, IL.

ond before any of the others. At the instant S1 closes, gate current flows through R1, S1, and diodes D2 and D3, so SCR1 conducts. Its anode current flows through indicator lamp LMP1, and the anode voltage falls to around 0.6 volt—the anode-cathode voltage drop across SCR1. That causes D1 to be forward-biased, so it also conducts, dropping point X to 1.2 volts—the sum of the diode-voltage drops across SCR1 and D1.

With point X at 1.2 volts, all the other circuits are locked out, because when any other pushbutton is pressed, the two series-connected silicon diodes (D5, D6, etc.) are not sufficiently forward-biased to pass the gate current needed to fire the associated SCR. After determining the winning contestant, the umpire resets the board by pushing S3 once to turn off the conducting SCR, and again to restore power.

The indicator lamps should be low-current types—drawing approximately 60 mA or so. If you use higher current types make sure that their cold resistance (as measured with an ohmmeter) is high enough to limit the initial inrush of lamp current to the maximum surge-current rating of the SCR.

If you need something more elaborate, consider building the "Electronic Umpire" described in the December 1970 issue of **Radio-Electronics**. It handles two teams of three players each, and indicates the order of response for the first four contestants.

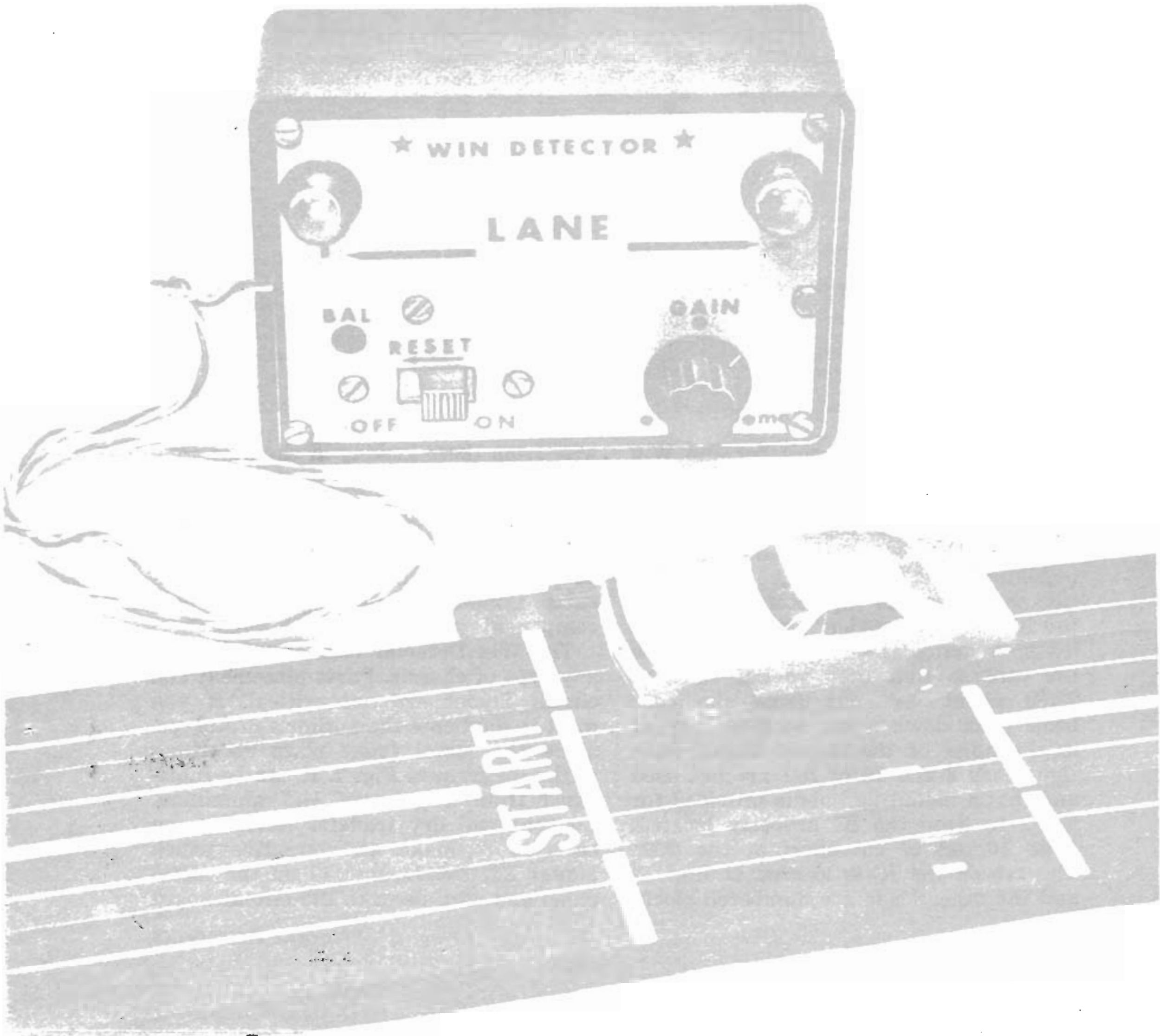
BUILD SLOT-CAR WIN DETECTOR

A FINISH-LINE JUDGE THAT CAN'T BE TRICKED

BY W. T. LEMEN

VISUAL determination of the winner in a close, fast slot-car race is almost impossible—the usual result is a heated discussion between the two participants. What you need is a photoelectric "Win Detector" that will end all the arguments by detecting the winner even if the two cars are separated by only 1/32 of an inch. You can build one from an integrated circuit (IC) and two fast-acting photo pickups mounted at the finish line.

The Win Detector uses its own battery and works in normal room lighting—the winner is indicated by a glowing lamp. Because only a single switch controls the operation, the Win Detector can be used by small fry easily and safely.



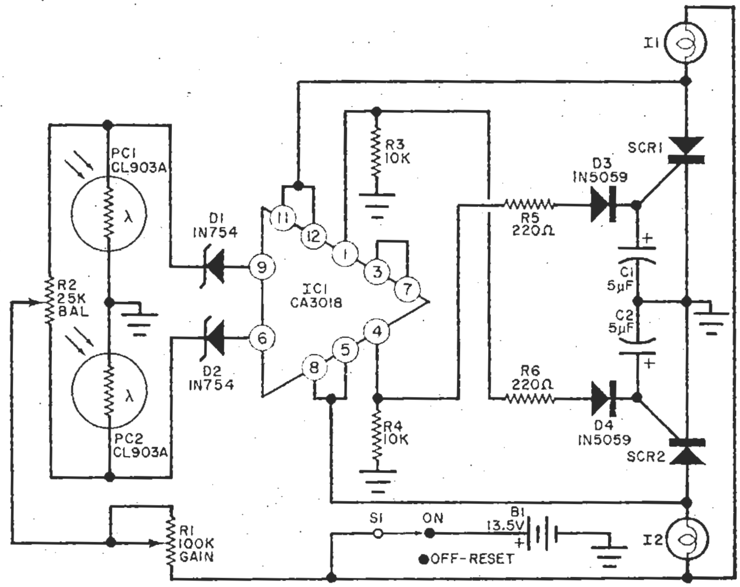


Fig. 1. The IC contains two independent circuits whose external components are arranged so that, when one of the two circuits operates, the other is automatically deactivated. This insures that only one track is winner.

PARTS LIST

B1—13.5-volt battery (Burgess XX9 or similar)
C1,C2—5-μF, 15-volt electrolytic capacitor
D1,D2—1N754 zener diode
D3,D4—1N5059 diode
I1,I2—14-volt lamp (#330) with suitable holder (Dialco 0931-502)
IC1—Integrated circuit (RCA CA-3018 or KD 2114)
PC1,PC2—Photoresistor (Clairex CL903A or similar)
R1—100,000-ohm potentiometer
R2—25,000-ohm printed-circuit potentiometer (Mallory MTC)
R3,R4—10,000-ohm, ¼-watt resistor
R5,R6—220-ohm, ¼-watt resistor
S1—S.p.s.t. slide switch
SCR1, SCR2—Silicon controlled rectifier (Texas Instruments TIC-46)
Misc.—Plastic case 4" x 2⅞" x 1 9/16" (Harry Davies #220); 1/16" aluminum panel 3¾" x 2⅝"; length of three-conductor cable; ¾" fiber spacers (2); battery connector; ¼" diameter fiber tubes 7/16" long (2) and wood block for photo pickups; knob; mounting hardware; etc.

Construction. The circuit for the Win Detector is shown in Fig. 1. Most of the components are mounted on the printed circuit board whose foil pattern is shown in Fig. 2. Figure 3 shows how the components are located. Observe the polarities on diodes and capacitors. To install the IC, make a "spider" formation of its leads, bending them about 1/16" below the case so that they go out radially. Then about 3/16" out from the case bend them down again so that they fit in the holes of the circuit board. Note that leads 2 and 10 of *IC1* are not used and that a mounting hole is provided for pin 2 to keep the IC properly located. Lead 10 can be cut short at the case. The tab on the IC is located at lead 12 and the other leads are numbered clockwise from there looking at the case from the bottom.

After forming the leads of the IC into a spider, insert it on the board, making sure that the orientation is correct. Also be sure that the SCR's are properly oriented. Connections to the panel-mounted components are also shown in Fig. 3.

The Win Detector can be mounted in any type of chassis. Parts placement and circuit layout are not critical. If you want to duplicate the author's prototype, make the metal front plate according to the diagram in Fig. 4. It can be fabricated from a piece of 1/16" aluminum. Conventional dry transfer lettering can be used to make an attractive panel. Mount *S1*, *R1*, *I1*, and *I2* on the metal panel and wire them to the circuit board

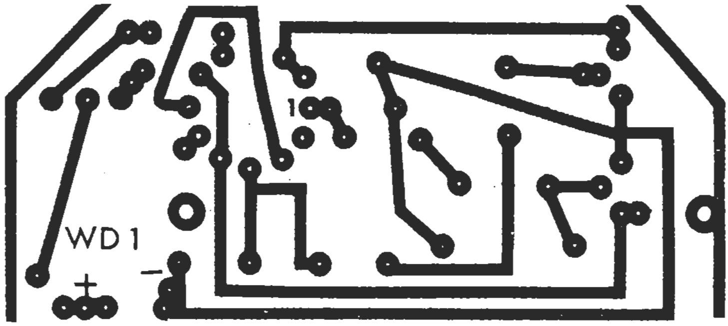


Fig. 2. Printed circuit board can be made from this actual-size pattern. The number "one" on the IC pattern is for pin 1.

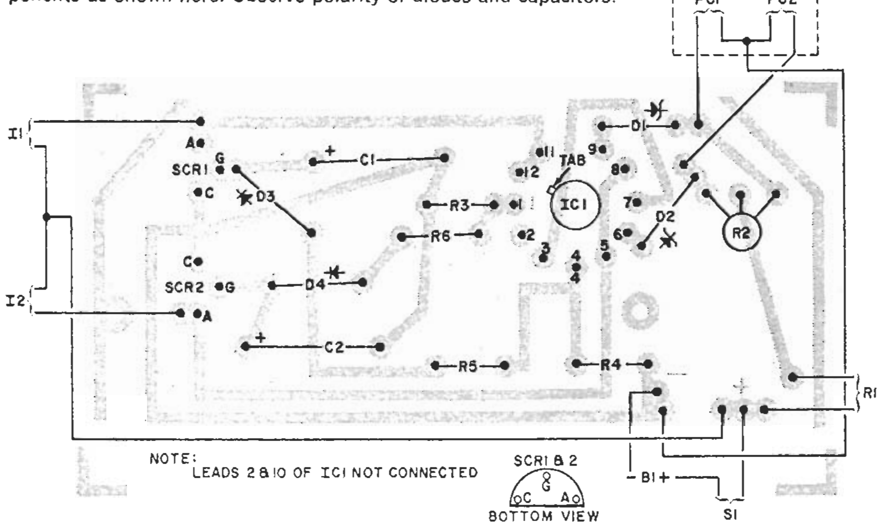
allowing enough wire to mount the board about ¾″ below the panel. Cut a small hole in the side of the plastic box to accommodate the three leads to the photo pickups. The three-conductor cable between the chassis and the photo-pickup assembly can be any reasonable length.

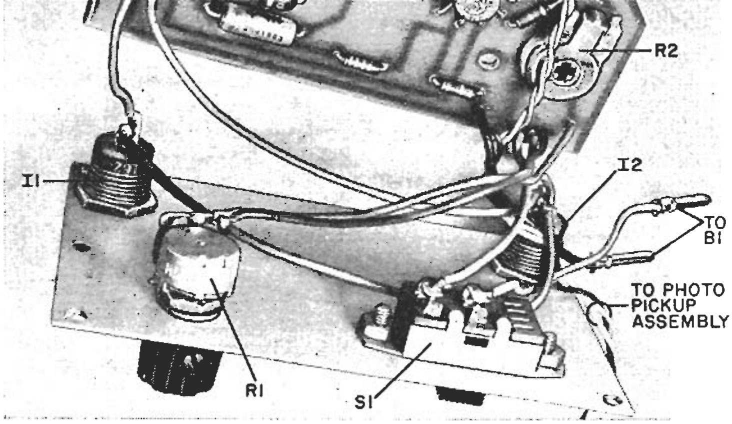
Attach the circuit board to the front panel using a pair of ¾″ insulated (fiber) spacers and appropriate hardware. The battery should fit inside the plastic case between the board and one long wall of the case.

The design of the photo-pickup assembly is contingent on the physical layout of the track you are using. If your finish line can be made to be at a raised portion of the track, you can use the layout shown in Fig. 5. In this case, the only two dimensions not given in the diagram are the width of the overall wooden block and the center-to-center distance between the two ¼″ holes. The block should be cut to fit snugly under and between the track edges at the finish line and the ¼″ holes should be spaced so that they are directly under the centers of the lanes. Press fit the photo pickups into the fiber tubes; then fit the fiber tubes into the ¼″ holes in the wooden block.

Connect the three leads from the electronic assembly to the photo pickups as shown in Fig. 1 and Fig. 3. Solder and insulate these leads to prevent accidental loosening or shorting. The photo-pickup assembly can be attached to the track now. A three-terminal disconnect plug may be used between the detector and pickups to permit the track to be

Fig. 3. Once the board has been made, install the various components as shown here. Observe polarity of diodes and capacitors.





Interior of the author's prototype. Access to R2 is through a small hole in the metal front panel.

disconnected from the detector for storage.

For the more common plastic tracks, drill ¼"-diameter holes adjacent to each track pin slot so that the car must pass over the hole to block the ambient light. Mount the two photo pickups, one at each track, and secure them in place with cement. Wire the pickups to the electronic assembly as described above.

Operation. With the slot-car track in position, be sure that the photo-pickup assembly is in unobstructed light. Place the RESET switch, S1, in the ON position and set GAIN control R1 to its maximum. One of the lights should come on. With *R1* at maximum, flip *S1* between the OFF and ON positions, simultaneously adjusting *R2* (through the hole in the cover) until one light or the

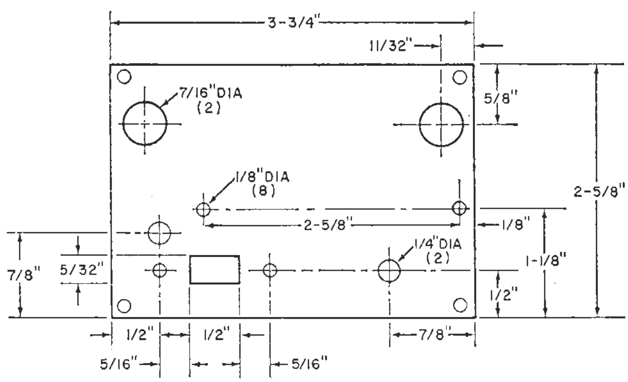
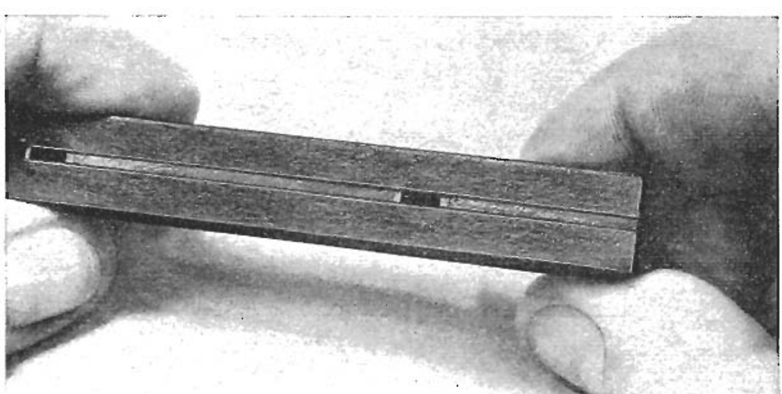


Fig. 4. Although any mechanical layout can be used, you can duplicate the author's front panel with these details.



Lengths of opaque tape are used to narrow the field of view of the two cells for more accuracy.

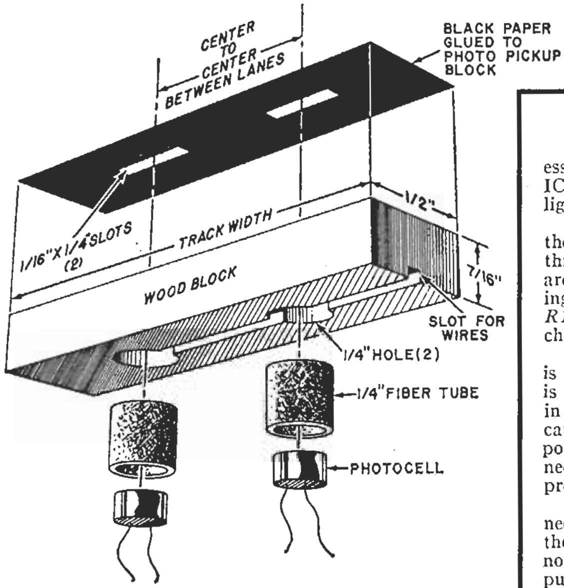


Fig. 5. If you have a raised track, make the photo-pickup assembly as shown here. If you have a plastic track, mount the photocells in drilled holes.

other comes on when *S1* is on. It is possible to balance the system so accurately that both lights come on. Back off on *R1* until operation of *S1* does not cause either light to come on.

Test the system by passing your hand across the photo pickups in one direction (causing one light to come on). Then reset the system and pass your hand over the block in the other direction to turn the other light on. You may have to adjust the setting of the GAIN control for best operation. Once a light comes on, it will remain on regardless of any other pass of the hand (or slot car) until the RESET switch is operated.

If you are using undersized slot cars or if you want faster triggering, reduce the values of capacitors *C1* and *C2*. —30—

HOW IT WORKS

The electronic portion of the Win Detector is essentially two balanced amplifiers (within one IC) with photo pickups as sensors and indicator lights driven by SCR's.

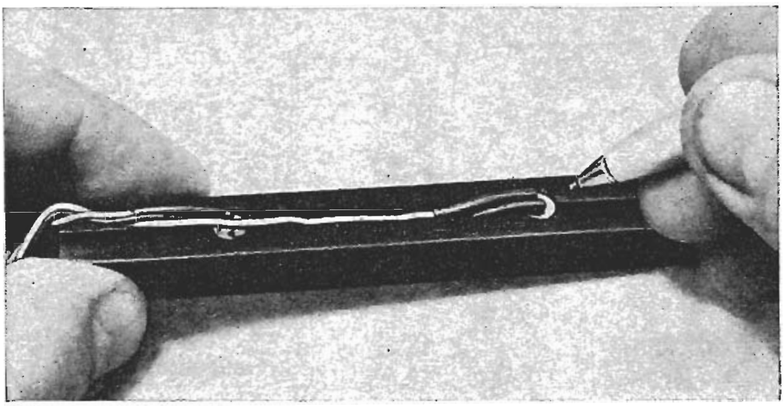
Photo pickups *PC1* and *PC2* are connected to the bases of the two input transistors of *IC1* through zener diodes *D1* and *D2*. The pickups are connected to battery *B1* through the balancing potentiometer *R2* and the gain potentiometer *R1*. The balance control adjusts for lighting changes and circuit differences.

In operation, *R1* is adjusted (after the circuit is balanced) so that the potential at either zener is just slightly below its firing level. A reduction in the amount of light reaching either pickup causes an increase in its resistance and raises the potential on the zener diode to which it is connected. This causes the zener to break down and provide a signal at the input to the IC.

The outputs of the IC (pins 1 and 4) are connected as emitter followers with *R3* and *R4* as their loads. The voltages at pins 1 and 4 are normally zero. When either amplifier has an input from its photo pickup, its output fires the associated SCR and turns on the indicator light. The IC outputs are connected to the SCR's through current-limiting resistors *R5* and *R6* and blocking diodes *D3* and *D4*.

Note that the positive supply for each half of the IC is taken from the junction of each lamp and its associated SCR and not from the battery. These points are normally positive when the lamps are off, but the potential drops to zero when the SCR conducts. In this way, when either lamp turns on, the power to the opposite channel is cut off so that it cannot be energized. Therefore, the first channel to operate shuts down the other one, providing a definite indication of the winner.

Capacitors *C1* and *C2* are transient filters which assure turn off of the SCR's when the RESET switch is operated.



After photocells are wired together, they are friction fitted into the two holes drilled into a wooden block. The slot accommodates 3 wires.