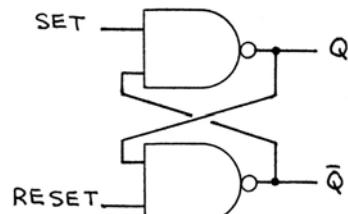
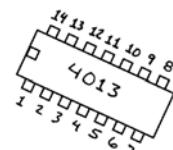
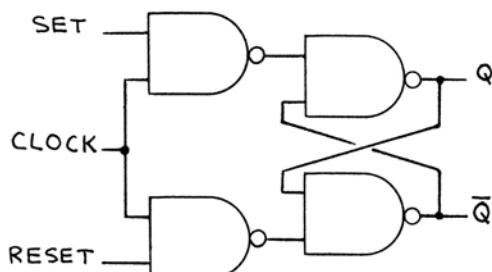
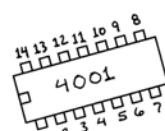
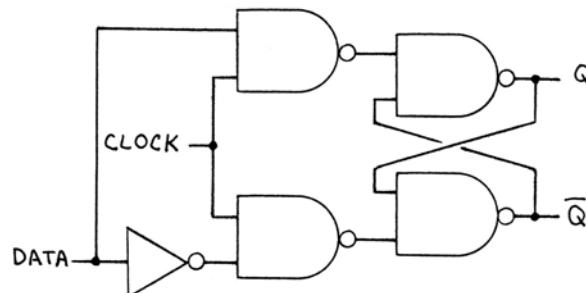
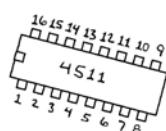
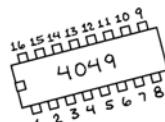
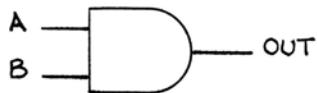


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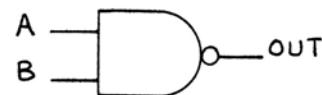
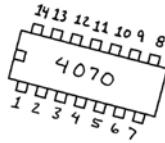
## WORKBOOK 2. DIGITAL LOGIC PROJECTS

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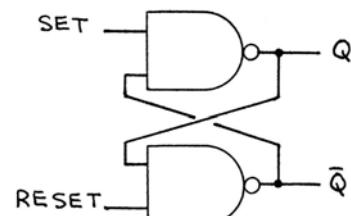
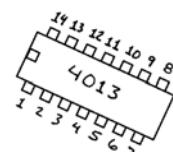
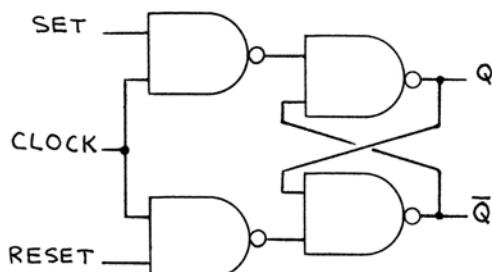
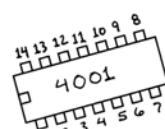
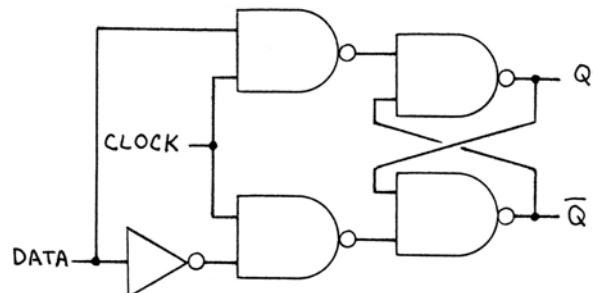
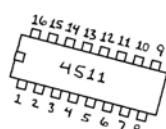
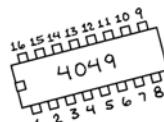
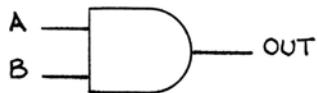
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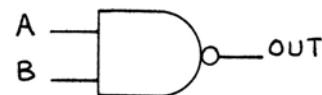
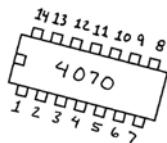
## WORKBOOK 2. DIGITAL LOGIC PROJECTS

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#### A NOTE FROM THE AUTHOR...

WELCOME TO THE WORLD OF DIGITAL ELECTRONICS! THE PROJECTS IN THIS MANUAL WILL TEACH YOU THE BASIC PRINCIPLES THAT MAKE POSSIBLE CALCULATORS, COMPUTERS, ELECTRONIC WATCHES AND MANY OTHER DIGITAL GADGETS. I HOPE YOU HAVE AS MUCH FUN EXPERIMENTING WITH THESE CIRCUITS AS I DID PREPARING THEM.

## GETTING STARTED WITH DIGITAL LOGIC

DIGITAL LOGIC IS THE KEY TO MUCH OF MODERN ELECTRONICS. DIGITAL WATCHES, CLOCKS, COUNTERS, TIMERS, CALCULATORS AND COMPUTERS ARE ALL DESIGNED WITH DIGITAL LOGIC.

ANALOG ELECTRONIC CIRCUITS CAN PROCESS A WIDE RANGE OF VOLTAGES. DIGITAL LOGIC PROCESSES ONLY TWO VOLTAGE LEVELS, ONE OF WHICH IS AT OR NEAR GROUND (0 VOLT OR THE LOW LOGIC STATE) AND THE OTHER BEING NEAR OR AT THE CIRCUIT'S SUPPLY VOLTAGE (HIGH LOGIC STATE). THE TWO LOGIC LEVELS OR STATES OF DIGITAL LOGIC CIRCUITS ALLOW THEM TO REPRESENT "YES" AND "NO" OR "ON" AND "OFF." THIS MEANS THAT DIGITAL LOGIC CIRCUITS CAN MAKE DECISIONS. THE TWO LOGIC STATES CAN ALSO REPRESENT 0 (LOW) AND 1 (HIGH), THE TWO DIGITS OF THE BINARY NUMBER SYSTEM. THIS MEANS THAT DIGITAL LOGIC CIRCUITS CAN PERFORM ARITHMETIC, PROCESS INSTRUCTIONS AND STORE INFORMATION.

## SOME BINARY BASICS

THE BINARY SYSTEM MIGHT SEEM COMPLICATED. BUT IT'S JUST A NUMBER SYSTEM WITH ONLY TWO DIGITS, OR BITS, 0 AND 1. TO COUNT IN BINARY, USE BOTH BITS AND THEN START OVER AGAIN LIKE THIS: 0, 1, 10, 11, 100, 101, 110, 111, 1000, AND SO FORTH. BINARY NUMBERS ARE USUALLY SHOWN WITH LEADING ZEROES, AS IN THE TABLE. MANY LOGIC CIRCUITS PROCESS PATTERNS OF 8 BITS CALLED BYTES. ONE BYTE CAN REPRESENT ANY OF UP TO 256 DECIMAL NUMBERS. IT CAN ALSO REPRESENT A VOLTAGE, SYMBOL, LETTER OF THE ALPHABET OR A COMPUTER INSTRUCTION.

DECIMAL	BINARY	DECIMAL	BINARY
0	0000	8	1000
1	0001	9	1001
2	0010	10	1010
3	0011	11	1011
4	0100	12	1100
5	0101	13	1101
6	0110	14	1110
7	0111	15	1111

## POSITIVE AND NEGATIVE LOGIC

LOGIC CIRCUITS REPRESENT THE TWO LOGIC STATES WITH ONE OF TWO VOLTAGES. USUALLY THE HIGHER VOLTAGE (SEVERAL VOLTS OR MORE) INDICATES 1 AND THE LOWER VOLTAGE (USUALLY NEAR 0 VOLTS OR GROUND) INDICATES 0. THIS IS KNOWN AS THE POSITIVE LOGIC SYSTEM ( $H = 1$  AND  $L = 0$ ). THE NEGATIVE LOGIC SYSTEM IS THE OPPOSITE ( $H = 0$  AND  $L = 1$ ). IT'S IMPORTANT TO KNOW THAT A POSITIVE LOGIC AND GATE IS A NEGATIVE LOGIC OR GATE, AND A NEGATIVE LOGIC AND GATE IS A POSITIVE LOGIC OR GATE. UNLESS OTHERWISE SPECIFIED, YOUR LAB KIT USES POSITIVE LOGIC.

## COMBINATIONAL LOGIC

THERE ARE TWO PRINCIPAL KINDS OF LOGIC, COMBINATIONAL AND SEQUENTIAL. LOGIC SYSTEMS MAY USE ONLY COMBINATIONAL OR SEQUENTIAL LOGIC, OR THEY CAN USE BOTH. IN COMBINATIONAL LOGIC, 0'S AND 1'S FLOW THROUGH A NETWORK OF LOGIC CIRCUITS AS FAST AS THE CIRCUITS WILL ALLOW. THE LOGIC SIGNALS MAY BE BLOCKED OR THEY MAY BE STEERED FIRST ONE WAY AND THEN ANOTHER. THEY DO NOT PAUSE, AND THEY ARE NOT STORED FOR LATER USE. THE MOST BASIC COMBINATIONAL LOGIC ELEMENT IS THE LOGIC GATE, OF WHICH THERE ARE SEVERAL KINDS:

INVERTERS. THE INVERTER HAS ONLY ONE INPUT AND ONE OUTPUT. AS IMPLIED BY ITS NAME, INVERTERS REVERSE THE LOGICAL STATE OF AN INCOMING SIGNAL. THUS AN INVERTER CAN BE THOUGHT OF AS A "NOT" CIRCUIT.

NOT	
A	OUT
L	H
H	L



GATES. GATES HAVE TWO OR MORE INPUTS AND ONLY ONE OUTPUT. THE PATTERN OF LOGIC SIGNALS AT THE INPUTS DETERMINES WHETHER THE OUTPUT IS 0 OR 1. THUS GATES ARE DECISION-MAKING LOGIC CIRCUITS. NETWORKS OF GATES FORM COMBINATIONAL LOGIC CIRCUITS. A PAIR OF GATES CAN FORM A FLIP-FLOP, THE SIMPLEST SEQUENTIAL LOGIC CIRCUIT.

SHOWN BELOW ARE THE LOGIC SYMBOLS FOR THE BASIC 2-INPUT GATES. ALSO SHOWN ARE THE TRUTH TABLES FOR EACH GATE. THE TRUTH TABLES SHOW THE OUTPUT OF EACH GATE FOR THE VARIOUS COMBINATIONS OF INPUTS. IT'S NOT NECESSARY TO MEMORIZE THESE TRUTH TABLES, ALTHOUGH YOU WILL PROBABLY DO SO AS YOU EXPERIMENT WITH YOUR ELECTRONICS LEARNING LAB. WHAT'S IMPORTANT IS TO UNDERSTAND THAT THE INPUTS TO A GATE FORM A SIMPLE CODE THAT DETERMINES THE OUTPUT. FOR EXAMPLE, THE AND GATE OUTPUT GOES HIGH (1) WHEN AND ONLY WHEN BOTH INPUTS ARE HIGH.

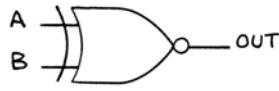


AND GATE		
A	B	OUT
L	L	L
L	H	L
H	L	L
H	H	H

NAND GATE		
A	B	OUT
L	L	H
L	H	H
H	L	H
H	H	L

OR GATE		
A	B	OUT
L	L	L
L	H	H
H	L	H
H	H	H

NOR GATE		
A	B	OUT
L	L	H
L	H	L
H	L	L
H	H	L

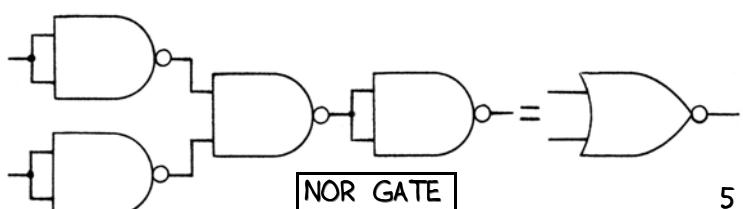
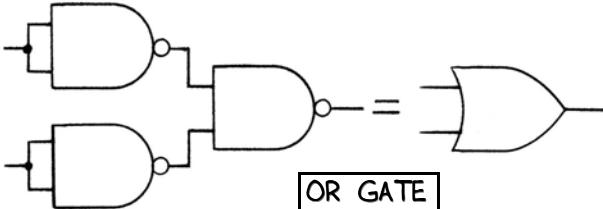
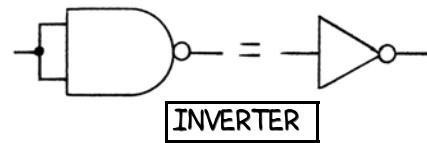
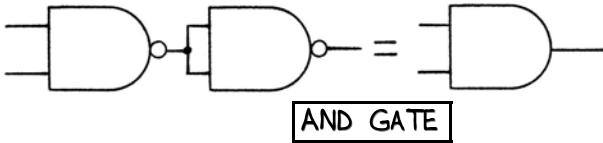


EX-OR GATE		
A	B	OUT
L	L	L
L	H	H
H	L	H
H	H	L

EX-NOR GATE		
A	B	OUT
L	L	H
L	H	L
H	L	L
H	H	H

NETWORKS OF GATES CAN TRANSFORM ONE PATTERN OF BINARY BITS INTO ANOTHER. FOR EXAMPLE, A BINARY-TO-DECIMAL GATE ARRAY CALLED A DECODER HAS 10 OUTPUTS DESIGNATED 0-9. WHEN A BINARY NUMBER IS APPLIED TO THE INPUT OF THE DECODER, THE APPROPRIATE OUTPUT IS ACTIVATED. EXCLUSIVE-OR GATES CAN ADD BINARY NUMBERS. THEY CAN ALSO COMPARE TWO BINARY NUMBERS AND DETERMINE IF THEY ARE EQUAL.

ALL THE BASIC GATES CAN BE MADE FROM ONLY NAND OR NOR GATES. FOR EXAMPLE:

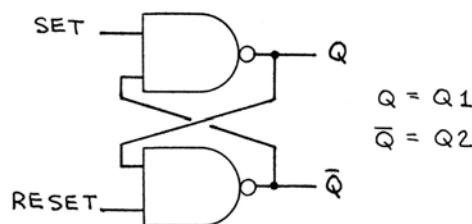


## SEQUENTIAL LOGIC

IN SEQUENTIAL LOGIC, 0'S AND 1'S ARE SENT THROUGH A LOGIC CIRCUIT ONLY WHEN ORDERED TO DO SO BY PULSES FROM A CIRCUIT CALLED A CLOCK. THE FLIP-FLOP IS THE MOST BASIC SEQUENTIAL LOGIC CIRCUIT. YOUR LEARNING LAB HAS MANY PROJECTS THAT USE FLIP-FLOPS.

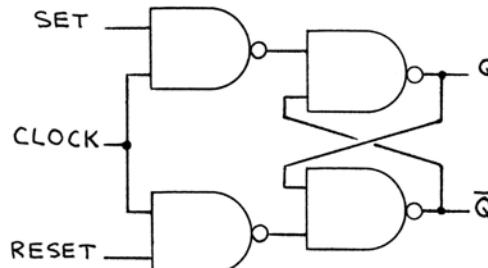
FLIP-FLOPS. THE FLIP-FLOP HAS TWO OUTPUTS, WHICH MUST ALWAYS BE AT OPPOSITE LOGIC STATES. THE FLIP-FLOP IS MADE FROM NAND OR NOR GATES. HERE ARE SOME OF THE MOST BASIC FLIP-FLOPS:

THE RESET-SET (RS) FLIP-FLOP IS ALSO KNOWN AS A LATCH SINCE IT SAVES CURRENT DATA UNTIL NEW DATA ARRIVE. DISALLOWED IN THE TABLE MEANS THE INPUTS CANNOT BOTH BE LOW AT THE SAME TIME.



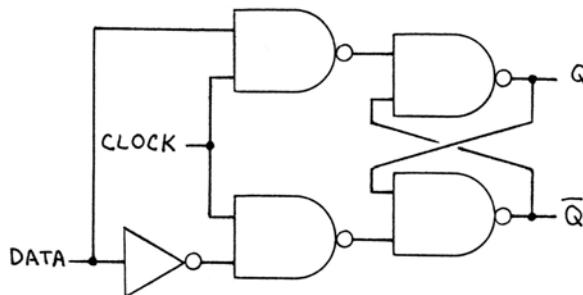
RESET-SET (RS) FLIP-FLOP			
S	R	Q <sub>1</sub>	Q <sub>2</sub>
L	L	(DISALLOWED)	
L	H	H	L
H	L	L	H
H	H	NO CHANGE	

THE CLOCKED RS FLIP-FLOP IGNORES INPUT DATA UNTIL A CLOCK PULSE ARRIVES. IT THEN CHANGES STATES.



CLOCKED RS FLIP-FLOP			
S	R	Q <sub>1</sub>	Q <sub>2</sub>
L	L	NO CHANGE	
L	H	L	H
H	L	H	L
H	H	(DISALLOWED)	

THE DATA (D) FLIP-FLOP STORES THE CURRENT DATA BETWEEN CLOCK PULSES. NEW INPUT DATA ARE ACCEPTED WITH EACH NEW CLOCK PULSE.



DATA (D) FLIP-FLOP		
D	Q <sub>1</sub>	Q <sub>2</sub>
L	L	H
H	H	L
VALID AFTER CLOCK PULSE ARRIVES		

REGISTERS. FLIP-FLOPS ARE USED TO MAKE MEMORY REGISTERS THAT STORE INFORMATION (DATA) IN THE FORM OF BINARY NUMBERS. ONE FLIP-FLOP IS PROVIDED FOR EACH BIT POSITION TO BE STORED.

COUNTERS. A DIGITAL COUNTER IS A STRING OF FLIP-FLOP, WITH ONE OUTPUT OF EACH GOING TO THE CLOCK INPUT OF THE NEXT. THE COUNT ADVANCES WHEN A CLOCK PULSE IS APPLIED TO THE FIRST FLIP-FLOP.

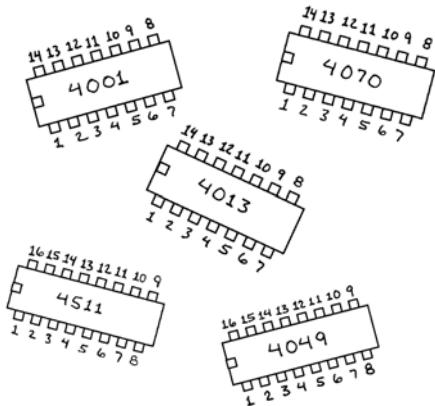
SHIFT REGISTERS. A SHIFT REGISTER IS A STRING OF FLIP FLOPS WITH ONE OUTPUT OF EACH GOING TO THE DATA INPUT OF THE NEXT. DATA (0'S AND 1'S) ARE PASSED FROM ONE FLIP-FLOP TO THE NEXT WHEN A CLOCK PULSE IS APPLIED TO ALL THE FLIP-FLOPS.

YOU CAN BUILD MANY COMBINATIONAL AND SEQUENTIAL LOGIC CIRCUITS WITH YOUR ELECTRONICS LEARNING LAB. THE MOST EXCITING CIRCUITS—AND ALSO THE MOST COMPLICATED—USE BOTH COMBINATIONAL AND SEQUENTIAL LOGIC CHIPS.

## THE CMOS LOGIC FAMILY

THE DIGITAL LOGIC INTEGRATED CIRCUITS OR "CHIPS" PROVIDED WITH YOUR LEARNING LAB ARE CMOS DEVICES. CMOS MEANS COMPLEMENTARY METAL-OXIDE-SEMICONDUCTOR. DOZENS OR EVEN HUNDREDS OF TRANSISTORS ARE FORMED FROM THREE LAYERS. THE BASE LAYER IS A SILICON DIE OR CHIP. AN ULTRA-THIN OXIDE LAYER COMES NEXT. FINALLY, A METAL LAYER IS APPLIED. ELECTRICAL CONTACT TO THE SILICON IS THROUGH HOLES FORMED IN THE OXIDE. SINCE THE OXIDE LAYER IS EXTREMELY THIN, CURRENT FLOWING THROUGH THE SILICON CAN BE SWITCHED OFF AND ON MERELY BY THE PRESENCE OF A TINY ELECTRICAL CHARGE IN THE METAL LAYER.

## CMOS HANDLING PRECAUTIONS



CMOS INTEGRATED CIRCUITS ARE MADE WITH VERY THIN LAYERS OF SILICON AND INSULATION SO THEY WILL OPERATE USING VERY LITTLE CURRENT. WHILE THIS PROVIDES MANY IMPORTANT ADVANTAGES, THE VERY THIN LAYERS OF CMOS ICS CAN BE EASILY PENETRATED BY EXCESSIVE VOLTAGE. THEREFORE, YOU MUST FOLLOW CERTAIN HANDLING PRECAUTIONS WHEN USING AND EXPERIMENTING WITH THEM.

1. BEFORE HANDLING CMOS CHIPS, GROUND YOURSELF TO DRAIN AWAY ANY STATIC ELECTRICAL CHARGE ON YOUR BODY BY TOUCHING A LARGE METAL OBJECT OR APPLIANCE. WHEN THE AIR IS VERY DRY AND COOL, THIS IS ESPECIALLY IMPORTANT. THE SPARKS THAT LEAP BETWEEN YOUR FINGER AND A DOOR KNOB ON SUCH DAYS HAVE ENOUGH VOLTAGE TO FRY A CMOS IC.
2. ALWAYS STORE CMOS CHIPS IN THE PACKAGING PROVIDED WITH YOUR LEARNING LAB. NEVER STORE CMOS CHIPS IN NON-CONDUCTIVE PLASTIC "SNOW," PLASTIC BAGS OR PLASTIC TRAYS.

## CMOS OPERATING PRECAUTIONS

1. SOME CIRCUITS YOU BUILD WILL NOT USE ALL THE GATES IN SOME CHIPS. UNUSED GATES CAN ARBITRARILY SWITCH OFF AND ON. THIS CAN CAUSE EXCESSIVE POWER CONSUMPTION AND OTHER PROBLEMS. AVOID THESE HASSLES BY ALWAYS CONNECTING UNUSED GATE INPUTS (BUT NOT OUTPUTS) TO GROUND OR TO THE POSITIVE SUPPLY VOLTAGE.
2. THE VOLTAGE AT A CMOS GATE INPUT MUCH NOT EXCEED THE SUPPLY VOLTAGE.
3. NEVER INSERT OR REMOVE A CMOS CHIP INTO OR FROM THE BREADBOARD OF YOUR LEARNING LAB UNLESS THE POWER SWITCH IS OFF.

## WHEN A CIRCUIT DOESN'T WORK...

WHEN YOU APPLY POWER TO A LOGIC CIRCUIT, THREE THINGS CAN HAPPEN: THE CIRCUIT WORKS PROPERLY, SOMETHING ELSE HAPPENS OR NOTHING HAPPENS. SOMETIMES A CIRCUIT MIGHT APPEAR TO WORK EVEN IF YOU FORGOT TO CONNECT THE IC'S POWER SUPPLY PIN TO THE + VOLTAGE. THIS HAPPENS WHEN THE CHIP BORROWS POWER THROUGH ANOTHER PIN. IF THE CIRCUIT DOESN'T WORK PROPERLY, YOU WILL NEED TO TROUBLESHOOT IT. INDIVIDUAL LOGIC GATES ARE VERY SIMPLE, BUT SOME LOGIC CIRCUITS ARE PRETTY COMPLEX. TROUBLESHOOTING A CIRCUIT THAT LOOKS LIKE A BOWL OF SPAGHETTI CAN BE A LITTLE TRICKY. THE NEXT PAGE GIVES SOME HELPFUL TIPS JUST FOR CMOS CIRCUITS. YOUR LEARNING LAB'S WORKBOOK 1 HAS A SECTION ON TROUBLESHOOTING (SEE PAGE 18) THAT WILL ALSO HELP.

## TROUBLESHOOTING CMOS DIGITAL LOGIC CIRCUITS

NOTHING HAPPENS: PUSH THE POWER SWITCH OFF. ARE THE WIRES FROM THE CHIP TO THE POSITIVE VOLTAGE AND GROUND IN PLACE? ARE THEY CONNECTED TO THE CORRECT PINS ON THE IC? IS A PIN BENT UNDER A CHIP INSTEAD OF INSERTED INTO ITS HOLE? IS THE CORRECT IC INSTALLED? IS IT INSTALLED BACKWARDS? ARE YOUR LEARNING LAB BATTERIES FRESH?

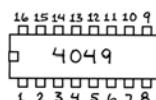
SOMETHING HAPPENS: PUSH THE POWER SWITCH OFF. IF THE CIRCUIT USES A POTENTIOMETER, ADJUST IT ACCORDING TO THE INSTRUCTIONS. PUSH THE POWER SWITCH ON. IF THE CIRCUIT STILL FAILS TO WORK PROPERLY, ONE OR MORE WIRES MAY BE MISSING OR INSTALLED INCORRECTLY. PUSH THE POWER SWITCH OFF AND CAREFULLY RECHECK YOUR WIRING.

THE BEST WAY TO TROUBLESHOOT IS TO COMPARE THE WIRES CONNECTED TO EACH IC PIN AGAINST THE CIRCUIT DIAGRAM. BEGIN AT PIN 1 AND THEN CHECK THE WIRES AT THE REST OF THE PINS. ALL CONNECTION WIRES SHOULD BE INSERTED SNUGLY INTO THE BREADBOARD. BE SURE ALL UNUSED INPUT PINS GO TO GROUND OR THE POSITIVE SUPPLY (+) VOLTAGE. WHEN ALL ELSE FAILS, TAKE APART THE CIRCUIT AND REBUILD IT. OFTEN THIS TAKES LESS TIME THAN TRYING TO FIND A MYSTERIOUS PROBLEM.

## BUILD A SIMPLE LOGIC PROBE

YOU CAN USE THIS SIMPLE PROBE TO TROUBLESHOOT YOUR LOGIC PROJECTS.

## PARTS YOU WILL NEED

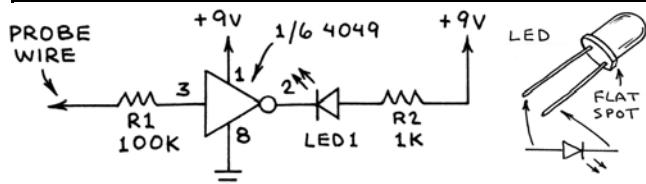


R1-10K (BRN-BLK-YEL)



LED 1-GREEN LED

## CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 5, 7, 9, 11 & 14).

GROUND (AND THE GROUND SYMBOL) IS THE - ROW ON THE BOTTOM OF THE BREADBOARD.

LEAVE THE LOGIC PROBE ON YOUR BREADBOARD TO HELP TROUBLESHOOT. OR JUST BUILD ONE ANYTIME IT'S NEEDED.

## 1. ASSEMBLE THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 ACROSS SLOT 5 (PIN 1 AT A25).
3.  CONNECT A21 TO V6 (+9 V) (WHT WIRE).
4.  CONNECT H21 TO GROUND (WHT WIRE).
5.  CONNECT E23 TO H23 (WHT WIRE).
6.  CONNECT G24 TO GROUND (RED WIRE).
7.  CONNECT H30 TO GROUND (WHT WIRE).
8.  CONNECT F29 TO GROUND (RED WIRE).
9.  CONNECT C27 TO F27 (WHT WIRE).
10.  INSERT R1 ACROSS C21 AND C17.
11.  INSERT R2 ACROSS A24 AND I24.
12.  INSERT LED ACROSS I22 (ANODE) AND B22 (CATHODE).
13.  INSERT PROBE WIRE AT C16 (BLU WIRE).

## 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. TOUCH THE PROBE WIRE TO A POSITIVE VOLTAGE GREATER THAN +3 VOLTS ON THE BREADBOARD. THE LED WILL GLOW (LOGICAL 1 OR HIGH). TOUCH THE PROBE TO GROUND, AND THE LED WILL SWITCH OFF (LOGICAL 0 OR LOW).

THE LOGIC PROBE IS POWERED BY +9 VOLTS SO IT CAN BE USED WITH ANY CIRCUIT ON THE BREADBOARD POWERED BY FROM 4.5 TO 9 VOLTS.

## BUILD A FANCY LOGIC PROBE

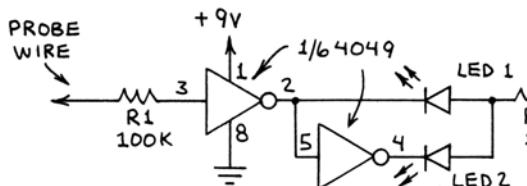
THIS LOGIC PROBE INDICATES HIGH WITH A GREEN LED AND LOW WITH A RED LED.

### PARTS YOU WILL NEED

YOU WILL NEED THE SIMPLE LOGIC PROBE ON PAGE 8 PLUS:



### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 7, 9, 11 & 14).

IN	GREEN	RED
L	OFF	ON
H	ON	OFF

### 1. MODIFY THE SIMPLE LOGIC PROBE ON PAGE 8

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHITE WIRE FROM E23 TO H23.
3.  CONNECT B23 TO E23 (WHT WIRE).
4.  INSERT LED 2 ACROSS I23 (ANODE) AND D23 (CATHODE).

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. TOUCH THE PROBE WIRE TO A POSITIVE VOLTAGE GREATER THAN +3 VOLTS ON THE BREADBOARD. ONLY THE GREEN LED WILL GLOW (LOGICAL 1 OR HIGH). TOUCH THE PROBE TO GROUND, AND ONLY THE RED LED WILL GLOW (LOGICAL 0 OR LOW).

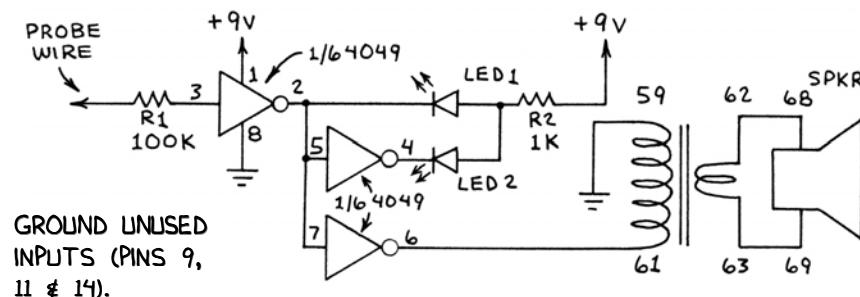
## BUILD AN AUDIO LOGIC PROBE

THIS LOGIC PROBE WILL LET YOU HEAR THE CLOCK SIGNALS PRODUCED BY SEQUENTIAL LOGIC CIRCUITS, SO LONG AS THE CLOCK OPERATES AT AN AUDIO FREQUENCY (ONE YOU CAN HEAR).

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFICATION OF THE LOGIC PROBE ABOVE. NO OTHER PARTS ARE NEEDED.

### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 9, 11 & 14).

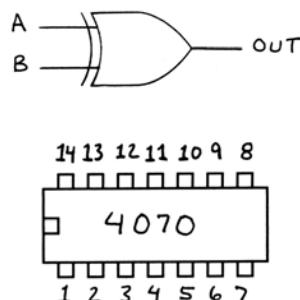
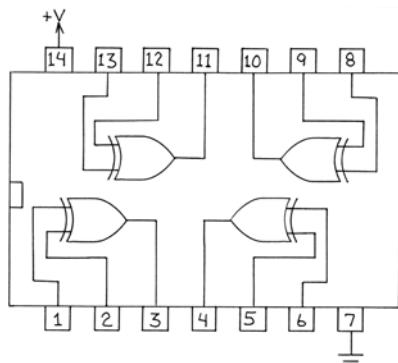
CHECK FOR ERRORS. PUSH THE POWER SWITCH ON. TOUCH THE PROBE WIRE TO THE CLOCK SIGNAL OF ANY SEQUENTIAL CIRCUIT IN THIS MANUAL. THE SPEAKER WILL EMIT A TONE. IT MAY EMIT 60-HZ POWER LINE BUZZ IF THE PROBE IS DISCONNECTED AND YOU TOUCH IT.

### 1. MODIFY THE FANCY LOGIC PROBE

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHITE WIRE FROM G24 TO GROUND.
3.  CONNECT B21 TO G21 (WHT WIRE).
4.  CONNECT SPRING 61 TO F24 (RED WIRE).
5.  CONNECT SPRING 59 TO GROUND (RED WIRE).
6.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
7.  CONNECT SPRINGS 63 AND 69 (RED WIRE).

## 4070 QUAD EXCLUSIVE OR GATE

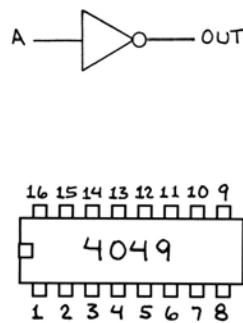
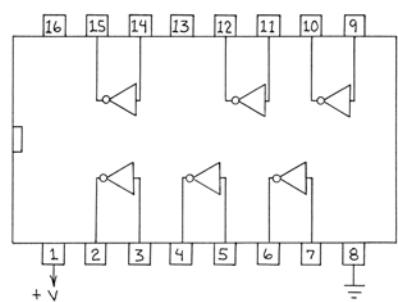
THE 4070 IS A CMOS LOGIC CHIP WITH FOUR INDEPENDENT EXCLUSIVE-OR GATES. USE TO COMPARE LOGIC SIGNALS AND PHASE DETECTION. FOLLOW WITH AN INVERTER TO MAKE AN EXCLUSIVE-NOR GATE. MAXIMUM SUPPLY AT PIN 14 MUST NOT EXCEED 15 VOLTS.



EX-OR GATE		
A	B	OUT
L	L	L
L	H	H
H	L	H
H	H	L

## 4049 HEX INVERTER

THE 4049 IS A CMOS LOGIC CHIP WITH SIX INDEPENDENT INVERTERS. USE FOR INTERFACING AND TO MAKE SIMPLE CLOCK PULSE GENERATORS AND OSCILLATORS. CONNECT TWO IN SERIES TO MAKE A NON-INVERTING BUFFER. MAXIMUM SUPPLY AT PIN 1 MUST NOT EXCEED 18 VOLTS.

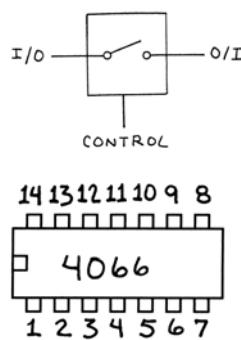
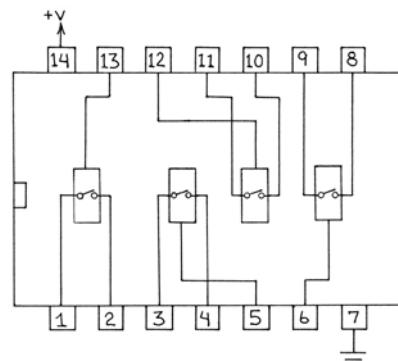


INVERTER	
A	OUT
L	H
H	L

NOTE THAT THE 4049 POSITIVE POWER SUPPLY PIN IS IN A NON-STANDARD LOCATION!

## 4066 QUAD ANALOG SWITCH

THE 4066 IS A CMOS LOGIC CHIP CONTAINING FOUR ANALOG SWITCHES THAT CAN BE SWITCHED ON OR OFF BY EXTERNAL LOGIC SIGNALS. VERY USEFUL FOR SWITCHING DIGITAL AND ANALOG SIGNALS. MAXIMUM SUPPLY AT PIN 14 MUST NOT EXCEED 18 VOLTS.

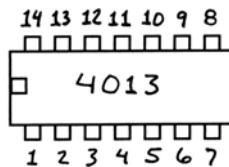
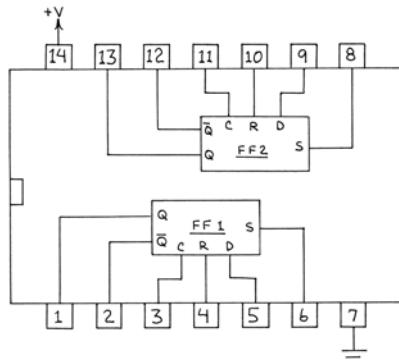


NAND GATE		
CONTROL	I/O	O/I
L	GATE OFF	
		GATE ON
H	I = 0	

I=INPUT AND O=OUTPUT

## 4013 DUAL D-TYPE FLIP-FLOP

THE 4013 IS A CMOS LOGIC CHIP WITH TWO D-TYPE (DATA) FLIP-FLOPS. A CLOCK PULSE WILL STORE THE DATA AT THE D INPUT. CONNECT CLOCK AND A Q OUTPUT TO MAKE A TOGGLE FLIP-FLOP FOR COUNTING. MAXIMUM SUPPLY AT PIN 14 MUST NOT EXCEED 18 VOLTS.



C-CLOCK  
D-DATA  
R-RESET  
S-SET

D-FLIP-FLOP					
C	D	R	S	Q1	Q2
/	0	0	0	0	1
/	1	0	0	1	0
\	X	0	0	NO CHANGE	
X	X	1	0	0	1
X	X	0	1	1	0
X	X	1	1	DISALLOWED	

/-RISING CLOCK PULSE  
\-FALLING CLOCK PULSE  
X-DOESN'T MATTER

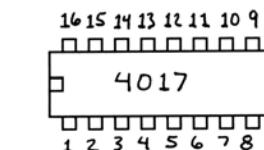
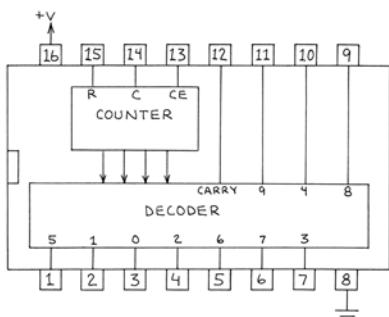
Q1-OUTPUT 1  
Q2-OUTPUT 2  
(IF Q1=1 THEN Q2=0.)

THE FIRST COLUMN IN THE TRUTH TABLE IS FOR THE CLOCK INPUT. A FORWARD SLASH (/) SYMBOLIZES THE RISING EDGE OF A CLOCK PULSE. A BACKWARDS SLASH (\) SYMBOLIZES THE FALLING EDGE OF A PULSE.

THE 4013 RESPONDS ONLY TO THE RISING EDGE OF A PULSE. NOTICE THAT BOTH THE R AND S INPUTS CAN BOTH BE 0 (LOW) BUT NOT 1 (HIGH-DISALLOWED).

## 4017 DECADE COUNTER/DIVIDER

THIS REALLY NEAT CHIP CONTAINS A COUNTER AND A DECODER CIRCUIT THAT ACTIVATES A SINGLE OUTPUT PIN FOR EACH COUNT FROM 0 TO 9. USE TO MAKE ALL KINDS OF TIMERS, LED SEQUENCERS AND CONTROLLERS. MAXIMUM SUPPLY AT PIN 1 MUST NOT EXCEED 18 VOLTS.



THE 4017 COUNTS WITH 5 D-TYPE FLIP-FLOPS.  
DECODING AND CONTROL IS BY 16 INVERTERS AND 15 GATES.

PIN 15 (R OR RESET)	L	OK TO COUNT
H	CLEAR TO 0	
PIN 14 (C OR CLOCK)	L	NO COUNT
	H	COUNT
PIN 13 (CE OR CLOCK ENABLE)	L	OK TO COUNT
	H	STOP

PIN 13 (CE) CONTROLS THE CLOCK. WHEN LOW, THE CLOCK IS ENABLED AND THE COUNTER ADVANCES ONE COUNT FOR EACH CLOCK PULSE. WHEN HIGH, THE CLOCK INPUT IS INHIBITED, AND THE COUNTER DOES NOTHING EVEN WHEN CLOCK PULSES ARRIVE.  
PIN 14 IS THE CLOCK INPUT. THE RISING SIDE OF EACH CLOCK PULSE TRIGGERS ONE COUNT. THE CLOCK PULSES MUST BE "CLEAN." IF THEY ARE "NOISY" THE COUNTER MAY ADVANCE TWO OR MORE TIMES DURING EACH CLOCK PULSE.

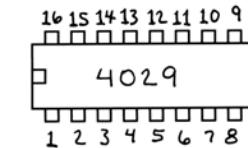
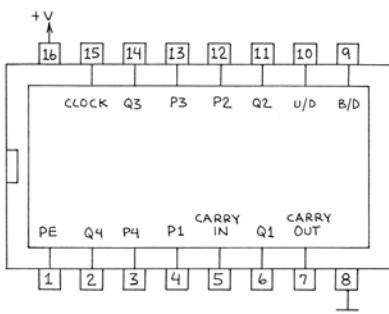
12

PIN 15 IS THE RESET PIN. IT IS NORMALLY LOW. WHEN MADE HIGH, THE COUNTER IS CLEARED OR RESET TO 0.

PINS 1-7 AND 9-11 ARE THE DECODED OUTPUT PINS. THE ACTIVE COUNT PIN GOES HIGH AND ALL OTHERS REMAIN LOW. CARRY OUTPUT PIN 12 IS FOR THE CLOCK INPUT OF AN ADDITIONAL COUNTER OR FOR NOTIFYING AN EXTERNAL CIRCUIT THAT THE COUNT IS COMPLETE.

## 4029 DECADE UP-DOWN COUNTER

THE 4029 IS A HIGHLY VERSATILE COUNTER THAT CAN COUNT UP OR DOWN FROM 0 TO 9 (BINARY-CODED DECIMAL) OR 0 TO 15 (BINARY). THE COUNT CAN BE FORCED TO ANY DESIRED STATE USING FOUR PRESET INPUTS. MAXIMUM SUPPLY AT PIN 16 MUST NOT EXCEED 18 VOLTS.



THE 4029 COUNTS WITH FOUR FLIP-FLOPS. SOME 50 GATES PROVIDE VARIOUS CONTROL FUNCTIONS.

PIN 15 (CLOCK)	L	NO COUNT
	/	COUNT
PIN 10 (U/D OR UP/DOWN)	L	COUNT DOWN
	H	COUNT UP
PIN 9 (B/D OR BINARY/BCD)	L	COUNT 0 TO 9
	H	COUNT 0 TO 15

PIN 15 IS THE CLOCK INPUT, TO WHICH UP TO AROUND 5 MILLION PULSE PER SECOND CAN BE APPLIED.

PIN 10 CONTROLS WHETHER THE CHIP COUNTS UP OR DOWN.

PIN 9 CONTROLS WHETHER THE CHIP COUNTS FROM 0 TO 9 (BINARY-CODED DECIMAL OR BCD) OR 0 TO 15 (TRUE BINARY) BEFORE RECYCLING.

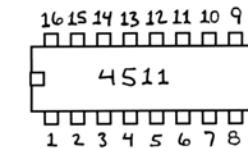
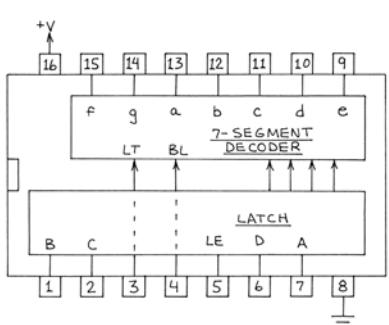
PIN 1 (PE OR PRESET ENABLE) CONTROLS THE PRESET INPUTS. NORMALLY PE IS LOW. WHEN

HIGH, THE COUNTER JUMPS TO THE OUTPUT STATE DETERMINED BY THE FOUR PRESET INPUTS.

THE 4029 DOES NOT HAVE A RESET PIN. THE COUNT IS EASILY RESET TO 0000 BY MAKING ALL FOUR PRESET INPUTS LOW AND THEN MAKING THE PE INPUT HIGH TO LOAD 0000 INTO THE COUNTER. USE THE 4511 DECODER TO CONVERT THE COUNT FROM THE 4029 INTO DECIMAL DIGITS ON THE LED DISPLAY.

## 4511 7-SEGMENT DISPLAY DECODER-DRIVER

THIS VITAL CHIP PROVIDES THE INTERFACE BETWEEN THE BINARY WORLD OF DIGITAL LOGIC CIRCUITS AND THE DECIMAL WORLD. DATA ARE STORED IN A LATCH. THE READOUT SIGNALS CAN BE SWITCHED OFF OR ON. SUPPLY VOLTAGE AT PIN 16 MUST NOT EXCEED 18 VOLTS.



THE 4511 INCLUDES SOME 56 FLIP-FLOPS, LOGIC GATES AND INVERTERS ON A SINGLE CHIP.

PIN 3 (LT OR LAMP TEST)	L	ALL LEDs ON
	H	NORMAL USE
PIN 4 (BL OR BLANKING)	L	ALL LEDs OFF
	H	NORMAL USE
PIN 5 (LE OR LATCH ENABLE)	L	CURRENT DATA
	H	SAVED DATA

BINARY-CODED DECIMAL (BCD) DATA TO BE DECODED AND DISPLAYED ARE APPLIED TO PINS 7, 1, 2 AND 6. THE DATA ARE DECODED INTO A PATTERN OF SEVEN LOGIC LEVELS THAT ARE APPLIED VIA OUTPUT PINS 9 TO 15 AND TO A SEVEN-SEGMENT READOUT DEVICE SUCH AS AN LED DISPLAY.

PIN 3 ALLOWS THE DISPLAY TO BE TESTED. WHEN LOW, ALL THE OUTPUT PINS ARE SWITCHED ON.

PIN 4 PERMITS THE READOUT TO BE SWITCHED OFF ENTIRELY (WHEN LOW) OR DIMMED (BY A SERIES OF PULSES).

PIN 5 PERMITS DATA TO BE SAVED AND DISPLAYED (WHEN HIGH). OTHERWISE THE LATEST DATA AT THE INPUTS ARE DISPLAYED (WHEN LOW).

CAUTION: SHORTING OUTPUT PINS MAY DAMAGE THE 4511. ALWAYS CHECK YOUR WIRING.

## USE SWITCHES TO MAKE A SIMPLE AND GATE

YOU WILL CONNECT TWO SWITCHES IN SERIES TO MAKE THE SIMPLEST POSSIBLE AND GATE. AN LED WILL INDICATE THE STATUS OF THE GATE. THE OUTPUT LED WILL GLOW ONLY WHEN S1 AND S2 ARE CLOSED AT THE SAME TIME. OTHERWISE THE LED STAYS OFF.

### PARTS YOU WILL NEED

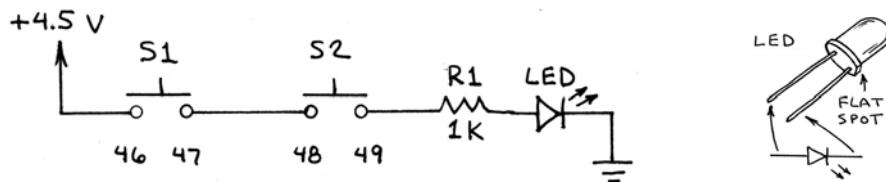


R1-1K (BRN-BLK-RED)



RED LED

### CIRCUIT DIAGRAM



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT R1 ACROSS K13 AND K18.
3.  INSERT LED BETWEEN K20 (ANODE) AND K21 (CATHODE).
4.  CONNECT K25 TO GROUND (WHT WIRE).
5.  CONNECT K11 TO SPRING 49 (RED WIRE).
6.  CONNECT SPRINGS 47 AND 48 (WHT WIRE).
7.  CONNECT SPRING 46 TO V3 (4.5 VOLTS) (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH TO ON. THE LED SHOULD BE OFF. WHEN YOU PRESS EITHER S1 OR S2, THE LED SHOULD STAY OFF. NOW PRESS BOTH S1 AND S2 AT THE SAME TIME. THE LED SHOULD GLOW. SINCE S1 AND S2 MUST BE CLOSED TO SWITCH THE LED ON, THIS CIRCUIT IS AN AND GATE.

### THE AND GATE TRUTH TABLE

RECALL THAT THE OPERATION OF A LOGIC GATE IS SUMMARIZED IN A SIMPLE TABLE CALLED A TRUTH TABLE. HERE'S THE ON-OFF TRUTH TABLE FOR YOUR AND GATE:

AND GATE		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

A SWITCH IS EITHER OFF OR ON. SO SWITCHES CAN REPRESENT THE 2 DIGITS (0 AND 1) IN THE BINARY NUMBER SYSTEM. HERE'S OUR TRUTH TABLE WHEN OFF = 0 AND ON = 1:

AND GATE		
S1	S2	LED
0	0	0
0	1	0
1	0	0
1	1	1

### MORE ABOUT BINARY NUMBERS

YOU LEARNED THE BINARY EQUIVALENTS OF THE FIRST 16 DECIMAL DIGITS IN THE PREVIOUS SECTION ON "GETTING STARTED WITH DIGITAL LOGIC." TO HELP YOU LEARN THEM, HERE THEY ARE AGAIN:

(0) 0000	(4) 0100	(8) 1000	(12) 1100
(1) 0001	(5) 0101	(9) 1001	(13) 1101
(2) 0010	(6) 0110	(10) 1010	(14) 1110
(3) 0011	(7) 0111	(11) 1011	(15) 1111

## USE SWITCHES TO MAKE A SIMPLE OR GATE

NOW YOU WILL CONNECT TWO SWITCHES IN PARALLEL TO MAKE THE SIMPLEST POSSIBLE OR GATE. AN LED WILL INDICATE THE STATUS OF THE GATE. THE LED WILL GLOW ONLY WHEN S1 OR S2, OR S1 AND S2, ARE CLOSED AT THE SAME TIME. OTHERWISE THE LED STAYS OFF.

### PARTS YOU WILL NEED

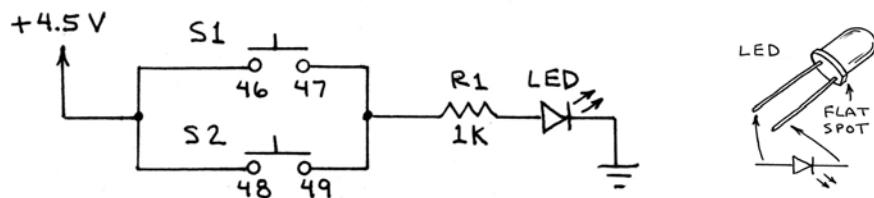


R1-1K (BRN-BLK-RED)



RED LED

### CIRCUIT DIAGRAM



#### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT R1 ACROSS K13 AND K18.
3.  INSERT LED BETWEEN K20 (ANODE) AND K21 (CATHODE).
4.  CONNECT K25 TO GROUND (WHT WIRE).
5.  CONNECT SPRINGS 46 AND 48 (WHT WIRE).
6.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
7.  CONNECT SPRING 46 TO V3 (RED WIRE).
8.  CONNECT SPRING 47 TO K11 (RED WIRE).

#### 2. TEST THE CIRCUIT

INSPECT THE CIRCUIT. IF EVERYTHING IS CORRECT, CLOSE THE POWER SWITCH. THE LED SHOULD BE OFF. WHEN YOU PRESS EITHER S1 OR S2, THE LED SHOULD GLOW. IT SHOULD ALSO GLOW WHEN YOU PRESS S1 AND S2 AT THE SAME TIME. SINCE THE LED GLOWS WHEN S1 OR S2 IS CLOSED, THIS CIRCUIT IS CALLED AN OR GATE.

### THE OR GATE TRUTH TABLE

HERE'S THE ON-OFF TRUTH TABLE FOR YOUR SWITCH OR GATE:

OR GATE		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON

HERE'S THE BINARY VERSION OF THE OR GATE TRUTH TABLE (OFF = 0 AND ON = 1):

OR GATE		
S1	S2	LED
0	0	0
0	1	1
1	0	1
1	1	1

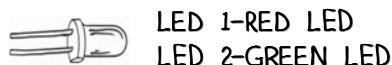
### GOING FURTHER: COMBINING GATES

NOW THAT YOU'VE BUILT THE BASIC GATES, IT'S TIME TO GLUE THEM TOGETHER. FIRST CLEAR THE BREADBOARD. THEN REBUILD THE AND GATE ON THE FACING PAGE. DO NOT CONNECT S2 TO R1. INSTEAD, CONNECT S3 AND S4 IN PARALLEL BETWEEN S2 AND R1 USING WHITE WIRES. YOU NOW HAVE AN AND-OR GATE. ON A SEPARATE SHEET OF PAPER, MAKE THE TRUTH TABLE FOR THIS GATE. (HINT: THERE ARE 16 POSSIBLE ON-OFF COMBINATIONS FOR THE FOUR SWITCHES.)

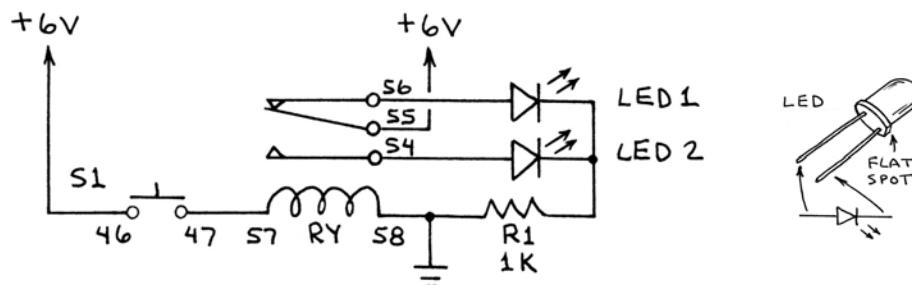
## USE A RELAY TO MAKE AN INVERTER (A NOT GATE)

IN THE ENGLISH LANGUAGE, THE WORD NO IS AT LEAST AS IMPORTANT AS THE WORD YES, THE SAME APPLIES TO THE BINARY LANGUAGE OF DIGITAL LOGIC. YOU WILL USE A RELAY TO MAKE AN INVERTER THAT CHANGES YES TO NO AND NO TO YES.

### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT R1 BETWEEN P23 AND GROUND.
3.  INSERT LED 1 BETWEEN M24 (ANODE) AND P24 (CATHODE).
4.  INSERT LED 2 BETWEEN P26 (ANODE) AND P25 (CATHODE).
5.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
6.  CONNECT SPRINGS 47 AND 57 (RED WIRE).
7.  CONNECT SPRING 58 TO GROUND (RED WIRE).
8.  CONNECT SPRING 55 TO V4 (+6V) (BLU WIRE).
9.  CONNECT SPRING 54 TO P30 (BLU WIRE).
10.  CONNECT SPRING 56 TO M21 (BLU WIRE).

### 2. TEST THE CIRCUIT

INSPECT YOUR WIRING TO MAKE SURE ALL CONNECTIONS ARE CORRECT. THEN PUSH THE POWER SWITCH TO ON. THE RED LED (LED 1) SHOULD GLOW. PRESS S1, AND THE RED LED WILL TURN OFF AND THE GREEN LED (LED 2) WILL GLOW.

### HOW THE CIRCUIT WORKS

YES GATE	
S1	LED 2
OFF	OFF
ON	ON

LED 2 IS THE OUTPUT FOR THE YES FUNCTION.  
LED 2 FOLLOWS THE ON-OFF STATUS OF INPUT SWITCH S1.

INVERTER	
S1	LED 1
OFF	ON
ON	OFF

LED 1 IS THE OUTPUT FOR THE NOT FUNCTION.  
LED 1 REVERSES OR INVERTS THE STATUS OF INPUT SWITCH S1.

YES-NOT GATE		
S1	LED 2	LED 1
OFF	OFF	ON
ON	ON	OFF

THIS SUMMARIZES THE YES AND NOT OPERATION OF THE CIRCUIT. THE NOT FUNCTION IS THE SAME AS A LOGIC INVERTER.

## USE SWITCHES AND A RELAY TO MAKE 4 KINDS OF LOGIC GATES

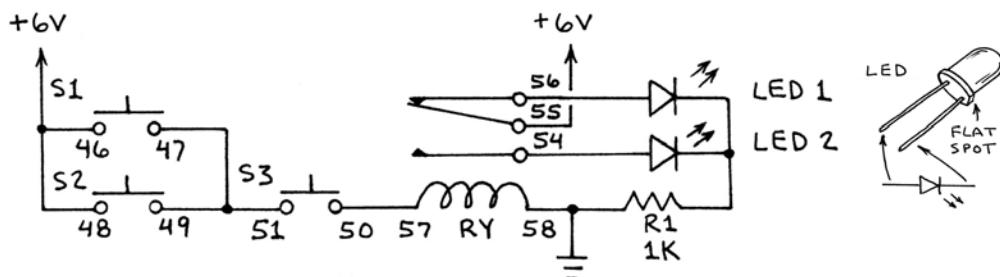
THE "NOT" GATE, WHICH IS ANOTHER NAME FOR THE INVERTER, PERMITS US TO MAKE NEW KINDS OF VERY IMPORTANT LOGIC GATES. YOU WILL ADD A RELAY TO AN AND GATE, AND AN OR GATE, TO MAKE A NOT-AND (NAND) GATE AND A NOT-OR (NOR) GATE.

### PARTS YOU WILL NEED

 R1-1K (BRN-BLK-RED)

 LED 1-RED LED  
LED 2-GREEN LED

### CIRCUIT DIAGRAM



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT R1 BETWEEN P23 AND GROUND.
3.  INSERT LED 1 BETWEEN M24 (ANODE) AND P24 (CATHODE).
4.  INSERT LED 2 BETWEEN P26 (ANODE) AND P25 (CATHODE).
5.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
6.  CONNECT SPRING 58 TO GROUND (RED WIRE).
7.  CONNECT SPRINGS 46 AND 48 (WHT WIRE).
8.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
9.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
10.  CONNECT SPRINGS 50 AND 57 (RED WIRE).
11.  CONNECT SPRING 55 TO V4 (+6V) (BLU WIRE).
12.  CONNECT SPRING 54 TO P30 (BLU WIRE).
13.  CONNECT SPRING 56 TO M21 (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH ON. LED 1 WILL GLOW RED. NOW TEST THE FOUR DIFFERENT LOGIC GATES USING THE TRUTH TABLES BELOW. REMEMBER THAT THE RED LED (LED 1) IS THE OUTPUT FOR THE NAND AND NOR GATES. THE GREEN LED (LED 2) IS THE OUTPUT FOR THE AND AND OR GATES. WHEN YOU TEST THE OR AND NOR GATES, CONNECT SPRINGS 50 AND 51 (WHITE WIRE) OR KEEP S3 PRESSED DOWN. HISTORICAL NOTE: THIS VERY SIMPLE CIRCUIT DEMONSTRATES A RELAY LOGIC BUILDING BLOCK LIKE THAT USED TO BUILD THE MARK 1, ONE OF THE FIRST ELECTRONIC DIGITAL COMPUTERS.

AND GATE		
S2	S3	LED 2
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

NAND GATE		
S2	S3	LED 1
OFF	OFF	ON
OFF	ON	ON
ON	OFF	ON
ON	ON	OFF

OR GATE (S3 ON)		
S1	S2	LED 2
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON

NOR GATE (S3 ON)		
S1	S2	LED 1
OFF	OFF	ON
OFF	ON	OFF
ON	OFF	OFF
ON	ON	OFF

## USE A TRANSISTOR TO MAKE A YES GATE (BUFFER)

IN ALL BUT THE SIMPLEST LOGIC CIRCUITS, TRANSISTOR SWITCHES ARE MUCH MORE EFFICIENT THAN MECHANICAL SWITCHES. YES GATES, WHICH ARE ALSO CALLED BUFFERS, ALLOW LOW-POWER GATES TO DRIVE LEDs OR GATES THAT REQUIRE EXTRA CURRENT. YOU WILL BUILD A SIMPLE TRANSISTOR YES BUFFER THAT DEMONSTRATES THESE POINTS.

### PARTS YOU WILL NEED



R1-10K (BRN-BLK-ORG)  
R2-1K (BRN-BLK-RED)

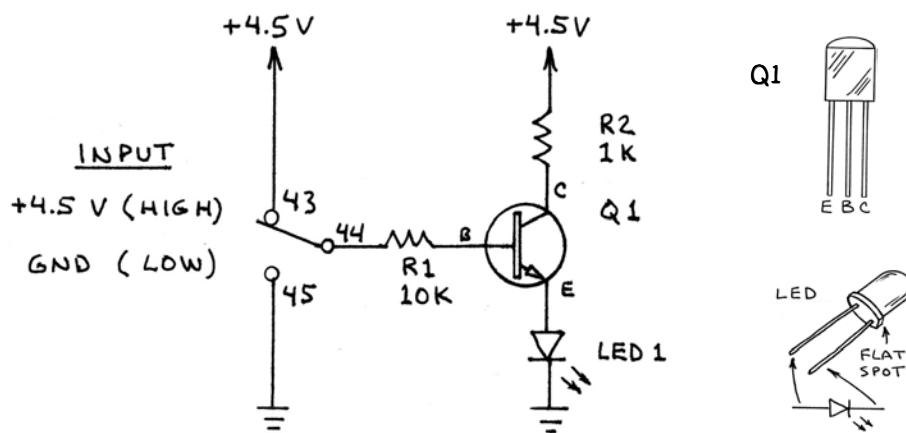


Q1-NPN TRANSISTOR  
(9014)



LED 1-GREEN LED

### CIRCUIT DIAGRAM



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT Q1 AT T5 (E), R5 (B) AND P5 (C).
3.  INSERT LED 1 BETWEEN T1 (ANODE) AND GROUND (CATHODE).
4.  INSERT R1 BETWEEN N1 AND R1.
5.  INSERT R2 BETWEEN L3 AND P3.
6.  CONNECT L1 TO V3 (+4.5V) (RED WIRE).
7.  CONNECT SPRING 44 TO N5 (RED WIRE).
8.  CONNECT SPRING 43 TO (+4.5V) V3 (BLU WIRE).
9.  CONNECT SPRING 45 TO GROUND (RED WIRE).

### 2. TEST THE CIRCUIT

INSPECT THE CIRCUIT. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH ON. THEN PUSH THE DPDT SWITCH UP (HIGH OR +4.5 V). THE LED WILL GLOW. NOW PUSH THE SWITCH DOWN (LOW OR GROUND). THE LED WILL SWITCH OFF.

### HOW THE YES CIRCUIT WORKS

THIS CIRCUIT IS A "YES GATE," OR BUFFER, SINCE THE OUTPUT FOLLOWS THE INPUT. THE TRANSISTOR IS OFF WHEN THE DPDT SWITCH IS DOWN AND R1 IS PULLED LOW (GROUNDED). WHEN THE SWITCH IS UP, A SMALL CURRENT FLOWS THROUGH R1 AND THE BASE-EMITTER JUNCTION OF Q1. THIS SWITCHES Q1 ON. THE LED THEN RECEIVES CURRENT THROUGH Q1 AND R2 AND GLOWS. THE TRUTH TABLES SHOW THE CIRCUIT'S OPERATION.

YES GATE	
INPUT	LED
OFF	OFF
ON	ON

BUFFER	
INPUT	LED
LOW	LOW
HIGH	HIGH

HIGH (LOGICAL 1) MEANS A VOLTAGE IS PRESENT. LOW (LOGICAL 0) MEANS GROUND.

## USE A TRANSISTOR TO MAKE A NOT GATE

THE INVERTER, OR "NOT" GATE, IS THE OPPOSITE OF THE BUFFER, OR "YES" GATE. THE LOGIC STATUS AT THE OUTPUT OF THE NOT GATE IS ALWAYS OPPOSITE THAT AT THE INPUT OF THE GATE. INVERTERS ARE ESSENTIAL FOR TRANSFORMING AND GATES INTO NAND GATES AND OR GATES INTO NOR GATES. YOU WILL BUILD THE NOT GATE NEXT TO THE YES GATE SO YOU CAN COMPARE THEIR OPERATION.

## PARTS YOU WILL NEED



R1-10K (BRN-BLK-ORG)  
R2-1K (BRN-BLK-RED)

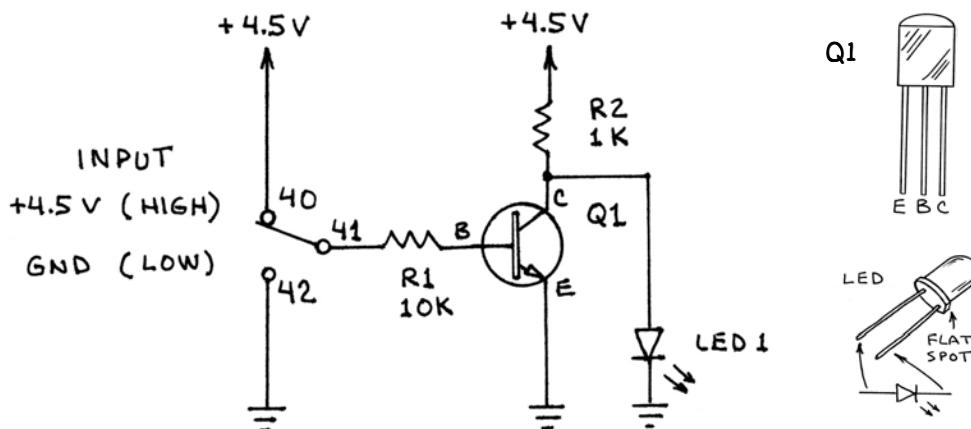


Q1-NPN TRANSISTOR  
(9014)



LED 1-RED LED

## CIRCUIT DIAGRAM



## 1. BUILD THE CIRCUIT

1.  LEAVE THE YES GATE ON THE BOARD.
2.  PUSH THE POWER SWITCH TO OFF.
3.  INSERT Q1 AT T8 (E), R8 (B) AND P8 (C).
4.  INSERT LED 1 BETWEEN P10 (ANODE) AND GROUND (CATHODE).
5.  INSERT R1 BETWEEN N9 AND R9.
6.  INSERT R2 BETWEEN L6 AND P6.
7.  CONNECT L10 TO V3 (+4.5V) (RED WIRE).
8.  CONNECT T6 TO GROUND (WHT WIRE).
9.  CONNECT SPRINGS 42 AND 45 (WHT WIRE).
10.  CONNECT SPRINGS 40 AND 43 (WHT WIRE).
11.  CONNECT SPRING 41 TO N8 (RED WIRE).

## 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH TO ON. THEN PUSH THE DPDT SWITCH DOWN (LOW OR GROUND). THE RED LED WILL GLOW. NOW PUSH THE SWITCH UP (HIGH OR +4.5 VOLTS). THE RED LED WILL SWITCH OFF. IF YOU LEFT THE YES GATE IN PLACE, THE RED LED IS OFF WHEN THE GREEN LED IS ON AND VICE VERSA.

## HOW THE NOT CIRCUIT WORKS

THIS CIRCUIT IS A "NOT GATE" SINCE THE OUTPUT IS THE OPPOSITE, OR INVERSE, OF THE INPUT. THAT'S WHY THE NOT GATE IS KNOWN AS AN INVERTER. WHEN Q1 IS OFF (BASE CONNECTED TO GROUND WHEN THE DPDT SWITCH IS PUSHED DOWN), Q1 IS OFF AND CURRENT FLOWS THROUGH R2 AND THE LED. WHEN Q1 IS ON (BASE CONNECTED TO +4.5 VOLTS WHEN THE DPDT SWITCH IS PUSHED UP), MOST OF THE CURRENT FLOWS THROUGH Q1 INSTEAD OF THE LED.

NOT GATE	
INPUT	LED
OFF	ON
ON	OFF

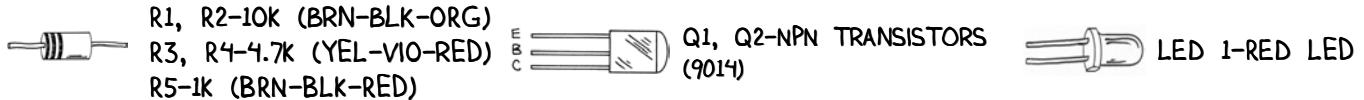
INVERTER	
INPUT	LED
LOW	HIGH
HIGH	LOW

INTEGRATED CIRCUIT NOT GATES ARE CALLED INVERTERS.

## USE TRANSISTORS TO MAKE AN AND GATE

CONNECT TWO TRANSISTOR YES GATES IN SERIES AND YOU HAVE AN AND GATE. IN THIS PROJECT YOU WILL FIRST BUILD AN AND GATE. THEN YOU WILL TEST THE GATE TO SEE IF ITS OPERATION MATCHES THE AND GATE TRUTH TABLE.

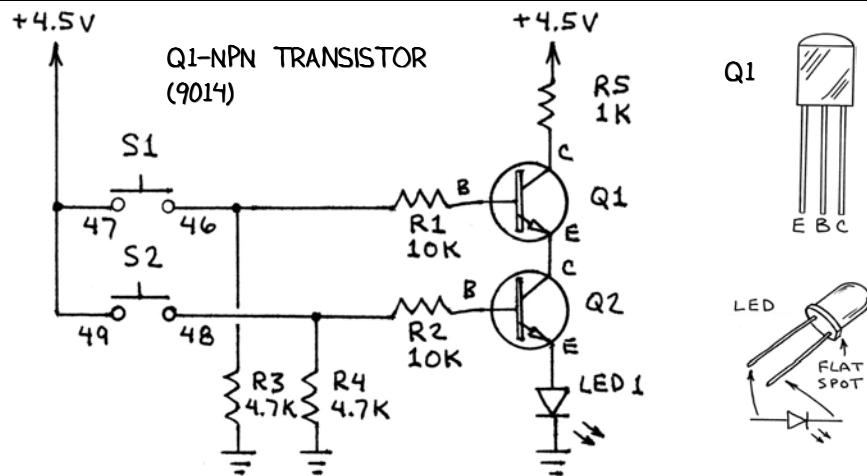
### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM

AND GATE		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

IN A SIMPLE GATE LIKE THIS ONE, THE LED MAY GLOW VERY DIMLY WHEN 'OFF.'



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT Q1 AT M23 (E), K23 (B) AND J23 (C).
3.  INSERT Q2 AT T23 (E), R23 (B) AND P23 (C).
4.  INSERT LED 1 BETWEEN T25 (ANODE) AND GROUND (CATHODE).
5.  INSERT R1 BETWEEN K20 AND K21.
6.  INSERT R2 BETWEEN R20 AND R21.
7.  INSERT R3 BETWEEN K18 AND GROUND.
8.  INSERT R4 BETWEEN R18 AND GROUND.
9.  INSERT R5 BETWEEN I24 AND A24.
10.  CONNECT M25 TO P25 (WHT WIRE).
11.  CONNECT A21 TO V3 (+4.5V) (WHT WIRE).
12.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
13.  CONNECT SPRING 46 TO K16 (RED WIRE).
14.  CONNECT SPRING 48 AND R16 (RED WIRE).
15.  CONNECT SPRING 47 TO (+4.5V) V3 (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. BE SURE NO EXPOSED RESISTOR WIRES ARE TOUCHING ONE ANOTHER. PUSH THE POWER SWITCH ON. NOW FIND OUT IF THE CIRCUIT'S LED OUTPUT MATCHES THE TRUTH TABLE. THE LED SHOULD GLOW ONLY WHEN YOU PRESS BOTH S1 AND S2. OTHERWISE THE LED WILL BE OFF.

### HOW THE AND GATE WORKS

TRANSISTORS Q1 AND Q2 ARE CONNECTED IN SERIES LIKE THE TWO SWITCHES IN A MECHANICAL SWITCH AND GATE. ONLY WHEN BOTH Q1 AND Q2 ARE SWITCHED ON DOES THE LED RECEIVE CURRENT AND GLOW. WE USED THE DPDT SWITCH TO CONTROL THE INPUTS OF THE TRANSISTOR YES AND NOT GATES. FOR THIS CIRCUIT WE NEED SEPARATE INPUT SWITCHES. SO R3 AND R4 ARE ADDED TO PULL THE BASES OF Q1 AND Q2 DOWN TO GROUND (LOW OR 0). CLOSING S1 OR S2 APPLIES CURRENT TO THE BASES OF Q1 AND Q2, THUS SWITCHING THEM ON (HIGH OR 1).

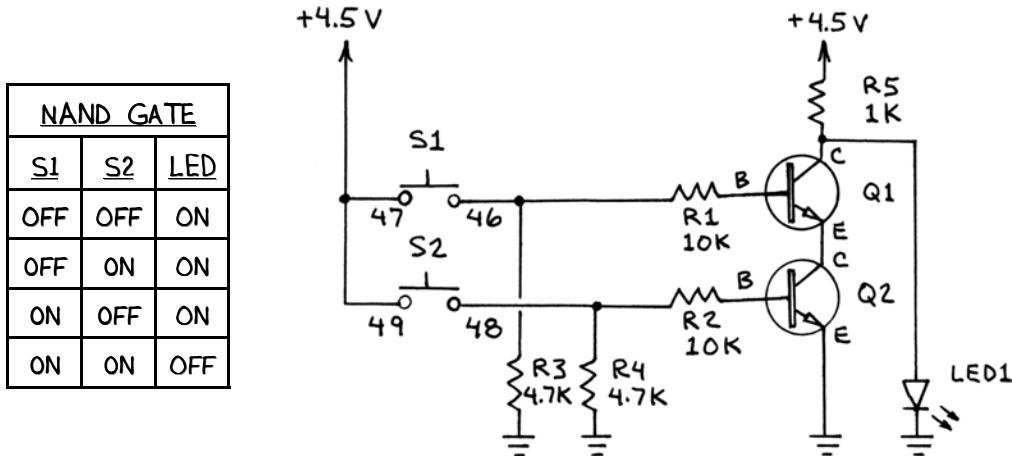
## USE TRANSISTORS TO MAKE A NAND GATE

A 2-TRANSISTOR AND GATE CAN ALSO BE USED AS A NAND GATE. YOU WILL MODIFY AN AND GATE TO FUNCTION AS A NAND GATE. THEN YOU WILL COMPARE THE OPERATION OF THE GATE WITH THE NAND GATE TRUTH TABLE.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE 2-TRANSISTOR AND GATE ON PAGE 20. NO ADDITIONAL PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



### 1. MODIFY THE AND GATE CIRCUIT ON PAGE 20

MODIFY THE AND GATE CIRCUIT ON PAGE 20 BY FOLLOWING THESE STEPS:

1.  PUSH THE POWER SWITCH TO OFF.
2.  MOVE LED 1'S ANODE FROM T25 TO T26.
3.  CONNECT T28 TO I25 (WHT WIRE).
4.  CONNECT T25 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

BE SURE ALL THE CONNECTIONS ARE CORRECT AND NO EXPOSED RESISTOR WIRES ARE TOUCHING ONE ANOTHER. THEN PUSH THE POWER SWITCH TO ON. THE LED WILL GLOW. NOW FIND OUT IF THE CIRCUIT'S LED OUTPUT MATCHES THE TRUTH TABLE. THE LED SHOULD TURN OFF ONLY WHEN YOU PRESS BOTH S1 AND S2. OTHERWISE THE LED WILL BE ON.

### HOW THE NAND GATE WORKS

THIS CIRCUIT SHOWS HOW TO TRICK AN AND GATE INTO BECOMING A NAND GATE SIMPLY BY MOVING THE OUTPUT LED. THIS IS THE SAME METHOD USED TO MAKE THE ONE-TRANSISTOR NOT GATE WE BUILT EARLIER. CURRENT FLOWS THROUGH Q1 AND Q2 ONLY WHEN BOTH Q1 AND Q2 ARE SWITCHED ON. WHEN THIS HAPPENS, MUCH MORE CURRENT FLOWS THROUGH Q1 AND Q2 THAN LED 1, AND THE LED SWITCHES OFF. WHEN Q1 AND Q2 OR EITHER Q1 OR Q2 ARE OFF, CURRENT FLOWS DIRECTLY THROUGH R5 AND LED 1, AND THE LED GLOWS.

### A REMINDER ABOUT LOGICAL 0 (LOW OR OFF) AND LOGICAL 1 (HIGH OR ON)

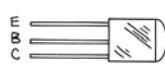
THE TRUTH TABLES FOR THE TRANSISTOR AND GATE AND NAND GATE USE OFF AND ON FOR THE TWO POSSIBLE LOGIC STATES. REMEMBER THAT OFF IS THE SAME AS LOGICAL 0 (LOW) AND ON IS THE SAME AS LOGICAL 1 (HIGH).

## USE TRANSISTORS TO MAKE AN OR GATE

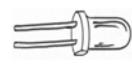
CONNECT TWO TRANSISTOR BUFFERS OR YES GATES IN PARALLEL AND YOU GET AN OR GATE. YOU WILL BUILD AN OR GATE. THEN YOU WILL TEST THE GATE TO SEE IF ITS OPERATION MATCHES THE OR GATE TRUTH TABLE.

## PARTS YOU WILL NEED

R1, R2-10K (BRN-BLK-ORG)  
R3, R4-4.7K (YEL-VIO-RED)  
R5-1K (BRN-BLK-RED)



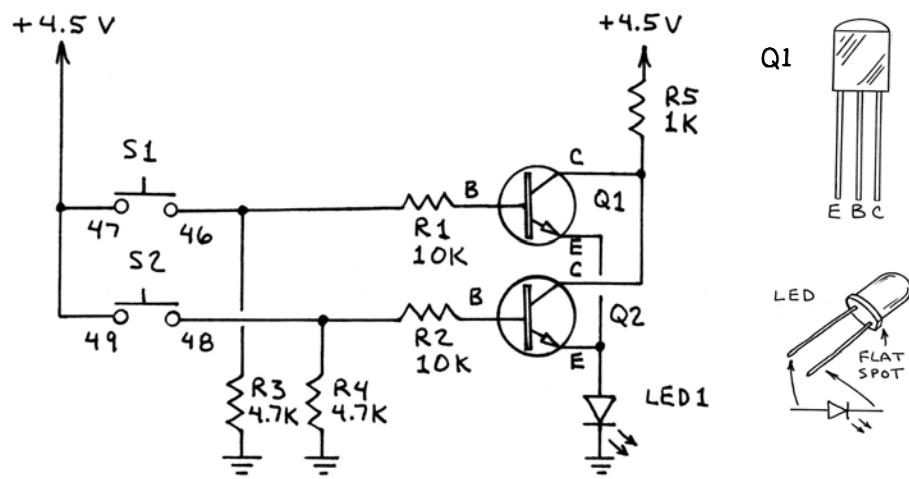
Q1, Q2  
NPN TRANSISTORS  
(9014)



LED 1-RED LED

## CIRCUIT DIAGRAM

OR GATE		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON



## 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT Q1 AT M23 (E), K23 (B) AND J23 (C).
3.  INSERT Q2 AT T23 (E), R23 (B) AND P23 (C).
4.  INSERT LED 1 BETWEEN T21 (ANODE) AND GROUND (CATHODE).
5.  INSERT R1 BETWEEN K20 AND K21.
6.  INSERT R2 BETWEEN R20 AND R21.
7.  INSERT R3 BETWEEN K18 AND GROUND.
8.  INSERT R4 BETWEEN R18 AND GROUND.
9.  INSERT R5 BETWEEN I24 AND A24.
10.  CONNECT M25 TO T25 (WHT WIRE).
11.  CONNECT I25 TO P25 (WHT WIRE).
12.  CONNECT A21 TO V3 (+4.5V) (WHT WIRE).
13.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
14.  CONNECT SPRING 46 TO K16 (RED WIRE).
15.  CONNECT SPRING 48 AND R16 (RED WIRE).
16.  CONNECT SPRING 47 TO V3 (+4.5V) (BLU WIRE).

## 2. TEST THE CIRCUIT

CAREFULLY CHECK YOUR WIRING. THEN PUSH THE POWER SWITCH ON. NOW TEST THE CIRCUIT TO SEE IF THE LED OUTPUT MATCHES THE TRUTH TABLE. PRESSING S1 OR S2, OR BOTH S1 AND S2, WILL SWITCH THE GATE ON AND LIGHT THE LED. OTHERWISE THE LED WILL BE OFF.

## HOW THE OR GATE WORKS

TRANSISTORS Q1 AND Q2 ARE CONNECTED IN PARALLEL LIKE THE TWO SWITCHES IN A SWITCH OR GATE. WHEN EITHER OR BOTH Q1 AND Q2 ARE SWITCHED ON, THE LED SWITCHES ON AND GLOWS. WE USED THE DPDT SWITCH TO CONTROL THE INPUTS OF THE TRANSISTOR YES AND NOT GATES. AS WITH THE AND GATE AND THE NAND GATE, WE NEED SEPARATE INPUT SWITCHES. R3 AND R4 PULL THE BASES OF Q1 AND Q2 DOWN TO GROUND (LOW OR 0). CLOSING S1 OR S2 APPLIES CURRENT TO THE BASES OF Q1 AND Q2 AND SWITCHES THEM ON (HIGH OR 1).

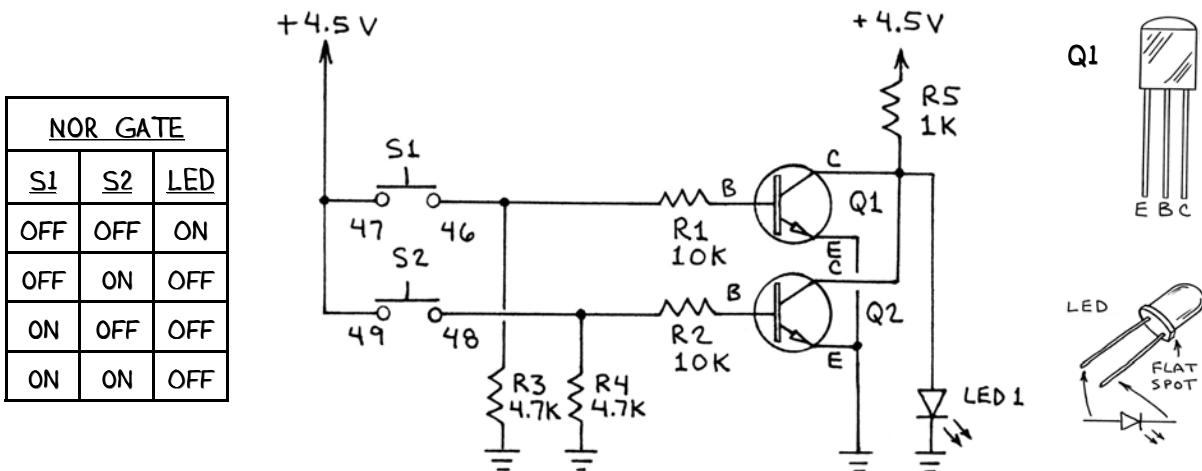
## USE TRANSISTORS TO MAKE A NOR GATE

A 2-TRANSISTOR OR GATE CAN ALSO BE USED AS A NOR GATE. YOU WILL MODIFY AN OR GATE TO FUNCTION AS A NOR GATE. THEN YOU WILL TEST THE GATE TO SEE IF ITS OPERATION MATCHES THE NOR GATE TRUTH TABLE.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE 2-TRANSISTOR OR GATE ON PAGE 22. NO ADDITIONAL PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



### 1. MODIFY THE OR GATE CIRCUIT ON PAGE 22

MODIFY THE OR GATE CIRCUIT ON PAGE 22 BY FOLLOWING THESE STEPS:

1.  PUSH THE POWER SWITCH TO OFF.
2.  MOVE LED 1'S ANODE FROM R21 TO T26.
3.  CONNECT T28 TO I22 (RED WIRE).
4.  CONNECT T21 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

BE SURE ALL THE CONNECTIONS ARE CORRECT. THEN PUSH THE POWER SWITCH TO ON. THE LED WILL GLOW. NOW TEST THE CIRCUIT TO FIND OUT IF THE LED MATCHES THE TRUTH TABLE. WHEN EITHER S1 OR S2, OR BOTH S1 AND S2, ARE PRESSED, THE LED WILL BE OFF. ONLY WHEN BOTH S1 AND S2 ARE OFF (LOW) WILL THE LED GLOW.

### HOW THE NOR GATE WORKS

JUST AS YOU USED AN AND GATE AS A NAND GATE, THIS CIRCUIT USES AN OR GATE AS A NOR GATE BY MOVING THE LED. WHEN BOTH S1 AND S2 ARE OPEN, BOTH Q1 AND Q2 ARE OFF, AND CURRENT FLOWS THROUGH THE LED. THE LED GLOWS (HIGH OR 1). WHEN EITHER S1 OR S2 IS CLOSED, Q1 OR Q2 SWITCHES ON AND DIVERTS THE CURRENT FROM FLOWING THROUGH THE LED. THE LED THEN SWITCHES OFF (LOW OR 0). R3 AND R4 PULL THE BASES OF Q1 AND Q2 TO GROUND, THUS KEEPING THEM SWITCHED OFF UNTIL EITHER S1 OR S2 IS CLOSED.

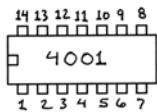
### STILL MORE ABOUT LOGICAL 0 (LOW) AND LOGICAL 1 (HIGH)

THE TRANSISTOR GATE CIRCUITS YOU HAVE BEEN BUILDING USE THE POSITIVE LOGIC SYSTEM IN WHICH OFF = LOW = 0 AND ON = HIGH = 1. LOGIC CIRCUITS CAN ALSO USE THE NEGATIVE LOGIC SYSTEM IN WHICH OFF = HIGH = 1 AND ON = LOW = 0.

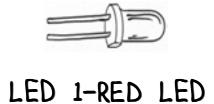
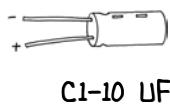
## 4001 QUAD NOR GATE: BUILD A SIMPLE LED FLASHER

NAND AND NOR GATES CAN BOTH BE USED TO BUILD OSCILLATOR CIRCUITS. JUST TIE THE INPUTS TOGETHER TO CONVERT THEM INTO INVERTERS. THIS CIRCUIT IS AN ULTRA-SIMPLE LED FLASHER MADE FROM HALF THE GATES IN A 4001.

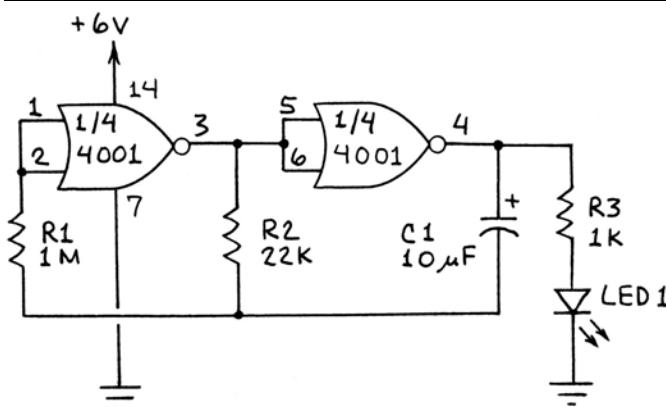
### PARTS YOU WILL NEED



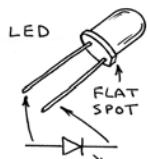
R1-1M (BRN-BLK-GRN)  
R2-22K (RED-RED-ORG)  
R3-1K (BRN-BLK-RED)



### CIRCUIT DIAGRAM



C1 IS AN ELECTROLYTIC CAPACITOR. OBSERVE THE POLARITY (+ AND -) OF THE LEADS WHEN INSERTING THEM INTO THE BREADBOARD.



LED FLASHERS DON'T GET MUCH SIMPLER.

GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 ACROSS SLOT 3 (PIN 1 AT F15).
3.  INSERT R1 ACROSS E14 AND F14.
4.  INSERT R2 ACROSS E13 AND H13.
5.  INSERT R3 ACROSS I14 AND T14.
6.  INSERT C1 ACROSS E11 (-) AND I11 (+).
7.  INSERT LED 1 ACROSS T11 (ANODE) AND GROUND (CATHODE).
8.  CONNECT F11 TO G11 (WHT WIRE).
9.  CONNECT H12 TO J12 (WHT WIRE).
10.  CONNECT J11 TO K11 (WHT WIRE).
11.  CONNECT L11 TO GROUND (WHT WIRE).
12.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
13.  CONNECT G20 TO GROUND (RED WIRE).
14.  CONNECT H20 TO GROUND (WHT WIRE).
15.  CONNECT K20 TO GROUND (WHT WIRE).
16.  CONNECT L20 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

INSPECT THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. THE LED SHOULD BEGIN FLASHING A FEW TIMES EACH SECOND. YOU CAN CHANGE THE FLASH RATE BY CHANGING THE VALUES OF R2 AND C1.

### HOW THE CIRCUIT WORKS

THIS CIRCUIT WORKS LIKE THE 4011 TONE OSCILLATOR ON PAGE 46. THE INPUTS OF BOTH GATES ARE TIED TOGETHER. THIS CONVERTS THEM TO INVERTERS. THIS MEANS THAT 4011 NAND GATES AND 4001 NOR GATES CAN BE USED INTERCHANGEABLY WHEN THEY ARE USED AS INVERTERS. LIKEWISE, YOU CAN USE THE 4001 IN 4011 TONE GENERATOR CIRCUITS. THE 4049 INCLUDES SIX INVERTERS IN A SINGLE CHIP. THIS CHIP WILL ALSO WORK IN SIMPLE TONE GENERATOR AND LED FLASHER CIRCUITS. THE ADVANTAGE OF USING NOR AND NAND GATES IS THAT WE CAN DISCONNECT ONE OF THE INPUTS AND USE IT TO CONTROL THE CIRCUIT (SEE PAGE 31).

## 4001 QUAD NOR GATE: BUILD A FANCY LED FLASHER

YOU WILL MODIFY THE SIMPLE LED FLASHER BY ADDING A SECOND LED THAT SWITCHES ON WHEN THE FIRST LED SWITCHES OFF. YOU WILL ALSO ADD A POTENTIOMETER THAT WILL ALLOW YOU TO CONTROL THE RATE OF THE BACK-AND-FORTH FLASHING OF THE TWO LEDs.

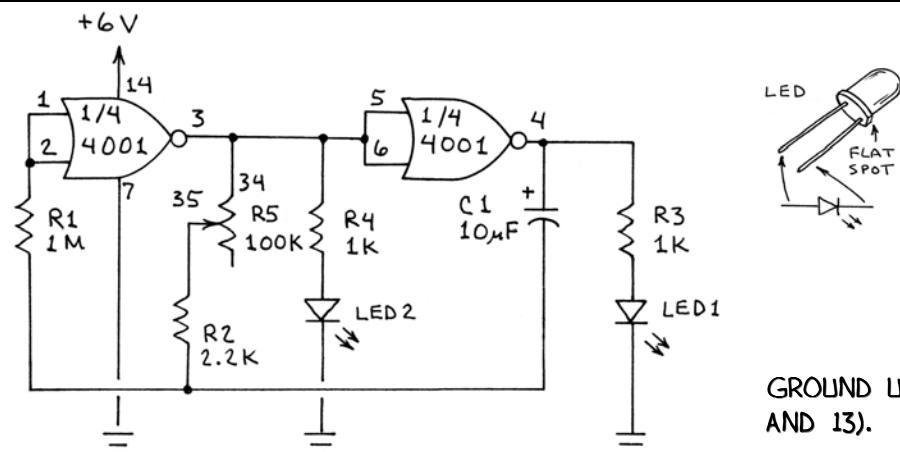
### PARTS YOU WILL NEED

YOU WILL NEED THE SIMPLE LED FLASHER ON PAGE 24 PLUS:

R2-2.2K (RED-RED-RED)  
R4-1K (BRN-BLK-RED)

LED 2-GREEN

### CIRCUIT DIAGRAM



THIS DUAL-LED FLASHER IS MORE ATTENTION-GETTING THAN A SINGLE-LED FLASHER.

GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. CONVERT THE SIMPLE LED FLASHER ON PAGE 24 INTO A FANCY LED FLASHER

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE OLD R2 FROM E13 AND H13.
3.  INSERT NEW R2 ACROSS E13 AND A13.
4.  INSERT R4 ACROSS J14 AND T16.
5.  INSERT LED 2 ACROSS T18 AND GROUND.
6.  CONNECT SPRING 34 TO H14 (RED WIRE).
7.  CONNECT SPRING 35 TO A11 (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. THE RED AND GREEN LEDS WILL FLASH ALTERNATELY. ROTATE CONSOLE POTENTIOMETER R5'S KNOB TO VARY THE BACK-AND-FORTH FLASH RATE FROM ONCE EVERY FEW SECONDS TO A FAST FLICKER.

### GOING FURTHER

SINCE THE INPUTS OF THE NOR GATES ARE TIED TOGETHER TO MAKE THEM INTO INVERTERS, ANY INVERTERS SHOULD WORK IN THIS CIRCUIT. TO PROVE THIS, SWITCH OFF THE POWER AND CAREFULLY REMOVE THE 4001 QUAD NOR GATE IC. THEN INSERT A 4011 QUAD NAND GATE IC IN ITS PLACE. BE SURE THAT PIN 1 ON THE 4011 IS AT F15. NOW SWITCH THE POWER BACK ON. THE LEDS SHOULD CONTINUE TO FLASH JUST AS THEY DID WHEN THE 4001 WAS INSTALLED.

YOU CAN USE A PUSHBUTTON SWITCH TO CHANGE THE FLASH RATE FROM FAST TO SLOW. FIRST, SET THE 100K CONSOLE POT FOR THE FAST FLASH RATE YOU WANT. THEN INSERT VARIOUS CAPACITORS IN PARALLEL WITH C1 UNTIL YOU GET THE SLOW FLASH RATE YOU WANT. INSERT THE NEW CAPACITOR ACROSS E15 (-) AND B15 (+). IMPORTANT: OBSERVE POLARITY (SEE PAGE 24) WHEN ADDING NEW CAPACITORS. CONNECT SPRING 46 TO I12 (RED WIRE) AND SPRING 47 TO B14 (BLU WIRE). PRESS S1 TO CHANGE THE FLASH RATE FROM FAST TO SLOW.

## 4001 QUAD NOR GATE: BUILD A DARK-ACTIVATED DUAL LED FLASHER

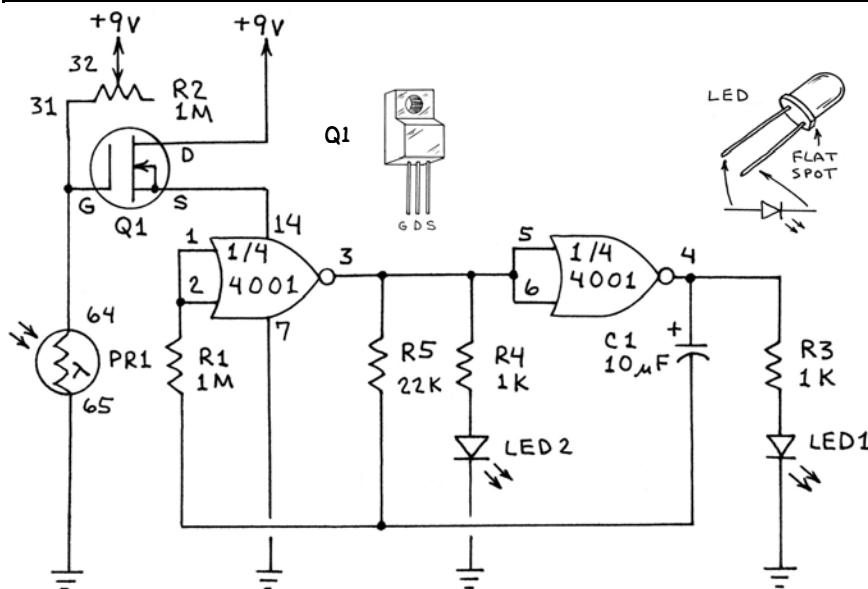
YOU WILL ADD A LIGHT-SENSING CIRCUIT BETWEEN THE SIMPLE LED FLASHER AND THE POWER SUPPLY. THE SENSOR CIRCUIT WILL APPLY POWER TO THE FLASHER ONLY WHEN THE LIGHT INTENSITY FALLS BELOW A THRESHOLD THAT YOU WILL ADJUST USING A POTENTIOMETER.

### PARTS YOU WILL NEED

YOU WILL NEED THE SIMPLE LED FLASHER ON PAGE 24 PLUS:



### CIRCUIT DIAGRAM



THIS IS THE SIMPLE LED FLASHER WITH A SECOND LED AND CURRENT LIMITING RESISTOR PLUS A POWER FET (Q1) BETWEEN +9V AND THE CIRCUIT. CONSOLE POT R2 AND PHOTORESISTOR PR1 FORM A VOLTAGE DIVIDER THAT SWITCHES Q1 ON WHEN THE RESISTANCE OF PR1 IS HIGH, WHICH OCCURS WHEN PR1 IS DARK. SO Q1 SWITCHES THE FLASHER ON WHEN PR1 IS DARK.

GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. CONVERT THE SIMPLE LED FLASHER ON PAGE 24 INTO A DARK ACTIVATED FLASHER

THESE STEPS ALSO APPLY TO THE FANCY LED FLASHER (JUST DELETE STEPS 3 AND 4).

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHITE WIRE FROM F20 TO V4 (+6V).
3.  INSERT R4 ACROSS J14 AND T16.
4.  INSERT LED 2 ACROSS T18 AND GROUND.
5.  INSERT Q1 AT C16 (G), B16 (D) AND A16 (S).
6.  CONNECT A20 TO F20 (WHT WIRE).
7.  CONNECT B20 TO V6 (+9V) (WHT WIRE).
8.  CONNECT SPRING 32 TO V6 (+9V) (BLU WIRE).
9.  CONNECT SPRING 31 TO C18 (BLU WIRE).
10.  CONNECT SPRING 64 TO C20 (BLU WIRE).
11.  CONNECT SPRING 65 TO GROUND (BLU WIRE).

### 2. TEST THE CIRCUIT

BE SURE ALL THE CONNECTIONS ARE CORRECT. PLACE BLACK TAPE OR AN OPAQUE OBJECT OVER THE PHOTORESISTOR APERTURE. THEN PUSH THE POWER SWITCH ON. NOW ADJUST THE 1M CONSOLE POTENTIOMETER (R2) UNTIL THE LEDs JUST BEGIN FLASHING. REMOVE THE TAPE OR COVER FROM THE PHOTORESISTOR AND THE LEDs SHOULD STOP FLASHING. THE CIRCUIT IS VERY SENSITIVE TO LIGHT.

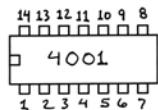
### GOING FURTHER

THIS CIRCUIT HAS PRACTICAL APPLICATIONS SINCE IT AUTOMATICALLY SWITCHES ON AT NIGHT OR WHEN THE ROOM LIGHTS GO OUT. REDUCE THE VALUE OF C1 TO SPEED THE FLASH RATE.

## 4001 QUAD NOR GATE: BUILD A SET-RESET LATCH

HAVE YOU WONDERED HOW PUSH-ON/PUSH-OFF SWITCHES WORK? MANY CIRCUITS AND PRODUCTS USE THEM. YOU WILL BUILD A COMMON VERSION OF THESE NEAT SWITCHES, A SET-RESET LATCH. YOU WILL ALSO LEARN HOW THIS SIMPLE CIRCUIT DOUBLES AS A MEMORY CELL.

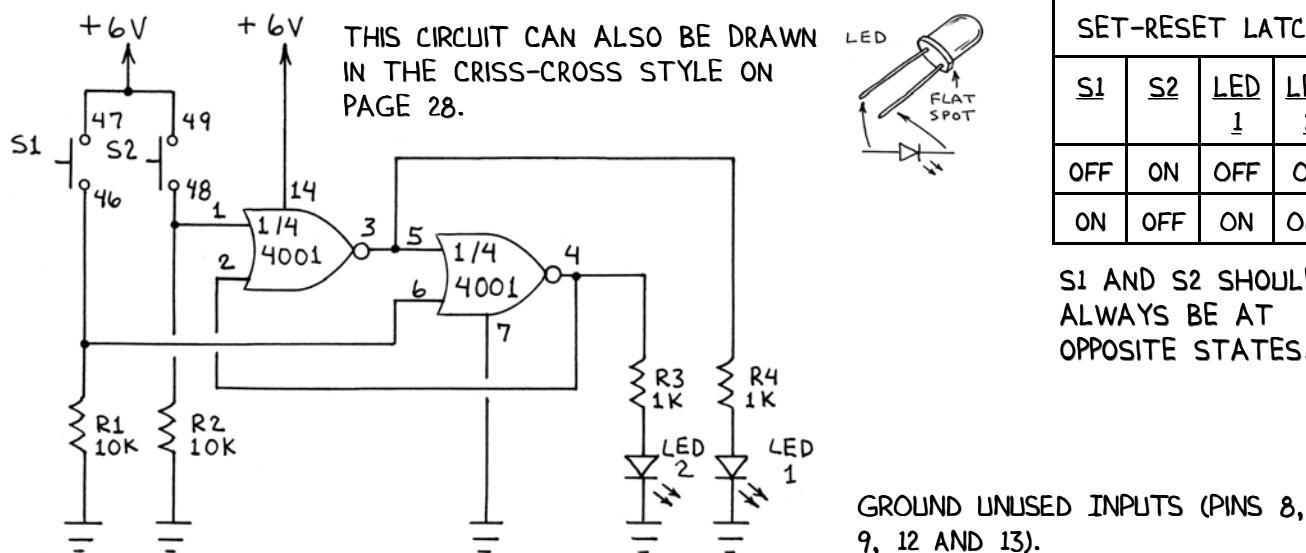
### PARTS YOU WILL NEED



R1, R2-10K (BRN-BLK-ORG)  
R3, R4-1K (BRN-BLK-RED)

LED 1-RED LED  
LED 2-GREEN LED

### CIRCUIT DIAGRAM



### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 ACROSS SLOT 3 (PIN 1 AT F15).
3.  INSERT R1 ACROSS K14 AND GROUND.
4.  INSERT R2 ACROSS F11 AND L11.
5.  INSERT R3 ACROSS I14 AND T17.
6.  INSERT R4 ACROSS H14 AND T14.
7.  INSERT LED 1 ACROSS T15 AND GROUND.
8.  INSERT LED 2 ACROSS T16 AND GROUND.
9.  CONNECT G11 TO I11 (WHT WIRE).
10.  CONNECT H11 TO J11 (WHT WIRE).
11.  CONNECT L13 TO GROUND (WHT WIRE).
12.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
13.  CONNECT SPRING 46 TO K11 (RED WIRE).
14.  CONNECT SPRING 48 TO F14 (RED WIRE).
15.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
16.  CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).
17.  CONNECT G20 TO H20 (WHT WIRE).
18.  CONNECT K20 TO L20 (WHT WIRE).
19.  CONNECT H19 TO K19 (WHT WIRE).
20.  CONNECT L19 TO GROUND (WHT WIRE).

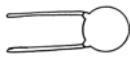
### 2. TEST THE CIRCUIT

CHECK TO MAKE SURE THERE ARE NO ERRORS AND THAT NO RESISTOR WIRES ARE TOUCHING. THEN PUSH THE POWER SWITCH ON. PRESS S1 AND LED 1 WILL GLOW AND LED 2 WILL SWITCH OFF. PRESS S2 AND LED 2 WILL GLOW AND LED 1 WILL SWITCH OFF. NOTICE THAT THE SELECTED LED REMAINS ON AFTER YOU RELEASE THE PUSHBUTTON SWITCH. THIS SHOWS THE LATCHING OR MEMORY ACTION OF THE SET-RESET LATCH. THIS BASIC PRINCIPLE IS USED IN VARIOUS KINDS OF DIGITAL MEMORY CHIPS. THE 4001 CIRCUIT ON PAGE 28 SHOWS HOW TO TRIGGER AN EXTERNAL CIRCUIT WITH THE SET-RESET LATCH.

## 4001 QUAD NOR GATE: USE A LATCH TO CONTROL ANOTHER CIRCUIT.

NOW THAT YOU KNOW HOW A LATCH CIRCUIT WORKS, LET'S USE A LATCH TO CONTROL ANOTHER CIRCUIT. YOU WILL BUILD A TONE GENERATOR THAT YOU WILL SWITCH OFF AND ON USING PUSHBUTTON SWITCHES CONNECTED TO THE INPUTS OF A LATCH. BESIDES DEMONSTRATING A PRACTICAL APPLICATION, THIS CIRCUIT SHOWS HOW A LOGIC SIGNAL CAN SWITCH A TONE.

### PARTS YOU WILL NEED

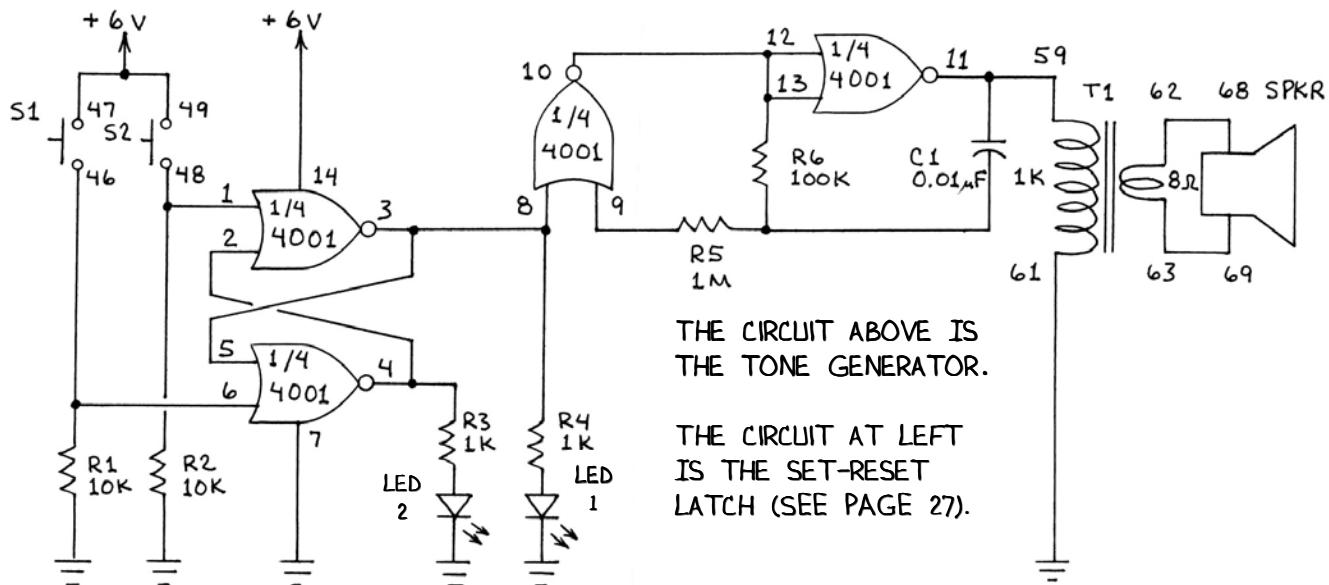


YOU WILL NEED THE  
SET-RESET LATCH ON  
PAGE 27 PLUS:

R5-1M (BRN-BLK-GRN)  
R6-100K (BRN-BLK-YEL)

C1-0.01 UF (103)

### CIRCUIT DIAGRAM



### 1. ADD THE TONE GENERATOR CIRCUIT TO THE BASIC LATCH ON PAGE 27

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WIRE FROM L19 TO GROUND.
3.  REMOVE WIRE FROM K20 TO L20.
4.  REMOVE WIRE FROM H19 TO K19.
5.  INSERT R5 ACROSS K17 AND D17.
6.  INSERT R6 ACROSS J18 AND D18.
7.  INSERT C1 ACROSS I19 AND D19.
8.  CONNECT G20 TO H20 (WHT WIRE).
9.  CONNECT H19 TO J20 (WHT WIRE).
10.  CONNECT L20 TO H13 (RED WIRE).
11.  CONNECT SPRING 59 TO I20 (RED WIRE).
12.  CONNECT SPRING 61 TO GROUND (RED WIRE).
13.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
14.  CONNECT SPRINGS 63 AND 69 (RED WIRE).

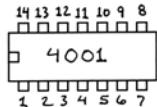
### 2. TEST THE CIRCUIT

CHECK FOR ERRORS AND BE SURE THAT THE LATCH CIRCUIT IS STILL OK. NOW PUSH THE POWER SWITCH ON. PRESS S1. THE RED LED (LED 1) WILL GLOW AND THE SPEAKER WILL BE SILENT. NOW PRESS S2. THE GREEN LED WILL GLOW AND THE SPEAKER WILL EMIT A BUZZ OR TONE. REPEAT THIS PROCEDURE SEVERAL TIMES TO MAKE SURE THE LATCH IS REALLY SWITCHING THE TONE GENERATOR OFF AND ON. LATCHES ARE USED IN SEQUENTIAL LOGIC CIRCUITS AND IN VARIOUS KINDS OF MEMORY APPLICATIONS.

## 4001 QUAD NOR GATE: BUILD A "ONE SHOT" MONOSTABLE MULTIVIBRATOR

THIS NIFTY CIRCUIT HAS A MIND OF ITS OWN. PRESS A PUSHBUTTON, AND AN LED GLOWS FOR A TIME DETERMINED BY THE CIRCUIT, NOT BY HOW LONG YOU PRESS THE PUSHBUTTON. YOU WILL BUILD AND LEARN HOW TO USE AND ADJUST THIS VERY USEFUL CIRCUIT.

### PARTS YOU WILL NEED

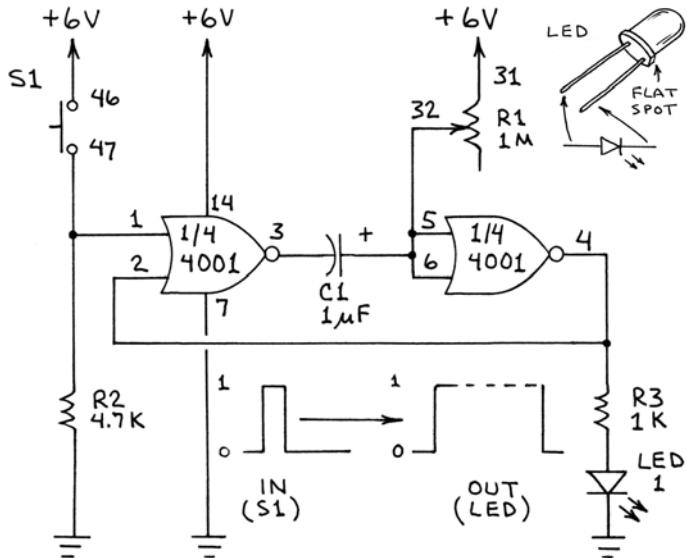


R2-4.7K (YEL-VIO-RED)  
R3-1K (BRN-BLK-RED)

C1-1 uF

LED 1-RED LED

### CIRCUIT DIAGRAM



POSITIVE LOGIC:  
OFF = LOW = 0  
ON = HIGH = 1

S1	LED 1
OFF	OFF
ON	ON UNTIL C1 DISCHARGES
OFF	

THIS CIRCUIT IS A MONOSTABLE MULTIVIBRATOR. MONO MEANS ONE AND A MULTIVIBRATOR IS A CIRCUIT THAT FLIPS BETWEEN TWO STATES. SO A MONOSTABLE FLIPS JUST ONCE AND ONLY WHEN TRIGGERED. THE MONOSTABLE MULTIVIBRATOR IS COMMONLY CALLED THE "ONE-SHOT."

GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 OVER SLOT 3 (PIN 1 AT F15).
3.  CONNECT G11 TO I11 (WHT WIRE).
4.  CONNECT J11 TO K11 (WHT WIRE).
5.  CONNECT L11 TO GROUND (WHT WIRE).
6.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
7.  CONNECT G20 TO GROUND (RED WIRE).
8.  CONNECT K20 TO GROUND (WHT WIRE).
9.  CONNECT H19 TO GROUND (RED WIRE).
10.  CONNECT L19 TO GROUND (WHT WIRE).
11.  CONNECT SPRING 31 TO F17 (BLU WIRE).
12.  CONNECT SPRING 32 TO K13 (BLU WIRE).
13.  CONNECT SPRING 47 TO F13 (RED WIRE).
14.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
15.  INSERT R2 ACROSS F12 AND L12.
16.  INSERT R3 ACROSS I13 TO T13.
17.  INSERT C1 ACROSS H12 (-) AND J12 (+).
18.  INSERT LED 1 ACROSS T15 (ANODE) AND GROUND (CATHODE).

### 2. TEST THE CIRCUIT

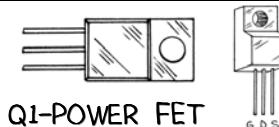
CHECK THE CIRCUIT FOR ERRORS. SET THE 1M CONSOLE POT (R1) TO ITS MID-POINT AND THEN PUSH THE POWER SWITCH ON. THE LED WILL BE OFF. NOW PRESS S1 TO APPLY LOGICAL 1 TO THE GATE INPUT. THE CIRCUIT WILL THEN EMIT AN OUTPUT PULSE, AND THE LED WILL GLOW DURING THE ENTIRE PULSE. THE DURATION OF THE OUTPUT PULSE, THUS THE TIME THE LED GLOWS, IS APPROXIMATELY  $0.8 \times R1 \times C1$ . SIMPLY BY ADJUSTING R1, YOU CAN CHANGE THE OUTPUT PULSE FROM A FRACTION OF A SECOND TO 1 SECOND OR SO. TRY IT AND SEE. IF THE LED STAYS ON INDEFINITELY AFTER YOU PRESS S1, ADJUST R1 TO A LOWER RESISTANCE.

## 4001 QUAD NOR GATE: BUILD A "ONE SHOT" TONE BURSTER

THE "ONE-SHOT" CIRCUIT ON PAGE 29 LIGHTS AN LED WHEN A SWITCH IS PRESSED. YOU WILL ADD A POWER FET THAT ACTIVATES THE CONSOLE BUZZER AT THE SAME TIME THE LED IS GLOWING.

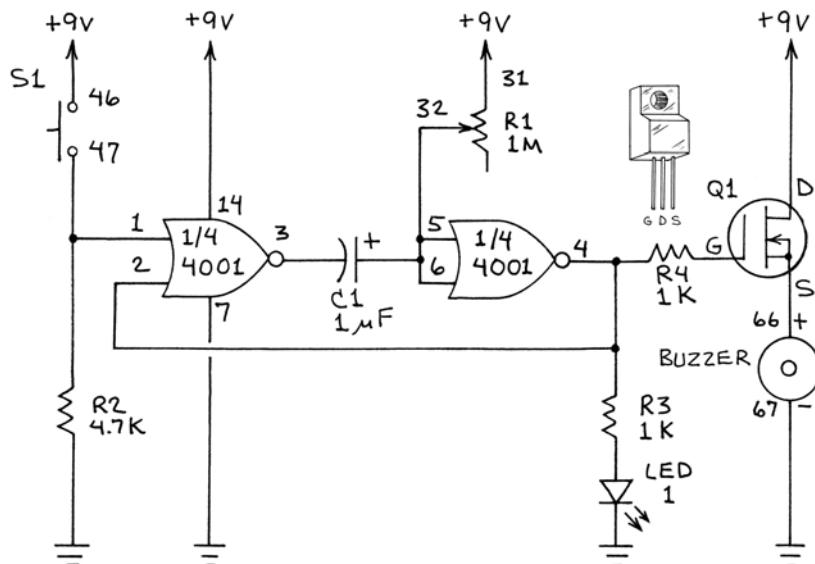
### PARTS YOU WILL NEED

YOU WILL NEED THE ONE-SHOT CIRCUIT PLUS:



R4-1K (BRN-BLK-RED)

### CIRCUIT DIAGRAM



POSITIVE LOGIC:  
OFF = LOW = 0  
ON = HIGH = 1

S1	BUZZER
OFF	OFF
ON	ON UNTIL C1 DISCHARGES
OFF	

POWER FET Q1 SWITCHES THE BUZZER OFF AND ON WITHOUT LOADING DOWN THE NOR GATE. TO DRIVE THE CONSOLE RELAY, JUST MOVE THE BLUE WIRES AT SPRINGS 66 AND 67 TO SPRINGS 57 AND 58.

GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. MODIFY THE ONE-SHOT CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT Q1 AT Q18 (G), P18 (D) AND O18 (S).
3.  INSERT R4 ACROSS I14 AND Q16.
4.  REMOVE WHITE WIRE FROM F20 TO V3 (+6V).
5.  CONNECT F20 TO V6 (+9V) (RED WIRE).
6.  CONNECT P20 TO V6 (+9V) (RED WIRE).
7.  CONNECT SPRING 66 TO O20 (BLU WIRE).
8.  CONNECT SPRING 67 TO GROUND (BLU WIRE).

### 2. TEST THE CIRCUIT

AFTER YOU CHECK THE CIRCUIT FOR ERRORS, SET THE 1M CONSOLE POT (R1) TO ITS MID-POINT AND PUSH THE POWER SWITCH ON. THE LED WILL BE OFF, AND THE BUZZER WILL BE SILENT. NOW PRESS S1. THE LED WILL GLOW BRIEFLY, AND THE BUZZER WILL EMIT A PULSE OF SOUND. IF YOU SET R1 TO A LOW RESISTANCE, THE OUTPUT PULSE WILL BE BRIEF AND THE TONE BURST WILL CEASE BEFORE YOU REMOVE YOUR FINGER FROM THE SWITCH. IF YOU SET R1 FOR A HIGHER RESISTANCE, THE TONE WILL SOUND FOR A SECOND OR SO. IF THE LED AND TONE STAY ON INDEFINITELY, REDUCE R1 TO A LOWER RESISTANCE. YOU MAY NEED TO SWITCH THE POWER SWITCH OFF AND BACK TO ON TO RESET THE CIRCUIT.

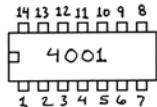
### GOING FURTHER

YOU CAN USE THIS CIRCUIT TO DEMONSTRATE THAT LIGHT TRAVELS FASTER THAN SOUND. LEAVE THE CONSOLE AT ONE END OF A LARGE ROOM OR HALLWAY WITH A FRIEND WHILE YOU WALK TO THE OPPOSITE END. WHILE YOUR FRIEND PURES S1, WATCH FOR THE FLASH OF THE LED AND LISTEN FOR THE TONE BURST. WHICH DO YOU DETECT FIRST?

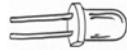
## 4001 QUAD NOR GATE: BUILD A CONTROL GATE

IF YOU GROUND (LOW OR LOGICAL 0) ONE INPUT OF A NOR GATE, THE GATE'S OUTPUT STATUS WILL ALWAYS BE OPPOSITE THAT OF THE LOGICAL SIGNAL AT THE SECOND INPUT. YOU WILL USE THIS ARRANGEMENT TO CONTROL AN LED.

### PARTS YOU WILL NEED

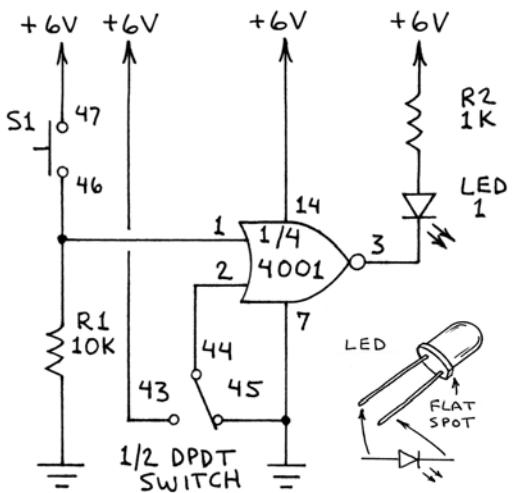


R1-10K (BRN-BLK-ORG)  
R2-1K (BRN-BLK-RED)



LED 1-RED

### CIRCUIT DIAGRAM



THE CELLS IN LOGIC TRUTH TABLES CAN INDICATE THE TWO LOGIC STATES (0 AND 1) WITH OFF AND ON, OR LOW AND HIGH, OR GROUND AND +V.

DPDT	S1	LED 1
DOWN (LOW)	OFF	OFF
	ON	ON
UP (HIGH)	ON	ON
	OFF	ON

IN THIS CIRCUIT THE LED IS CONNECTED TO +6V SO IT WILL GLOW TO INDICATE WHEN PIN 3 GOES LOW. TO MAKE THE LED GLOW WHEN PIN 3 IS HIGH, REVERSE THE LED AND CONNECT R2 TO GROUND INSTEAD OF +6V.

GROUND UNUSED INPUTS (PINS 5, 6, 8, 9, 12 AND 13).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 OVER SLOT 3 (PIN 1 AT F15).
3.  CONNECT L11 TO GROUND (WHT WIRE).
4.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
5.  CONNECT SPRING 46 TO F14 (RED WIRE).
6.  CONNECT SPRING 47 TO F19 (RED WIRE).
7.  CONNECT SPRING 43 TO V4 (+6V) (BLU WIRE).
8.  CONNECT SPRING 44 TO G11 (BLU WIRE).
9.  CONNECT SPRING 45 TO GROUND (RED WIRE).
10.  INSERT R1 ACROSS F12 AND L12.
11.  INSERT R2 ACROSS D15 AND F17.
12.  INSERT LED 1 ACROSS D13 (ANODE) AND H13 (CATHODE).
13.  CONNECT G20 TO H20 (WHT WIRE).
14.  CONNECT K20 TO L20 (WHT WIRE).
15.  CONNECT H19 TO K19 (WHT WIRE).
16.  CONNECT L19 TO GROUND (WHT WIRE).
17.  CONNECT J14 TO K14 (WHT WIRE).
18.  CONNECT K13 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. PUSH THE DPDT SWITCH DOWN TO GROUND ONE INPUT OF THE NOR GATE. THEN PUSH THE POWER SWITCH ON. THE LED SHOULD BE OFF. NOW PRESS S1 TO APPLY LOGICAL 1 TO THE SECOND GATE INPUT. THE LED SHOULD GLOW. THIS THE LED INDICATES THE STATUS OF S1 (S1 OFF = LED OFF AND S1 ON = LED ON). NOW PUSH THE DPDT SWITCH UP TO CONNECT THE FIRST GATE INPUT TO +6V. NOW THE LED GLOWS WHETHER OR NOT S1 IS PRESSED, AND THE GATE OUTPUT NO LONGER FOLLOWS THE INPUT.

### GOING FURTHER

YOU CAN REPLACE THE LED AND R2 WITH ONE OF THE 10 CONSOLE LEDs. REMOVE LED 1 AND R2. CONNECT SPRING 11 TO H13 (RED WIRE) AND SPRING 12 TO V4 (+6V) (WHT WIRE). YOU DON'T NEED R2 SINCE THE CONSOLE LEDs HAVE THEIR OWN SERIES RESISTORS.

## 4001 QUAD NOR GATE: BUILD A LIGHT-ACTIVATED TONE GENERATOR

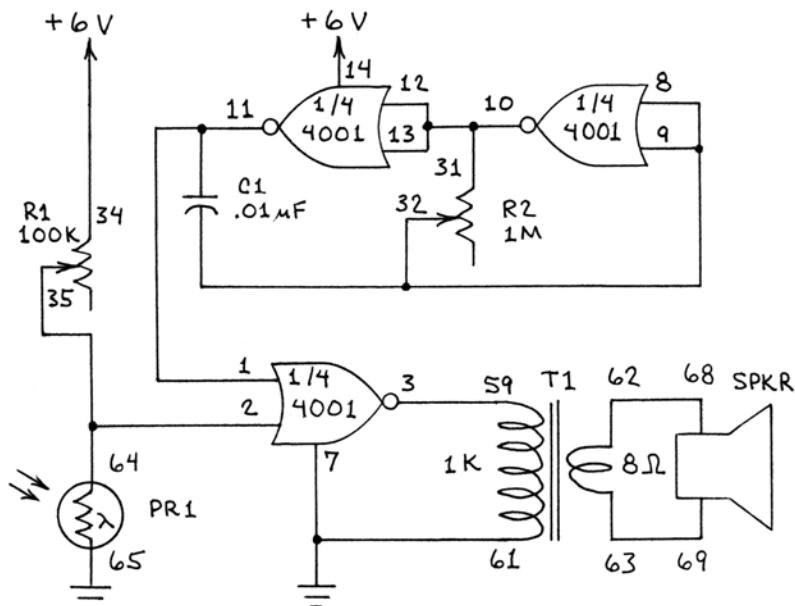
HERE'S A PRACTICAL APPLICATION FOR A CONTROL GATE. YOU WILL BUILD A VERY SIMPLE TONE GENERATOR AND CONNECT IT TO A CONTROL GATE. YOU WILL THEN CONNECT ONE INPUT OF THE CONTROL GATE TO A PHOTORESISTOR TO MAKE A LIGHT-CONTROLLED TONE CIRCUIT.

### PARTS YOU WILL NEED



C1-0.01 UF (103)

### CIRCUIT DIAGRAM



PHOTORESISTOR	TONE
DARK (0 OR LOW)	OFF
LIGHT (1 OR HIGH)	ON

THE TWO UPPER GATES FORM AN OSCILLATOR. WHEN PHOTORESISTOR PR1 IS DARK, THE LOWER GATE BLOCKS THE SIGNAL FROM THE SPEAKER. WHEN PR1 IS ILLUMINATED, ITS RESISTANCE DROPS, PULLING PIN 2 TO GROUND. THIS SWITCHES ON THE GATE, AND THE SIGNAL REACHES THE SPEAKER.

GROUND UNUSED INPUTS (PINS 5 AND 6).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 OVER SLOT 3 (PIN 1 AT F15).
3.  INSERT C1 ACROSS I18 AND K18.
4.  CONNECT L11 TO GND (WHT WIRE).
5.  CONNECT J11 TO K11 (WHT WIRE).
6.  CONNECT G20 TO H20 (WHT WIRE).
7.  CONNECT K20 TO L20 (WHT WIRE).
8.  CONNECT H19 TO J19 (WHT WIRE).
9.  CONNECT F14 TO I17 (WHT WIRE).
10.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
11.  CONNECT SPRING 31 TO J17 (BLU WIRE).
12.  CONNECT SPRING 32 TO L17 (BLU WIRE).
13.  CONNECT SPRING 34 TO F18 (BLU WIRE).
14.  CONNECT SPRING 35 TO G11 (BLU WIRE).
15.  CONNECT SPRING 59 TO H14 (BLU WIRE).
16.  CONNECT SPRING 61 TO GND (RED WIRE).
17.  CONNECT SPRING 64 TO G14 (BLU WIRE).
18.  CONNECT SPRING 65 TO GND (BLU WIRE).
19.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
20.  CONNECT SPRINGS 63 AND 69 (RED WIRE).

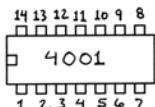
### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN SET CONSOLE POTTS R1 AND R2 TO THEIR MID-POINTS AND PUSH THE POWER SWITCH ON. PLACE A FINGER OVER PHOTORESISTOR PR1 AND ADJUST THE 100K CONSOLE POT (R1) UNTIL THE SPEAKER IS SILENT. REMOVE YOUR FINGER, AND THE SPEAKER WILL EMIT A TONE. YOU CAN CHANGE THE TONE FREQUENCY BY ADJUSTING THE 1M CONSOLE POT (R2). IF THE TONE STOPS, ROTATE R2 UNTIL IT RESUMES. THIS CIRCUIT IS VERY SENSITIVE! IN A DARK ROOM ADJUST THE 100K CONSOLE POT FOR PEAK SENSITIVITY. THEN SHINE A FLASHLIGHT ON YOUR LEARNING LAB CONSOLE TO SEE WHAT HAPPENS.

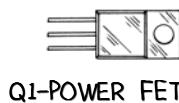
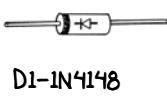
## 4001 QUAD NOR GATE: BUILD A LATCHED RELAY.

YOU WILL USE A LATCH TO CONTROL A RELAY WITH A PUSHBUTTON SWITCH.

### PARTS YOU WILL NEED

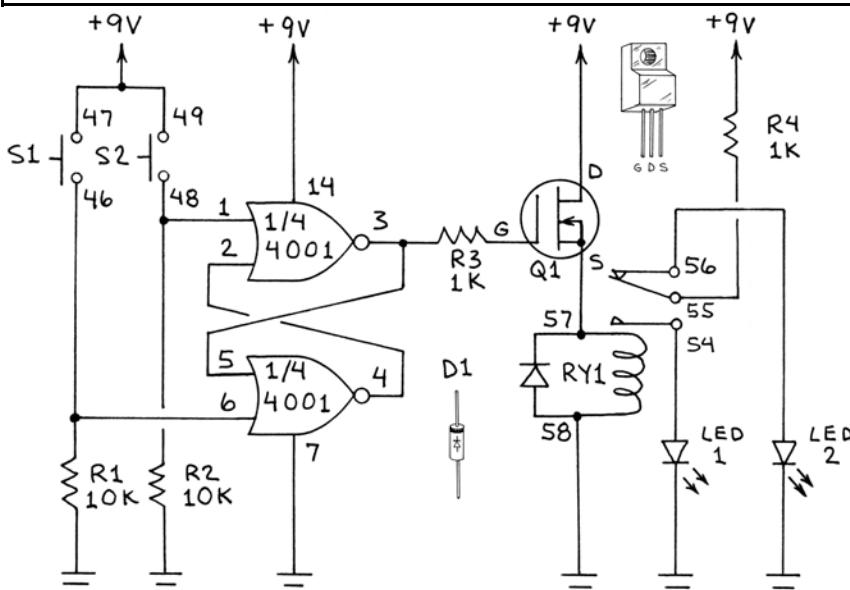


R1, R2-10K (BRN-BLK-ORG)  
R3, R4-1K (BRN-BLK-RED)



LED 1-RED, LED 2-GREEN

### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### HOW IT WORKS

POWER FET Q1 IS SWITCHED ON WHEN PIN 3 OF THE LATCH GOES HIGH. Q1 IS SWITCHED OFF WHEN PIN 3 GOES LOW. WHEN Q1 IS OFF, NO CURRENT FLOWS THROUGH THE RELAY AND LED 2 IS ON. WHEN Q1 IS ON, CURRENT FLOWS THROUGH THE RELAY AND PULLS IN THE ARMATURE, SWITCHING ON LED 1 AND TURNING OFF LED 2. DIODE D1 PROTECTS Q1 FROM THE HIGH VOLTAGE PULSE THAT IS GENERATED IN THE RELAY COIL WHEN THE RELAY IS SWITCHED OFF.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4001 ACROSS SLOT 3 (PIN 1 AT F15).
3.  INSERT Q1 AT C16 (G), B16 (D) AND A16 (S).
4.  INSERT R1 ACROSS K14 AND GROUND.
5.  INSERT R2 ACROSS F11 AND L11.
6.  INSERT R3 ACROSS H14 AND C17.
7.  INSERT R4 ACROSS V6 (+9V) AND A23.
8.  INSERT LED 1 ACROSS T11 AND GROUND.
9.  INSERT LED 2 ACROSS T16 AND GROUND.
10.  INSTALL D1 ACROSS SPRINGS 57 (CATHODE-BAND) AND 58 (ANODE).
11.  CONNECT G11 TO I11 (WHT WIRE).
12.  CONNECT H11 TO J11 (WHT WIRE).
13.  CONNECT L13 TO GROUND (WHT WIRE).
14.  CONNECT F20 TO V6 (+9V) (WHT WIRE).
15.  CONNECT B20 TO V6 (+9V) (WHT WIRE).
16.  CONNECT G20 TO GROUND (WHT WIRE).
17.  CONNECT H20 TO GROUND (WHT WIRE).
18.  CONNECT K20 TO GROUND (WHT WIRE).
19.  CONNECT L20 TO GROUND (WHT WIRE).
20.  CONNECT SPRING 54 TO T15 (BLU WIRE).
21.  CONNECT SPRING 56 TO T18 (BLU WIRE).
22.  CONNECT SPRING 55 TO A25 (BLU WIRE).
23.  CONNECT SPRING 57 TO A20 (BLU WIRE).
24.  CONNECT SPRING 58 TO GROUND (RED WIRE).
25.  CONNECT SPRING 46 TO K11 (RED WIRE).
26.  CONNECT SPRING 48 TO F14 (RED WIRE).
27.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
28.  CONNECT SPRING 49 TO V6 (+9V) (BLU WIRE).

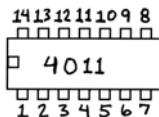
### 2. TEST THE CIRCUIT

MAKE SURE THERE ARE NO ERRORS. THEN PUSH THE POWER SWITCH ON. LED 2 WILL GLOW. PRESS S1 AND LED 1 WILL GLOW. PRESS S2 AND LED 2 WILL GLOW. THE LATCH IS A SINGLE-BIT MEMORY CELL THAT KEEPS THE RELAY AT THE SELECTED POSITION, UNTIL YOU PRESS S1 OR S2 AGAIN, OR UNTIL THE POWER IS SWITCHED OFF.

## 4011 QUAD NAND GATE: HOW THE NAND GATE WORKS

THE 4011 QUAD NAND GATE INCLUDES FOUR SEPARATE POSITIVE LOGIC NAND GATES ON A SINGLE SILICON CHIP. YOU WILL EXPERIMENT WITH ONE OF THESE GATES BY USING PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS TO ITS TWO INPUTS. AN LED WILL INDICATE THE GATE'S OUTPUT. YOU WILL THEN VERIFY THE NAND GATE TRUTH TABLE.

### PARTS YOU WILL NEED

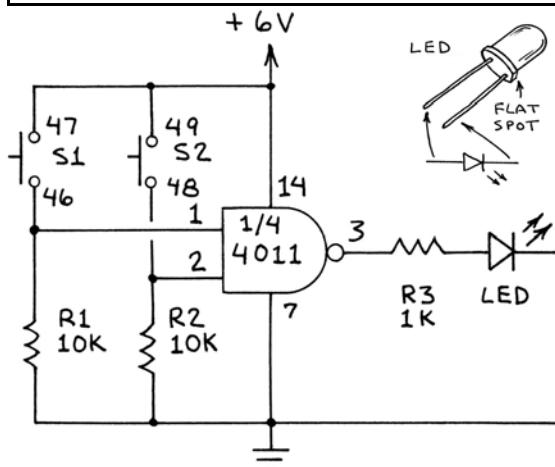


R1, R2-10K (BRN-BLK-ORG)  
R3-1K (BRN-BLK-RED)



LED-GREEN LED

### CIRCUIT DIAGRAM



GROUND 4011 UNUSED INPUTS (PINS 5, 6, 8, 9, 12 AND 13).

ON-OFF  
TRUTH TABLE

S1	S2	LED
OFF	OFF	ON
OFF	ON	ON
ON	OFF	ON
ON	ON	OFF

HIGH-LOW  
TRUTH TABLE

S1	S2	OUT
L	L	H
L	H	H
H	L	H
H	H	L

BINARY  
TRUTH TABLE

S1	S2	LED
0	0	1
0	1	1
1	0	1
1	1	0

POSITIVE LOGIC: OFF = LOW = 0 AND ON = HIGH = 1

R1 AND R2 ARE PULL-DOWN RESISTORS THAT KEEP THE GATE INPUTS LOW (L). CLOSING S1 OR S2 FORCES THE RESPECTIVE INPUT HIGH (H). WHEN THE OUTPUT IS HIGH, THE LED GLOWS (H).

### 1. BUILD THE CIRCUIT

- PUSH THE POWER SWITCH TO OFF.
- INSERT THE 4011 IC ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT H5).
- CONNECT N1 TO GROUND (WHT WIRE).
- CONNECT H10 TO V4 (+6V) (RED WIRE).
- INSTALL R1 ACROSS SPRING 46 AND GROUND.
- INSTALL R2 ACROSS SPRING 48 AND GROUND.
- INSERT R3 ACROSS J1 AND T1.
- INSERT GREEN LED ACROSS T5 (ANODE) AND GROUND (CATHODE).
- CONNECT L1 TO GROUND (WHT WIRE).
- CONNECT M1 TO GROUND (WHT WIRE).
- CONNECT M10 TO GROUND (WHT WIRE).
- CONNECT N10 TO GROUND (WHT WIRE).
- CONNECT I10 TO GROUND (WHT WIRE).
- CONNECT J10 TO GROUND (WHT WIRE).
- CONNECT SPRING 46 TO H1 (BLU WIRE).
- CONNECT SPRING 48 TO I1 (BLU WIRE).
- CONNECT SPRINGS 47 AND 49 (WHT WIRE).
- CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH TO ON. THE LED SHOULD GLOW SINCE BOTH INPUT SWITCHES ARE OFF (NAND GATE: OFF AND OFF = ON). WHEN YOU PRESS EITHER S1 OR S2, THE LED SHOULD STILL GLOW. THE LED WILL TURN OFF WHEN YOU PRESS BOTH S1 AND S2 AT THE SAME TIME. CHECK OUT THE TRUTH TABLES ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING 34 IN THE BLANK LED CELLS IN THE ADJACENT TABLE.

YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

## 4011 QUAD NAND GATE: WHEN NO IS YES AND YES IS NO

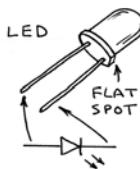
THIS CIRCUIT IS IDENTICAL TO THE PREVIOUS ONE WITH THE ADDITION OF A SECOND LED THAT IS ALWAYS AT THE OPPOSITE STATE OF THE FIRST LED. SINCE A NOT-NAND GATE IS AN AND GATE, THE SECOND LED ALLOWS THE NAND GATE TO FUNCTION AS AN AND GATE.

### PARTS YOU WILL NEED

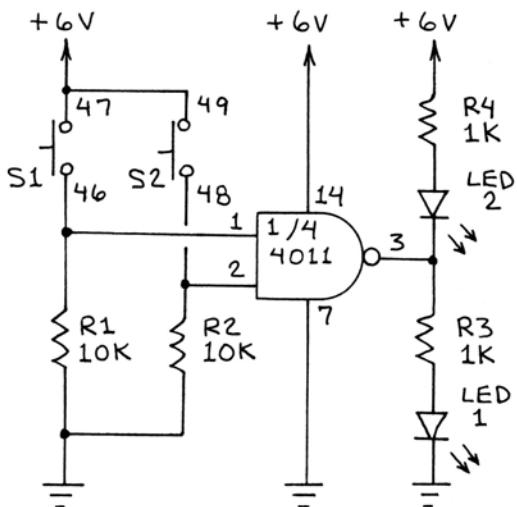
THE NAND GATE CIRCUIT ON PAGE 34 PLUS THESE PARTS:

R4-1K (BRN-BLK-RED)

LED 2-RED LED



### CIRCUIT DIAGRAM



ON-OFF TRUTH TABLE			
S1	S2	NAND LED 1	AND LED 2
OFF	OFF	ON	OFF
OFF	ON	ON	OFF
ON	OFF	ON	OFF
ON	ON	OFF	ON

HIGH-LOW TRUTH TABLE			
S1	S2	NAND LED 1	AND LED 2
L	L	H	L
L	H	H	L
H	L	H	L
H	H	L	H

POSITIVE LOGIC: OFF = LOW = 0 AND ON = HIGH = 1

LED 1 (GREEN) AND LED 2 (RED) ARE AT OPPOSITE STATES. WHEN ONE IS ON, THE OTHER MUST BE OFF.

### 1. MODIFY THE NAND GATE CIRCUIT ON PAGE 34

MODIFY THE NAND GATE CIRCUIT ON PAGE 34 FOLLOWING THESE STEPS:

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT R4 ACROSS G2 AND H7.
3.  INSERT RED LED 2 ACROSS G2 (ANODE) AND J2 (CATHODE).

### 2. TEST THE CIRCUIT

MAKE SURE THERE ARE NO ERRORS. THEN PUSH THE POWER SWITCH TO ON. NOW VERIFY THE TRUTH TABLE FOR LED 1 (NAND GATE) BY PRESSING S1 AND S2 AS SHOWN IN THE TRUTH TABLE. THEN VERIFY THE TRUTH TABLE FOR LED 2 (AND GATE) IN THE SAME MANNER. WHEN S1 AND S2 ARE OFF (OPEN), THE NAND GATE INPUTS ARE PULLED LOW THROUGH R1 AND R2. WHEN S1 AND S2 ARE ON (CLOSED), THE INPUTS ARE PULLED HIGH. THUS, IN THIS CIRCUIT, AN OPEN OR OFF SWITCH IS A LOGICAL LOW (0) AND A CLOSED OR ON SWITCH IS A LOGICAL HIGH (1).

### MORE ABOUT PULL-UP AND PULL-DOWN RESISTORS

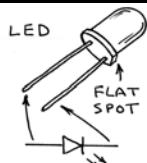
MANY LOGIC CIRCUITS THAT USE INPUT SWITCHES USE A RESISTOR TO KEEP A LOGIC INPUT EITHER HIGH OR LOW WHEN THE SWITCH IS NOT CLOSED. REMEMBER THAT A PULL-UP RESISTOR KEEPS THE INPUT HIGH. A PULL-DOWN RESISTOR KEEPS THE INPUT LOW. WITHOUT THE PULL-UP OR PULL-DOWN RESISTOR, AN UNCONNECTED CMOS INPUT WILL "FLOAT" AND BE TRIGGERED BY STRAY ELECTRICAL SIGNALS. THE EXACT RESISTANCE OF PULL-UP AND PULL-DOWN RESISTORS IS RARELY CRITICAL. WHILE THESE CIRCUITS USE 10K RESISTORS FOR R1 AND R2, THEY WILL WORK FINE WITH 4.7K OR 22K.

## 4011 QUAD NAND GATE: WHEN AND = OR AND NAND = NOR

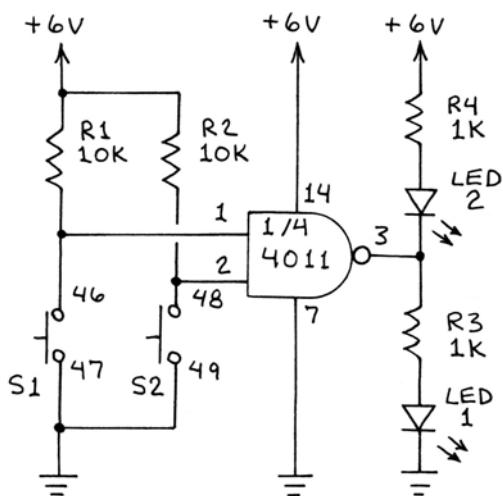
A POSITIVE LOGIC AND GATE IS EQUIVALENT TO A NEGATIVE LOGIC OR GATE. A POSITIVE LOGIC NAND GATE IS IDENTICAL TO A NEGATIVE LOGIC NOR GATE. YOU WILL APPLY NEGATIVE LOGIC INPUTS TO A NAND GATE TO CONVERT IT TO A POSITIVE LOGIC NOR GATE.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFICATION OF THE CIRCUIT ON PAGE 35. NO OTHER PARTS ARE REQUIRED.



### CIRCUIT DIAGRAM



POSITIVE LOGIC: CLOSED SWITCH = ON = HIGH = 1.  
NEGATIVE LOGIC: CLOSED SWITCH = ON = LOW = 0.  
NEGATIVE LOGIC NAND GATE = POSITIVE LOGIC NOR GATE.

ON-OFF TRUTH TABLE			
S1	S2	NOR (LED 2)	OR (LED 1)
OFF	OFF	ON	OFF
OFF	ON	OFF	ON
ON	OFF	OFF	ON
ON	ON	OFF	ON

BINARY TRUTH TABLE			
S1	S2	NOR (LED 2)	OR (LED 1)
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

### 1. MODIFY THE "NO IS YES" NAND GATE CIRCUIT ON PAGE 35

MODIFY THE NAND GATE CIRCUIT ON PAGE 35 BY FOLLOWING THESE STEPS:

- PUSH THE POWER SWITCH TO OFF.
- REMOVE R1 AND R2 FROM BETWEEN SPRINGS 46 AND 48 AND THE BREADBOARD.
- REMOVE BLUE WIRE FROM SPRING 49 TO V4 (+6V).
- INSERT R1 ACROSS H4 AND H8.
- INSERT R2 ACROSS I4 AND H9.
- CONNECT SPRING 49 TO GROUND (RED WIRE).

NOTE: LED 1 = GREEN AND LED 2 = RED

### 2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH TO ON. NEXT, VERIFY THE TRUTH TABLE FOR LED 2 (RED) BY PRESSING S1 AND S2 AS SHOWN IN THE TRUTH TABLE. THEN VERIFY THE TRUTH TABLE FOR LED 1 (GREEN) IN THE SAME MANNER. WHEN S1 AND S2 ARE OFF (OPEN), THE NAND GATE INPUTS ARE PULLED HIGH THROUGH R1 AND R2. WHEN S1 AND S2 ARE ON (CLOSED), THE INPUTS ARE PULLED LOW. THIS IN THIS CIRCUIT, AN OPEN OR OFF SWITCH IS LOGICAL HIGH (1) AND A CLOSED OR ON SWITCH IS LOGICAL LOW (0). THANKS TO NEGATIVE LOGIC, THE NAND GATE NOW FUNCTIONS AS A NOR GATE (LED 2) AND AN OR GATE (LED 1). BOTH NOR AND OR ARE MADE POSSIBLE BY CONNECTING THE LEDs TO + AND TO GROUND.

### TECH NOTE

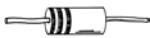
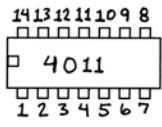
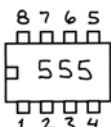
THE EQUIVALENCE OF THE POSITIVE LOGIC NAND GATE AND THE NEGATIVE LOGIC NOR GATE IS KNOWN AS DE MORGAN'S THEOREM. THE THEOREM COVERS ALL THE BASIC GATES.

36 (POSITIVE LOGIC OR GATE = NEGATIVE LOGIC AND GATE, ETC.).

## 4011 QUAD NAND GATE: MAKE A RED-GREEN ALTERNATING LED FLASHER

ALL THIS LOGIC STUFF CAN GET A LITTLE TEDIOUS, SO LET'S TAKE A BREAK TO HAVE A LITTLE FUN. THIS CIRCUIT SHOWS HOW TO MAKE A FULLY ADJUSTABLE RED-GREEN LED FLASHER BY USING A 555 PULSE GENERATOR TO SWITCH A NAND GATE OFF AND ON.

### PARTS YOU WILL NEED



R2, R4, R5-1K (BRN-BLK-RED)  
R3-100K (BRN-BLK-YEL)

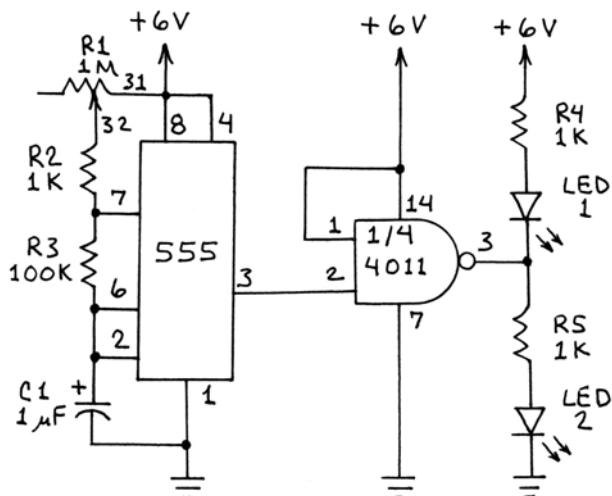


C1-1 uF



LED 1-RED LED  
LED 2-GREEN LED

### CIRCUIT DIAGRAM



### ABOUT THE CIRCUIT

THE 555 IS CONNECTED AS A VARIABLE RATE PULSE GENERATOR. PULSES FROM THE 555 ARE DELIVERED TO ONE INPUT OF THE 4011 NAND GATE. THE LEDs THEN FLASH ALTERNATELY DEPENDING ON THE LOGICAL STATUS OF THE INCOMING PULSES. INCREASING C1 TO 4.7 uF OR 10 uF WILL SLOW THE FLASH RATE. TO CHANGE THE DURATION OF THE FLASHES, REMOVE R3 AND USE RED WIRES TO CONNECT SPRINGS 34 AND 35 OF THE 100K CONSOLE POT IN ITS PLACE. ADJUST THE POT TO VARY THE DURATION OF THE PULSES.

GROUND UNUSED 4011 INPUTS (PINS 5, 6, 8, 9, 12, 13.)

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 555 ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT A5).
3.  INSERT THE 4011 IC ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT H5).
4.  INSERT R2 ACROSS B10 AND F10.
5.  INSERT R3 ACROSS B4 AND B7.
6.  CONNECT A1 TO GROUND (RED WIRE).
7.  CONNECT B3 TO C7 (WHT WIRE).
8.  CONNECT D4 TO A7 (WHT WIRE).
9.  CONNECT A10 TO V4 (+6V) (WHT WIRE).
10.  INSERT C1 ACROSS B2 (+) AND A2 (-).
11.  CONNECT SPRING 31 TO V4 (+6V) (RED WIRE).
12.  CONNECT SPRING 32 TO F6 (RED WIRE).
13.  CONNECT C2 TO I2 (WHT WIRE).
14.  CONNECT H4 TO H7 (WHT WIRE).
15.  CONNECT N1 TO GROUND (WHT WIRE).
16.  CONNECT H10 TO V4 (+6V) (WHT WIRE).
17.  CONNECT L1 TO GROUND (WHT WIRE).
18.  CONNECT M1 TO GROUND (WHT WIRE).
19.  CONNECT M10 TO GROUND (WHT WIRE).
20.  CONNECT N10 TO GROUND (WHT WIRE).
21.  CONNECT I10 TO GROUND (WHT WIRE).
22.  CONNECT J10 TO GROUND (WHT WIRE).
23.  INSERT R4 ACROSS G2 AND H8.
24.  INSERT RED LED 1 ACROSS G1 (ANODE) AND J1 (CATHODE).
25.  INSERT R5 ACROSS J4 AND T4.
26.  INSERT GREEN LED 2 ACROSS T5 (ANODE) AND GROUND (CATHODE).

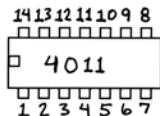
### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. WHEN EVERYTHING IS CORRECT, PUSH THE POWER SWITCH TO ON. THE LEDS WILL SWITCH ON AND OFF ALTERNATELY. ADJUST R1 TO VARY THE FLASH RATE. IF THE LEDS DO NOT FLASH, CAREFULLY COMPARE YOUR WIRING WITH THE CIRCUIT DIAGRAM. THE MOST LIKELY ERROR IS A MISSING OR INCORRECTLY INSTALLED WIRE OR COMPONENT.

## 4011 QUAD NAND GATE: MAKE INVERTERS AND BUFFERS USING NAND GATES

OFTEN A LOGIC CIRCUIT NEEDS AN EXTRA INVERTER (A "NOT" GATE) OR BUFFER ("YES" GATE). IF THE CIRCUIT HAS A 4011 WITH SOME UNUSED GATES, JUST TIE TOGETHER THE INPUTS OF A NAND GATE TO MAKE AN INVERTER. CONNECT TWO INVERTERS IN SERIES TO GET A BUFFER.

### PARTS YOU WILL NEED

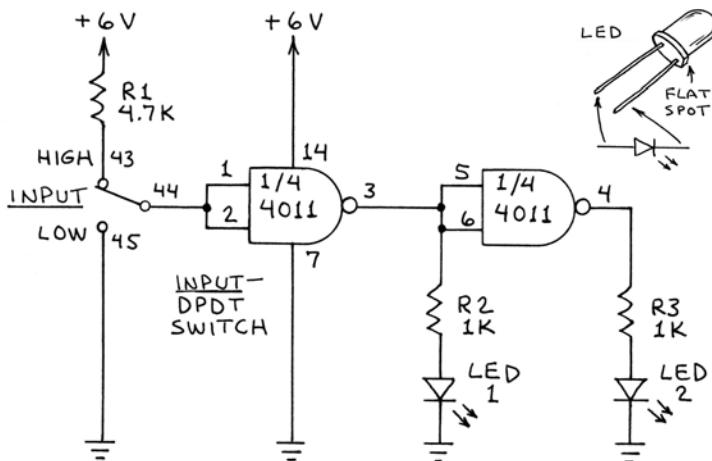


R1-4.7k (YEL-VLT-RED)  
R2, R3-1k (BRN-BLK-RED)



LED 1- GREEN LED  
LED 2- RED LED

### CIRCUIT DIAGRAM



**OUTPUTS:**  
LED 1 = GREEN  
LED 2 = RED

**POSITIVE LOGIC:**  
OFF = LOW = 0  
ON = HIGH = 1

<u>INPUT (DPDT SWITCH)</u>	<u>INVERTER (LED 1)</u>	<u>BUFFER (LED 2)</u>
L	H	L
H	L	H

GROUND 4011 UNUSED INPUTS (PINS 8, 9, 12 AND 13).

### 1. BUILD THE CIRCUIT

1.  PUSH POWER SWITCH TO OFF.
2.  INSERT 4011 ACROSS SLOT 1 (PIN 1 AT H5).
3.  CONNECT H1 AND I1 (WHT WIRE).
4.  CONNECT L1 AND M1 (WHT WIRE).
5.  CONNECT J4 TO L4 (WHT WIRE).
6.  CONNECT N1 TO GROUND (WHT WIRE).
7.  CONNECT H10 TO V4 (+6V) (RED WIRE).
8.  CONNECT I10 TO GROUND (WHT WIRE).
9.  CONNECT J10 TO GROUND (WHT WIRE).
10.  CONNECT M10 TO GROUND (WHT WIRE).
11.  CONNECT N10 TO GROUND (WHT WIRE).
12.  INSERT R1 ACROSS H8 AND H12.
13.  INSERT R2 ACROSS J1 AND S2.
14.  INSERT R3 ACROSS K4 AND T4.
15.  INSERT GREEN LED BETWEEN S1 (ANODE) AND GROUND (CATHODE).
16.  INSERT RED LED 2 BETWEEN T5 (ANODE) AND GROUND (CATHODE).
17.  CONNECT SPRING 43 TO H15 (RED WIRE).
18.  CONNECT SPRING 41 TO H3 (BLU WIRE).
19.  CONNECT SPRING 45 TO GROUND (RED WIRE).

### 2. TEST THE CIRCUIT

CHECK THE WIRING. IF ALL CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH ON. NOW CHECK THE TRUTH TABLE ABOVE. FIRST, PUSH THE DPDT SWITCH DOWN (LOW OR 0). GREEN LED 1 WILL GLOW, AND RED LED 2 WILL BE OFF. NOW PUSH THE DPDT SWITCH UP (HIGH OR 1). LED 1 WILL BE OFF, AND LED 2 WILL GLOW. THE PURPOSE OF R1 IS TO SHOW THAT THE LOGIC INPUT CAN BE APPLIED THROUGH A PULLUP RESISTOR.

### MORE ABOUT INVERTERS AND BUFFERS

THE LOGIC STATE AT THE OUTPUT OF A BUFFER IS THE SAME AS THE LOGIC STATE AT THE INPUT. BUFFERS HELP GATES DRIVE LEDs AND OTHER LOGIC CIRCUITS. THE LOGIC STATE AT THE OUTPUT OF AN INVERTER IS OPPOSITE THE LOGIC STATE AT THE INPUT.

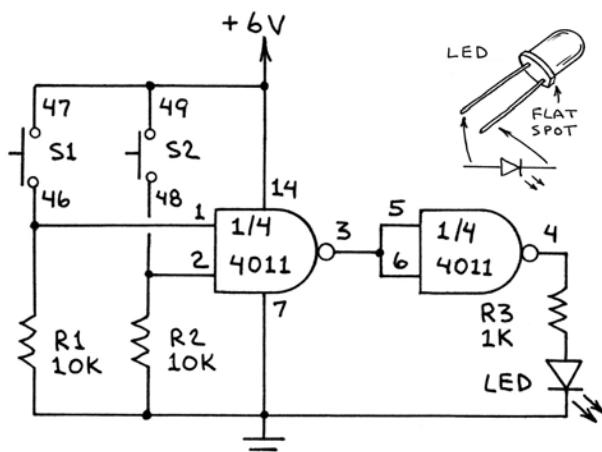
## 4011 QUAD NAND GATE: MAKE AN AND GATE FROM TWO NAND GATES

A NAND GATE CAN BE CONVERTED TO AN AND GATE BY ADDING AN INVERTER. YOU WILL MAKE AN INVERTER BY CONNECTING TOGETHER THE INPUTS OF A NAND GATE. YOU WILL THEN ADD THE INVERTER TO A NAND GATE TO MAKE AN AND GATE. YOU WILL USE TWO PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS TO THE GATE.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE 4011 NAND GATE CIRCUIT ON PAGE 34. NO OTHER PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 8, 9, 12 AND 13).

AND GATE		
IN 1	IN 2	OUT
L	L	L
L	H	L
H	L	L
H	H	H

THIS CIRCUIT		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

POSITIVE LOGIC: OFF = LOW = 0 AND ON = HIGH = 1

AS IN THE NAND GATE CIRCUIT, R1 AND R2 ARE PULL-DOWN RESISTORS THAT KEEP THE GATE INPUTS LOW WHEN S1 OR S2 ARE OPEN (OFF).

### 1. MODIFY THE NAND GATE CIRCUIT ON PAGE 34

MODIFY THE NAND GATE CIRCUIT ON PAGE 34 BY:

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE R3.
3.  REMOVE WHITE WIRE FROM L1 TO GROUND.
4.  REMOVE WHITE WIRE FROM M1 TO GROUND.
5.  CONNECT L1 TO M1 (WHT WIRE).
6.  CONNECT J4 TO L4 (WHT WIRE).
7.  INSERT R3 ACROSS K1 AND T1.

### 2. TEST THE CIRCUIT

INSPECT YOUR WIRING. IF THE CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH TO ON. THE LED SHOULD BE OFF SINCE BOTH INPUT SWITCHES ARE OFF (AND GATE: OFF AND OFF = OFF). WHEN YOU PRESS EITHER S1 OR S2, THE LED SHOULD ALSO BE OFF. ONLY WHEN YOU PRESS S1 AND S2 AT THE SAME TIME WILL THE LED GLOW. VERIFY THE TRUTH TABLE ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING IN THE BLANK LED CELLS IN THE ADJACENT TABLE.

YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

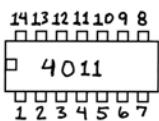
### GOING FURTHER

YOU CAN SHOW HOW THE OUTPUTS OF THE NAND AND THE AND GATES ARE ALWAYS OPPOSITE BY ADDING THE RED LED TO THE OUTPUT OF THE FIRST NAND GATE. INSTALL A 1K RESISTOR ACROSS J2 AND S2. THEN INSTALL THE RED LED ACROSS S3 AND GROUND.

## 4011 QUAD NAND GATE: HOW TO MAKE AN OR GATE

EVERY BASIC LOGIC FUNCTION CAN BE IMPLEMENTED BY USING NAND GATES OR NOR GATES. YOU WILL USE THREE OF THE NAND GATES IN A 4011 TO MAKE AN OR GATE. YOU WILL USE PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS TO THE GATE. AN LED WILL INDICATE THE GATE'S OUTPUT.

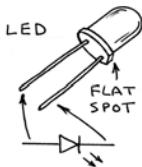
### PARTS YOU WILL NEED



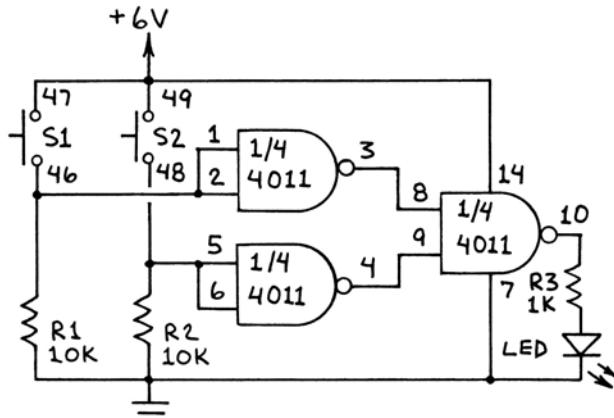
R1, R2-10K (BRN-BLK-ORG)  
R3-1K (BRN-BLK-RED)



GREEN LED



### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 12 AND 13).

OR GATE		
IN 1	IN 2	OUT
L	L	L
L	H	H
H	L	H
H	H	H

THIS CIRCUIT		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON

TO MONITOR ALL 3 GATES, CONNECT SPRING 12 TO J3 AND SPRING 14 TO K3 (BLU WIRES). CONNECT SPRINGS 11 AND 13 (WHT WIRES). CONNECT SPRING 11 TO GROUND (BLU WIRE).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4011 IC ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT H5).
3.  CONNECT N1 TO GROUND (WHT WIRE).
4.  CONNECT H10 TO V4 (+6V) (RED WIRE).
5.  INSTALL R1 ACROSS SPRING 46 AND GROUND.
6.  INSTALL R2 ACROSS SPRING 48 AND GROUND.
7.  INSTALL R3 ACROSS L7 AND T7.
8.  INSERT GREEN LED ACROSS T6 (ANODE) AND GROUND (CATHODE).
9.  CONNECT H1 TO I1 (WHT WIRE).
10.  CONNECT L1 TO M1 (WHT WIRE).
11.  CONNECT J4 TO N7 (WHT WIRE).
12.  CONNECT K4 TO M7 (WHT WIRE).
13.  CONNECT I10 TO GROUND (WHT WIRE).
14.  CONNECT J10 TO GROUND (WHT WIRE).
15.  CONNECT SPRING 46 TO H2 (BLU WIRE).
16.  CONNECT SPRING 48 TO L2 (BLU WIRE).
17.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
18.  CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF THE CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH ON. THE LED SHOULD BE OFF. (OR GATE: OFF + OFF = OFF). PRESS EITHER S1 OR S2, AND THE LED WILL GLOW. IT WILL ALSO GLOW WHEN YOU PRESS S1 AND S2 AT THE SAME TIME.

NOW CHECK THE TRUTH TABLE SHOWN ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING IN THE BLANK CELLS IN THE ADJACENT TABLE. DOES YOUR TABLE GIVE THE SAME RESULTS AS THE ONE ABOVE?

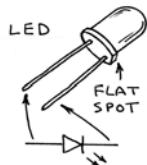
YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

## 4011 QUAD NAND GATE: HOW TO MAKE A NOR GATE

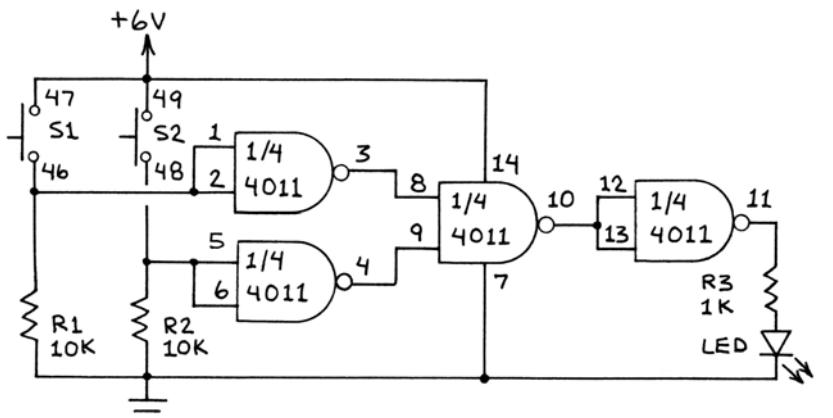
A POSITIVE LOGIC NAND GATE IS THE SAME AS A NEGATIVE LOGIC NOR GATE. A POSITIVE LOGIC NOR GATE REQUIRES ALL FOUR OF THE NAND GATES IN A 4011. YOU WILL BUILD A NOR GATE FROM NAND GATES AND USE PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS. AN LED WILL INDICATE THE GATE'S OUTPUT.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE OR GATE CIRCUIT ON THE PREVIOUS PAGE. NO ADDITIONAL PARTS ARE REQUIRED.



### CIRCUIT DIAGRAM



NOR GATE		
IN 1	IN 2	OUT
L	L	H
L	H	L
H	L	L
H	H	L

THIS CIRCUIT		
S1	S2	LED
OFF	OFF	ON
OFF	ON	OFF
ON	OFF	OFF
ON	ON	OFF

### 1. MODIFY THE OR GATE CIRCUIT

MODIFY THE OR GATE CIRCUIT ON THE PREVIOUS PAGE BY FOLLOWING THESE STEPS:

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE R3.
3.  REMOVE WHITE WIRE FROM J10 TO GROUND.
4.  REMOVE WHITE WIRE FROM J10 TO GROUND.
5.  CONNECT I10 TO J10 (WHT WIRE).
6.  CONNECT J9 TO L9 (WHT WIRE).
7.  INSERT R3 ACROSS K7 AND T7.

### 2. TEST THE CIRCUIT

INSPECT YOUR WIRING. IF THERE ARE NO ERRORS, PUSH THE POWER SWITCH TO ON. THE LED WILL BE ON. (NOR GATE: OFF + OFF = ON). WHEN YOU PRESS EITHER S1 OR S2, THE LED WILL BE OFF. IT WILL ALSO BE OFF WHEN YOU PRESS S1 AND S2 AT THE SAME TIME.

NOW CHECK THE TRUTH TABLE SHOWN ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING IN THE BLANK CELLS IN THE ADJACENT TABLE. DOES YOUR TABLE GIVE THE SAME RESULTS AS THE ONE ABOVE?

YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

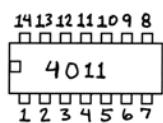
### GOING FURTHER

YOU CAN SHOW HOW THE OUTPUTS OF THE NOR GATE AND THE OR GATE ARE ALWAYS AT OPPOSITE STATES WHEN THE INPUT STATES ARE THE SAME BY ADDING THE RED LED TO THE INPUT OF THE FINAL NAND GATE. INSTALL A 1K RESISTOR ACROSS L10 AND S10. THEN INSTALL THE RED LED ACROSS S9 AND GROUND.

## 4011 QUAD NAND GATE: HOW TO MAKE AN EXCLUSIVE-OR GATE

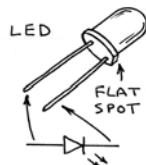
THE OUTPUT OF THE EXCLUSIVE-OR GATE GOES HIGH ONLY WHEN EITHER INPUT IS HIGH BUT NOT WHEN BOTH ARE HIGH. THE FOUR NAND GATES IN THE 4011 CAN BE CONNECTED AS AN EXCLUSIVE-OR GATE. YOU WILL BUILD AN EXCLUSIVE-OR GATE AND USE PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS TO THE GATE.

### PARTS YOU WILL NEED

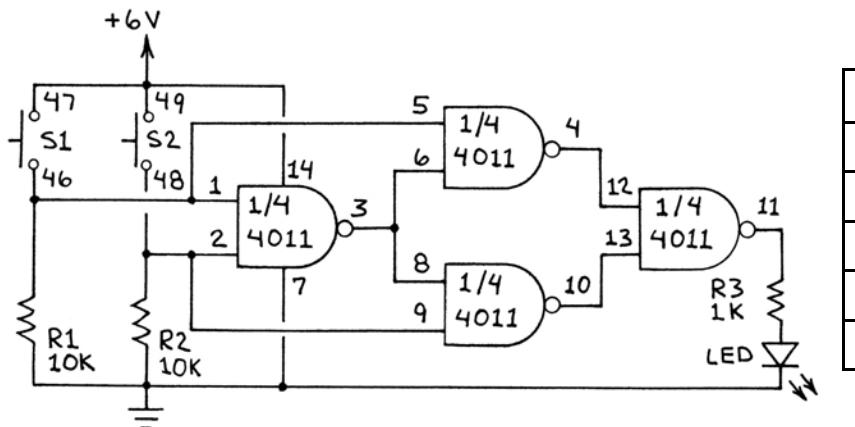


R1, R2-10K (BRN-BLK-ORG)  
R3-1K (BRN-BLK-RED)

GREEN LED



### CIRCUIT DIAGRAM



EX-OR GATE		
IN 1	IN 2	OUT
L	L	L
L	H	H
H	L	H
H	H	L

THIS CIRCUIT		
S1	S2	LED
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	OFF

### 1. BUILD THE CIRCUIT

- PUSH THE POWER SWITCH TO OFF.
- INSERT THE 4011 IC ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT H5).
- CONNECT N1 TO GROUND (WHT WIRE).
- CONNECT H10 TO V4 (+6V) (RED WIRE).
- INSTALL R1 ACROSS SPRING 46 AND GROUND.
- INSTALL R2 ACROSS SPRING 48 AND GROUND.
- INSTALL R3 ACROSS K7 AND T7.
- INSERT GREEN LED ACROSS T6 (ANODE) AND GROUND (CATHODE).
- CONNECT H1 TO L1 (WHT WIRE).
- CONNECT J1 TO M1 (WHT WIRE).
- CONNECT I4 TO M7 (WHT WIRE).
- CONNECT M4 TO N7 (WHT WIRE).
- CONNECT K4 TO J7 (WHT WIRE).
- CONNECT I10 TO L10 (WHT WIRE).
- CONNECT SPRING 46 TO H2 (BLU WIRE).
- CONNECT SPRING 48 TO I2 (BLU WIRE).
- CONNECT SPRINGS 47 AND 49 (WHT WIRE).
- CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. IF THE CONNECTIONS ARE CORRECT, PUSH THE POWER SWITCH TO ON. THE LED WILL BE OFF (EX-OR GATE: OFF + OFF = OFF). WHEN YOU PRESS EITHER S1 OR S2, BUT NOT BOTH S1 AND S2, THE LED WILL GLOW. OTHERWISE THE LED SHOULD BE OFF.

NOW CHECK THE TRUTH TABLE SHOWN ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING IN THE BLANK CELLS IN THE ADJACENT TABLE. DOES YOUR TABLE GIVE THE SAME RESULTS AS THE ONE ABOVE?

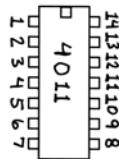
YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

## 4011 QUAD NAND GATE: HOW TO MAKE AN EXCLUSIVE-NOR GATE

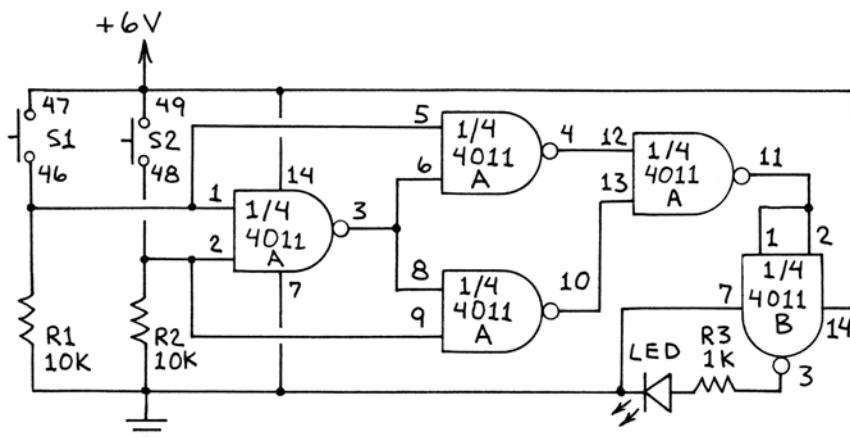
THE OUTPUT OF THE EXCLUSIVE-NOR GATE GOES LOW ONLY WHEN EITHER INPUT IS HIGH BUT NOT WHEN BOTH ARE HIGH. YOU WILL CONVERT THE EXCLUSIVE-OR GATE CIRCUIT ON THE PREVIOUS PAGE TO AN EXCLUSIVE-NOR GATE BY ADDING AN INVERTER STAGE. YOU WILL THEN USE PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS TO THE GATE.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE EX-OR GATE CIRCUIT ON THE PREVIOUS PAGE. YOU WILL NEED ONE ADDITIONAL 4011.



### CIRCUIT DIAGRAM



EX-NOR GATE		
IN 1	IN 2	OUT
L	L	H
L	H	L
H	L	L
H	H	H

THIS CIRCUIT		
S1	S2	LED
OFF	OFF	ON
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

GROUND UNUSED INPUTS OF 4011B (PINS 5, 6, 8, 9, 12 AND 13).

### 1. MODIFY THE EXCLUSIVE-OR GATE

MODIFY THE EX-OR GATE CIRCUIT ON THE PREVIOUS PAGE BY FOLLOWING THESE STEPS:

1.  REMOVE R3.
2.  INSERT THE SECOND 4011 (B) ACROSS SLOT 3 WITH PIN 1 AT H15.
3.  INSERT R3 ACROSS J11 AND T10.
4.  CONNECT N11 TO GROUND (WHT WIRE).
5.  CONNECT H20 TO V4 (+6V) (WHT WIRE).
6.  CONNECT K10 TO H11 (WHT WIRE).
7.  CONNECT H14 TO I14 (WHT WIRE).
8.  CONNECT L11 TO GROUND (WHT WIRE).
9.  CONNECT M11 TO GROUND (WHT WIRE).
10.  CONNECT M20 TO GROUND (WHT WIRE).
11.  CONNECT N20 TO GROUND (WHT WIRE).
12.  CONNECT I20 TO GROUND (WHT WIRE).
13.  CONNECT J20 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. THEN PUSH THE POWER SWITCH TO ON. THE LED WILL GLOW. IT WILL NOT GLOW WHEN YOU PRESS EITHER S1 OR S2. SINCE THIS IS AN EXCLUSIVE-OR GATE, THE LED WILL CONTINUE TO GLOW WHEN BOTH S1 AND S2 ARE PRESSED AT THE SAME TIME.

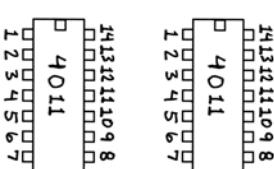
NOW CHECK THE TRUTH TABLE SHOWN ABOVE BY MAKING YOUR OWN TABLE OR BY FILLING IN THE BLANK LED CELLS IN THE ADJACENT TABLE. AND CONGRATULATIONS! IF YOU BUILT ALL THE 4011 PROJECTS SO FAR, THEN YOU HAVE DUPLICATED ALL THE BASIC LOGIC FUNCTIONS.

YOUR CIRCUIT		
S1	S2	LED
OFF	OFF	
OFF	ON	
ON	OFF	
ON	ON	

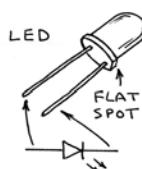
## 4011 QUAD NAND GATE: HOW TO MAKE A 4-INPUT NAND GATE

SO FAR WE HAVE EXPERIMENTED WITH GATES HAVING NO MORE THAN TWO INPUTS. THERE ARE MANY APPLICATIONS FOR GATES WITH MORE THAN TWO INPUTS. YOU WILL USE FIVE NAND GATES TO EXPAND A STANDARD 2-INPUT NAND GATE INTO A 4-INPUT NAND GATE. YOU WILL TEST THE GATE BY APPLYING INPUT SIGNALS WITH FOUR PUSHBUTTON SWITCHES.

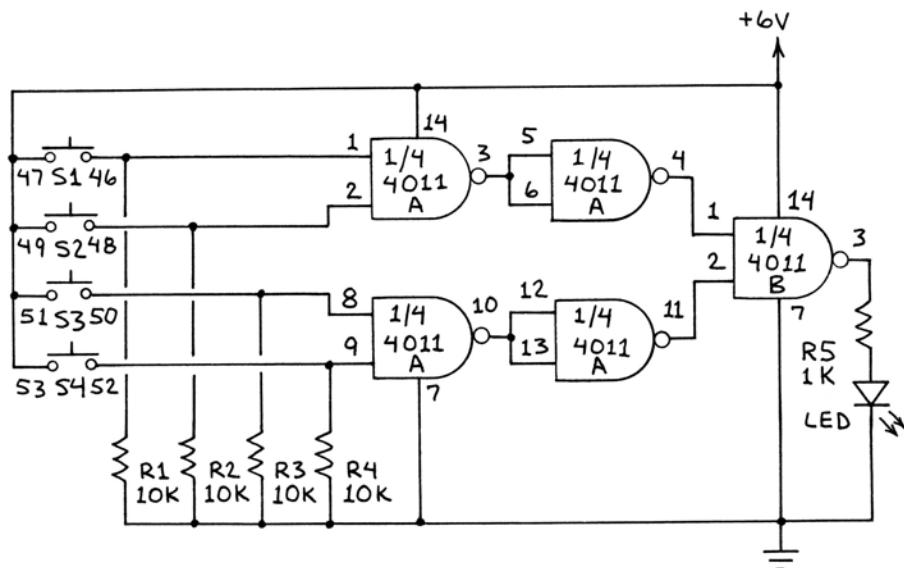
### PARTS YOU WILL NEED



R1, R2, R3, R4-10K (BRN-BLK-ORG)  
R5-1K (BRN-BLK-RED)



### CIRCUIT DIAGRAM



A 4-INPUT GATE HAS 16 INPUT COMBINATIONS. THE TRUTH TABLE FOR THIS 4-INPUT NAND GATE IS SHOWN ON THE NEXT PAGE. THE TRUTH TABLE CAN BE SUMMARIZED WITH THIS:

THE OUTPUT OF A 4-INPUT NAND GATE IS ALWAYS HIGH UNLESS ALL INPUTS ARE HIGH. THE OUTPUT IS THEN LOW.

GROUND UNUSED INPUTS OF 4011B (PINS 5, 6, 8, 9, 12 AND 13).

### 1. INSTALL AND CONNECT THE GATES FIRST

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT A 4011 (A) ACROSS SLOT 1 ON THE BREADBOARD (PIN 1 AT H5).
3.  INSERT A 4011 (B) ACROSS SLOT 3 ON THE BREADBOARD (PIN 1 AT H15).
4.  CONNECT N1 TO GROUND (WHT WIRE).
5.  CONNECT H10 TO V4 (+6V) (RED WIRE).
6.  CONNECT N11 TO GROUND (WHT WIRE).
7.  CONNECT H20 TO V4 (+6V) (WHT WIRE).
8.  INSTALL R1 ACROSS SPRING 46 AND GROUND.
9.  INSTALL R2 ACROSS SPRING 48 AND GROUND.
10.  INSTALL R3 ACROSS SPRING 50 AND GROUND.
11.  INSTALL R4 ACROSS SPRING 52 AND GROUND.
12.  INSERT R5 ACROSS J14 AND T14.
13.  INSERT GREEN LED ACROSS T15 (ANODE) AND GROUND (CATHODE).
14.  CONNECT L1 TO M1 (WHT WIRE).
15.  CONNECT I10 TO J10 (WHT WIRE).
16.  CONNECT J4 TO L4 (WHT WIRE).
17.  CONNECT J7 TO L7 (WHT WIRE).
18.  CONNECT K10 TO I11 (WHT WIRE).
19.  CONNECT K4 TO H11 (RED WIRE).
20.  CONNECT L11 TO GROUND (WHT WIRE).
21.  CONNECT M11 TO GROUND (WHT WIRE).
22.  CONNECT M20 TO GROUND (WHT WIRE).
23.  CONNECT N20 TO GROUND (WHT WIRE).
24.  CONNECT I20 TO GROUND (WHT WIRE).
25.  CONNECT J20 TO GROUND (WHT WIRE).

## 2. CONNECT THE INPUT SWITCHES NEXT

1.  CONNECT SPRING 46 TO H1 (BLU WIRE).
2.  CONNECT SPRING 48 TO I1 (BLU WIRE).
3.  CONNECT SPRING 50 TO M10 (BLU WIRE).
4.  CONNECT SPRING 52 TO N10 (BLU WIRE).
5.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
6.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
7.  CONNECT SPRINGS 51 AND 53 (WHT WIRE).
8.  CONNECT SPRING 53 TO V4 (+6V) (BLU WIRE).

## 3. TEST THE CIRCUIT

CHECK YOUR WIRING. IF THERE ARE NO ERRORS, CLOSE THE POWER SWITCH. THE LED WILL GLOW. THE LED WILL CONTINUE TO GLOW WHEN YOU PRESS ALL COMBINATIONS OF SWITCHES S1-S4 EXCEPT ONE. ONLY WHEN ALL FOUR SWITCHES ARE CLOSED (HIGH) IS THE LED OFF. AS YOU CAN SEE BELOW, THE TRUTH TABLE FOR THIS SIMPLE CIRCUIT IS HUGE. THAT'S BECAUSE A 4-INPUT GATE HAS FOUR TIMES AS MANY INPUT COMBINATIONS AS A 2-INPUT GATE. A 2-INPUT GATE HAS FOUR INPUT COMBINATIONS (BINARY 00, 01, 10, 11). A 4-INPUT GATE HAS 16 INPUT COMBINATIONS (BINARY 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111)

NOW IT'S YOUR TURN. VERIFY THE TRUTH TABLE FOR THE 4-INPUT NAND GATE SHOWN BELOW BY FILLING IN THE BLANK CELLS IN THE LAST TABLE.

4-INPUT NAND GATE				
IN 1	IN 2	IN 3	IN 4	OUT
L	L	L	L	H
L	L	L	H	H
L	L	H	L	H
L	L	H	H	H
L	H	L	L	H
L	H	L	H	H
L	H	H	L	H
L	H	H	H	H
H	L	L	L	H
H	L	L	H	H
H	L	H	L	H
H	L	H	H	H
H	H	L	L	H
H	H	L	H	H
H	H	H	L	H
H	H	H	H	L

THIS CIRCUIT				
S1	S2	S3	S4	LED
OFF	OFF	OFF	OFF	ON
OFF	OFF	OFF	ON	ON
OFF	OFF	ON	OFF	ON
OFF	OFF	ON	ON	ON
OFF	ON	OFF	OFF	ON
OFF	ON	OFF	ON	ON
OFF	ON	ON	OFF	ON
OFF	ON	ON	ON	ON
ON	OFF	OFF	OFF	ON
ON	OFF	OFF	ON	ON
ON	OFF	ON	OFF	ON
ON	OFF	ON	ON	ON
ON	ON	OFF	OFF	ON
ON	ON	OFF	ON	ON
ON	ON	ON	OFF	ON
ON	ON	ON	ON	ON

YOUR CIRCUIT				
S1	S2	S3	S4	LED
OFF	OFF	OFF	OFF	
OFF	OFF	OFF	ON	
OFF	OFF	ON	OFF	
OFF	OFF	ON	ON	
OFF	ON	ON	OFF	
OFF	ON	ON	ON	
OFF	ON	OFF	OFF	
OFF	ON	OFF	ON	
OFF	ON	ON	OFF	
OFF	ON	ON	ON	
ON	OFF	OFF	OFF	
ON	OFF	OFF	ON	
ON	OFF	ON	OFF	
ON	OFF	ON	ON	
ON	ON	OFF	OFF	
ON	ON	OFF	ON	
ON	ON	ON	OFF	
ON	ON	ON	ON	

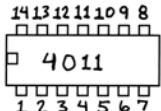
## GOING FURTHER

THINK OF SOME APPLICATIONS FOR THE 4-INPUT NAND GATE. ONE POSSIBILITY IS AN ALARM THAT MONITORS ALL FOUR DOORS IN A CAR AND SOUNDS A BUZZER WHEN A DOOR IS OPEN.

## 4011 NAND GATE: BUILD A SIMPLE TONE GENERATOR

FEEDBACK IN AN ANALOG CIRCUIT CAN CAUSE OSCILLATION. YOU CAN USE FEEDBACK IN A DIGITAL CIRCUIT TO DO THE SAME THING. HERE YOU WILL USE HALF THE GATES IN A 4011 TO MAKE A VERY SIMPLE AUDIO OSCILLATOR WITH SURPRISINGLY LOUD VOLUME.

### PARTS YOU WILL NEED

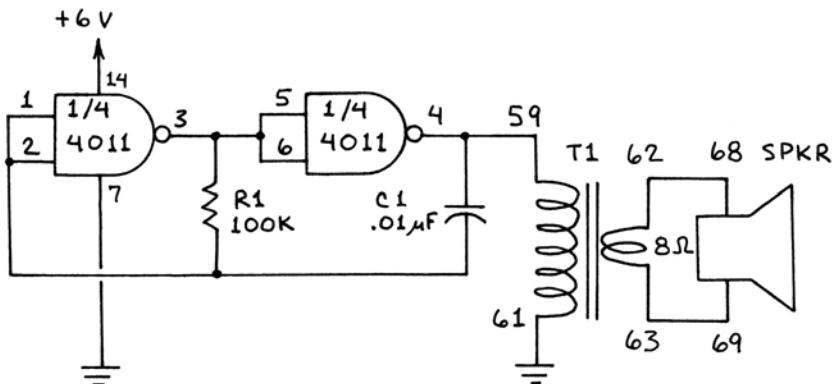


R1-100K (BRN-BLK-YEL)



C1-0.01 UF (103)

### CIRCUIT DIAGRAM



THE TRANSFORMER PREVENTS THE VERY LOW RESISTANCE OF THE SPEAKER (8 OHMS) FROM LOADING DOWN THE CIRCUIT AND POSSIBLY EVEN STOPPING ITS OSCILLATION.

GROUND UNUSED 4011 INPUTS (PINS 8, 9, 12 AND 13).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4011 ACROSS SLOT 4 (PIN 1 AT F20).
3.  INSERT R1 ACROSS F19 AND H19.
4.  INSERT C1 ACROSS G19 AND I19.
5.  CONNECT F16 TO G16 (WHT WIRE).
6.  CONNECT H17 TO J17 (WHT WIRE).
7.  CONNECT J16 TO K16 (WHT WIRE).
8.  CONNECT L19 TO GROUND (WHT WIRE).
9.  CONNECT K25 TO GROUND (WHT WIRE).
10.  CONNECT L25 TO GROUND (WHT WIRE).
11.  CONNECT G25 TO GROUND (WHT WIRE).
12.  CONNECT H25 TO GROUND (WHT WIRE).
13.  CONNECT F24 TO V4 (+6V) (RED WIRE).  
(A RED WIRE ALLOWS SOME CHANGES TO BE MADE LATER).
14.  CONNECT SPRING 59 TO I18 (RED WIRE).
15.  CONNECT SPRING 61 TO GROUND (RED WIRE).
16.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
17.  CONNECT SPRINGS 63 AND 69 (RED WIRE).

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS AND BE SURE THE LEADS OF C1 AND R1 DO NOT TOUCH. THEN PUSH THE POWER SWITCH ON. THE CONSOLE SPEAKER SHOULD EMIT A TONE WITH ENOUGH VOLUME TO BE EASILY HEARD SOME DISTANCE AWAY. TOO LOUD? THEN MOVE THE RED WIRE AT V4 (+6V) TO V3 (+4.5V) OR EVEN V2 (+3V). THIS REDUCES THE SUPPLY VOLTAGE AND LOWERS THE VOLUME.

### HOW THE CIRCUIT WORKS

ASSUME THE OUTPUT OF GATE 1 (PIN 3) IS HIGH. THIS MEANS THE OUTPUT OF GATE 2 (PIN 4) IS LOW. THE VOLTAGE AT PIN 3 THEN BEGINS CHARGING C1 THROUGH R1. BUT C1 IS ALSO CONNECTED TO THE INPUT OF GATE 1. EVENTUALLY THE CHARGE ON C1 BECOMES HIGH ENOUGH TO SWITCH GATE 1'S OUTPUT FROM HIGH TO LOW. THIS CAUSES GATE 2 TO CHANGE STATES, AND ITS OUTPUT GOES HIGH. NOW C1 IS DISCHARGED BY THE OUTPUT OF GATE 2. EVENTUALLY THE VOLTAGE AT C1 AND R1 BECOMES SO LOW THAT GATE 1 IS SWITCHED BACK TO ITS FORMER STATE. THIS BACK AND FORTH CYCLE THEN CONTINUES.

## 4011 NAND GATE: BUILD A BETTER TONE GENERATOR

YOU WILL MODIFY THE SIMPLE TONE GENERATOR ON PAGE 46 SO THE OSCILLATION FREQUENCY AND VOLUME CAN BE ADJUSTED. YOU WILL ALSO LEARN HOW TO SWITCH THE TONE GENERATOR ON AND OFF BY APPLYING A LOGIC SIGNAL TO ONE OF ITS GATE INPUTS.

## PARTS YOU WILL NEED

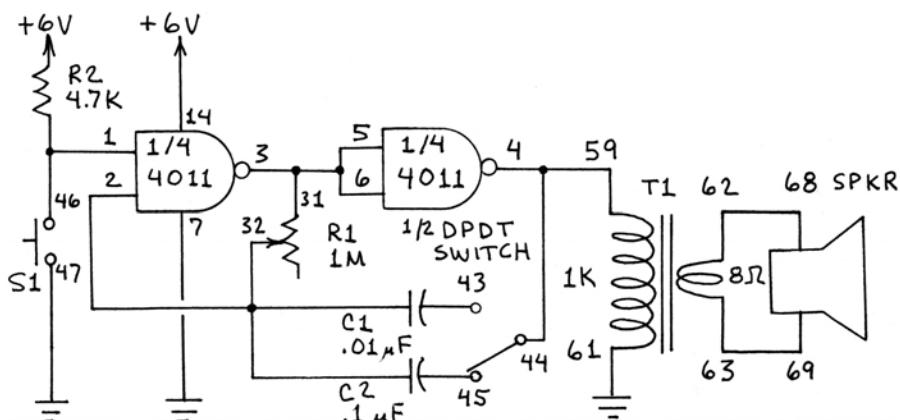
THE SIMPLE TONE GENERATOR ON  
PAGE 46 PLUS THESE PARTS:



R2-4.7K (YEL-VIO-RED)

C2-0.1 11F (104)

## CIRCUIT DIAGRAM



YOU CAN SLOW THE TONE  
TO A SERIES OF CLICKS  
BY REPLACING C1 WITH A  
10 UF CAPACITOR. INSERT  
THE + LEAD OF THE 10  
UF CAPACITOR AT G19  
AND THE - LEAD AT D19.

GROUND UNUSED 4011 INPUTS (PINS 8, 9, 12 AND 13).

#### 1. CONVERT THE TONE GENERATOR ON PAGE 46 INTO A BETTER TONE GENERATOR

1.  PUSH THE POWER SWITCH TO OFF.
  2.  REMOVE WHITE WIRE AT F16-G16.
  3.  REMOVE R1 AND C1.
  4.  INSERT R2 ACROSS F17 AND V4 (+6 V).
  5.  INSERT C1 ACROSS G19 AND D19.
  6.  INSERT C2 ACROSS G18 AND C18.
  7.  CONNECT SPRING 47 TO GROUND (RED WIRE).
  8.  CONNECT SPRING 46 TO F16 (RED WIRE).
  9.  CONNECT SPRING 43 TO D16 (BLU WIRE).
  10.  CONNECT SPRING 44 TO I16 (BLU WIRE).
  11.  CONNECT SPRING 45 TO C16 (BLU WIRE).
  12.  CONNECT SPRING 31 TO H16 (BLU WIRE).
  13.  CONNECT SPRING 32 TO G16 (BLU WIRE).

## 2. TEST THE CIRCUIT

INSPECT THE CIRCUIT FOR ERRORS. BE SURE ALL THE WIRES BETWEEN THE SPRINGS AND THE BREADBOARD ARE IN PLACE. PUSH THE DPDT SWITCH UP. THEN PUSH THE POWER SWITCH ON. THE CONSOLE SPEAKER SHOULD EMIT A TONE. ROTATE THE KNOB OF THE 1M CONSOLE POT (R1) TO CHANGE THE FREQUENCY OF THE TONE. NOW PUSH THE DPDT SWITCH DOWN. THE TONE WILL CHANGE TO A HUM OR BUZZ--WHICH IS A SLOW TONE. ADJUST R1 TO CHANGE THE FREQUENCY OF THE BUZZ. PRESS S1 TO DISABLE THE CIRCUIT.

## GOING FURTHER

SAVE THIS CIRCUIT! WE'RE GOING TO MAKE IT EVEN BETTER ON THE NEXT PAGE. MEANWHILE, HOW CAN YOU CONTROL THE TONE FREQUENCY WITH LIGHT? MOVE THE TWO BLUE WIRES AT SPRINGS 31 AND 32 TO SPRINGS 64 AND 65. THIS REPLACES THE 1M POTENTIOMETER WITH THE PHOTORESISTOR. THE CIRCUIT NOW RESPONDS TO LIGHT! THE TONE FREQUENCY INCREASES WHEN THE LIGHT INTENSITY AT THE PHOTORESISTOR INCREASES.

## 4011 NAND GATE: BUILD A PULSATING TONE GENERATOR

YOU WILL MODIFY THE BETTER TONE GENERATOR ON PAGE 47 SO THAT IT EMITS A PULSATING BUZZ OR TONE. YOU WILL USE TWO CONSOLE POTS TO CHANGE THE FREQUENCY AND PULSATION RATE. THIS MODIFICATION WILL USE THE TWO UNUSED GATES IN THE 4011.

## PARTS YOU WILL NEED

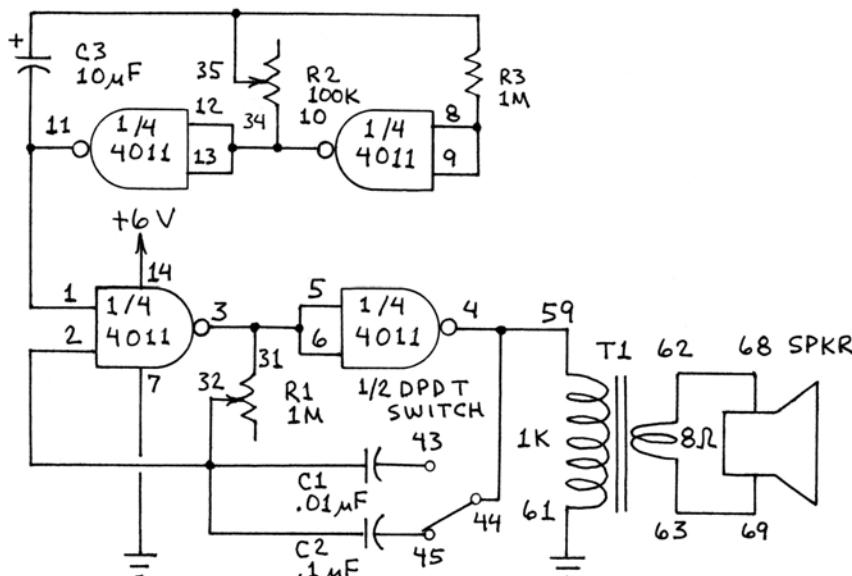
THE TONE GENERATOR ON  
PAGE 47 PLUS THESE PARTS:



R3-1M (BRN-BLK-GRN)

C3-10 UF

## CIRCUIT DIAGRAM



THE LOWER HALF OF THE CIRCUIT IS THE BETTER TONE GENERATOR YOU PREVIOUSLY BUILT (PAGE 47). THE TOP HALF OF THE CIRCUIT IS THE SAME CIRCUIT MODIFIED TO PRODUCE A MUCH SLOWER TRAIN OF PULSES. THE SLOW PULSES FROM THE UPPER PULSE GENERATOR SWITCH THE TONE OR BUZZ FROM THE LOWER PULSE GENERATOR ON AND OFF AT PIN 1.

1. CONVERT THE BETTER TONE GENERATOR ON PAGE 47 INTO A PULSATING TONE

1.  PUSH THE POWER SWITCH TO OFF.
  2.  REMOVE R2 FROM THE PREVIOUS CIRCUIT.
  3.  REMOVE RED WIRES BETWEEN SPRINGS 46 AND 47 AND THE BREADBOARD.
  4.  REMOVE WHT WIRE FROM G25 TO GROUND.
  5.  REMOVE WHT WIRE FROM H25 TO GROUND.
  6.  REMOVE WHT WIRE FROM K25 TO GROUND.
  7.  REMOVE WHT WIRE FROM L25 TO GROUND.
  8.  CONNECT G25 TO H25 (WHT WIRE).
  9.  CONNECT H24 TO J24 (WHT WIRE).
  10.  CONNECT K25 TO L25 (WHT WIRE).
  11.  CONNECT F19 TO I22 (WHT WIRE).
  12.  INSERT C3 ACROSS I25 (-) AND I26 (+).
  13.  INSERT R3 ACROSS L23 AND I28.
  14.  CONNECT SPRING 34 TO J22 (BLU WIRE).
  15.  CONNECT SPRING 35 TO I30 (BLU WIRE).

## 2. TEST THE CIRCUIT

EVERY PIN OF THE 4011 IC IS NOW CONNECTED TO AT LEAST ONE WIRE OR COMPONENT LEAD. SO BE SURE TO INSPECT THE CIRCUIT CAREFULLY. BE SURE EACH WIRE IS PUSHED ALL THE WAY INTO ITS BREADBOARD HOLE. THEN PUSH THE DPDT SWITCH DOWN AND ROTATE BOTH THE 1M (R1) AND 100K (R2) CONSOLE POTENTIOMETER KNOBS TO THEIR MIDPOINTS. NOW PUSH THE POWER SWITCH TO ON. YOU SHOULD HEAR AN INTERRUPTED BUZZ OR TONE. IF NOT, ROTATE THE 100K POT KNOB UNTIL YOU DO. ADJUST THE PULSE RATE BY ROTATING THE 100K POT'S KNOB. THEN ADJUST THE FREQUENCY OF THE SOUND BY ROTATING THE 1M POT'S KNOB. PUSH THE DPDT SWITCH UP TO REDUCE THE TONE FREQUENCY. YOU CAN MAKE THE CIRCUIT RESPOND TO LIGHT BY MOVING THE WIRES FROM ONE OF THE TWO POTS TO THE PHOTORESISTOR.

## 4049 HEX INVERTER: HOW THE LOGIC INVERTER WORKS

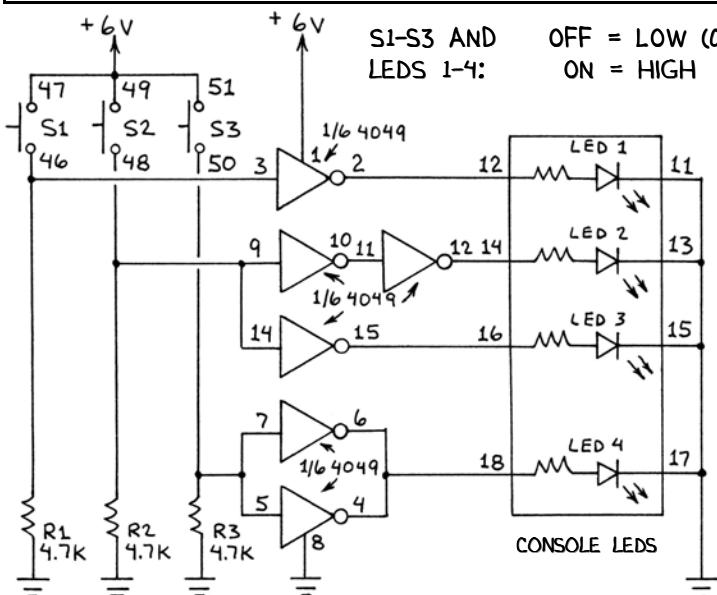
THIS PROJECT WILL INTRODUCE YOU TO THE VERY IMPORTANT 4049. YOU WILL BUILD A CIRCUIT THAT DEMONSTRATES THREE FUNCTIONS OF THE 4049. YOU WILL USE PUSHBUTTON SWITCHES TO APPLY LOGIC SIGNALS. LEDS WILL INDICATE THE OUTPUT OF EACH FUNCTION.

### PARTS YOU WILL NEED



R1, R2, R3-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



OFF = LOW (0)  
ON = HIGH  
THIS CIRCUIT SHOWS  
THAT THE INPUT AND  
THE OUTPUT OF THE  
INVERTER HAVE  
OPPOSITE STATES.

S1	LED 1
OFF	ON
ON	OFF

THIS CIRCUIT SHOWS  
HOW INVERTERS CAN BE  
CONNECTED IN SERIES  
AND USED TO EXPAND  
AN OUTPUT.

S2	LED 2	LED 3
OFF	OFF	ON
ON	ON	OFF

THIS CIRCUIT SHOWS  
HOW TO CONNECT 2  
INVERTERS IN PARALLEL  
TO INCREASE THE  
OUTPUT CURRENT.

S3	LED 4
OFF	ON
ON	OFF

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 ACROSS SLOT 3 (PIN 1 AT F15).
3.  CONNECT M11 TO GROUND (WHT WIRE).
4.  CONNECT F11 TO V4 (+6V) (WHT WIRE).
5.  CONNECT I11 TO K11 (WHT WIRE).
6.  CONNECT J11 TO L11 (WHT WIRE).
7.  CONNECT H20 TO M20 (WHT WIRE).
8.  CONNECT K20 TO L20 (WHT WIRE).
9.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
10.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
11.  CONNECT SPRING 51 TO V4 (+6V) (BLU WIRE).
12.  INSERT R1 ACROSS SPRING 46 AND GROUND.
13.  INSERT R2 ACROSS SPRING 48 AND GROUND.
14.  INSERT R3 ACROSS SPRING 50 AND GROUND.
15.  CONNECT SPRING 46 TO H13 (RED WIRE).
16.  CONNECT SPRING 48 TO M18 (RED WIRE).
17.  CONNECT SPRING 50 TO L13 (RED WIRE).
18.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
19.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
20.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
21.  CONNECT SPRING 17 TO GROUND (BLU WIRE).
22.  CONNECT SPRING 12 AND G13 (RED WIRE).
23.  CONNECT SPRING 14 AND J17 (RED WIRE).
24.  CONNECT SPRING 16 AND G17 (RED WIRE).
25.  CONNECT SPRING 18 AND I13 (RED WIRE).

### 2. TEST THE CIRCUIT

INSPECT THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. LEDS 1, 3 AND 4 WILL GLOW. THE TRUTH TABLES ABOVE SHOW HOW THIS PROJECT'S THREE GATE EXPERIMENTS WORK. THE INPUTS TO THE THREE CIRCUITS ARE PULLED LOW (0) BY RESISTORS R1, R2 AND R3. PRESSING A SWITCH PULLS AN INPUT HIGH (1). TEST THE TRUTH TABLES. ARE THEY CORRECT?

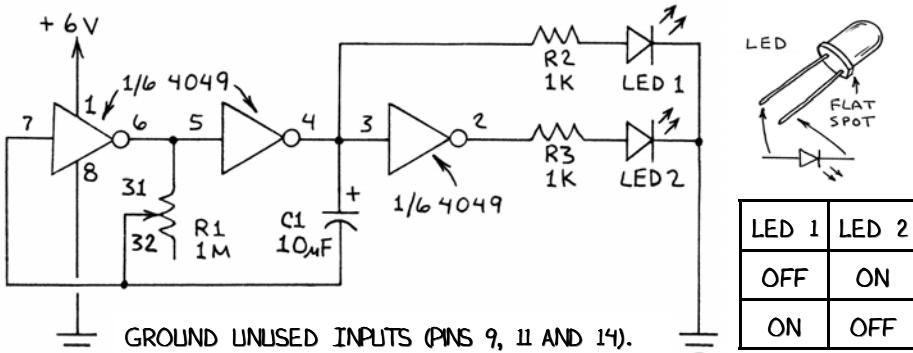
## 4049 HEX INVERTER: BUILD A DUAL LED FLASHER

A BASIC PULSE GENERATOR CAN BE MADE FROM ONLY TWO INVERTERS, WHICH MEANS A 4049 CAN PROVIDE THREE SEPARATE PULSE GENERATORS. YOU WILL BUILD A 2-INVERTER PULSE GENERATOR AND USE IT TO DRIVE A PAIR OF LEDs.

### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM



YOU CAN MAKE A SECOND FLASHER FROM THE THREE UNUSED INVERTERS IN THE 4049. CONNECT THE OUTPUTS TO CONSOLE LEDs. IF YOU CONNECT THEM OUT OF ORDER, THEY WILL APPEAR TO FLASH RANDOMLY.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 ACROSS SLOT 3 (PIN 1 AT F15).
3.  CONNECT M11 TO GROUND (WHT WIRE).
4.  CONNECT F11 TO V4 (+6V) (WHT WIRE).
5.  CONNECT H11 TO I11 (WHT WIRE).
6.  CONNECT J12 TO K12 (WHT WIRE).
7.  CONNECT SPRING 31 TO K11 (RED WIRE).
8.  CONNECT SPRING 32 AND L11 (RED WIRE).
9.  INSERT R2 ACROSS I14 AND T16.
10.  INSERT R3 ACROSS G11 AND T11.
11.  INSERT C1 ACROSS I13 (+) AND L13 (-).
12.  INSERT LED 1 ACROSS T18 (ANODE) AND GROUND (CATHODE).
13.  INSERT LED 2 ACROSS T13 (ANODE) AND GROUND (CATHODE).
14.  CONNECT H20 TO GROUND (WHT WIRE).
15.  CONNECT K20 TO GROUND (WHT WIRE).
16.  CONNECT M20 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ROTATE THE 1M CONSOLE POTENTIOMETER (R1) UNTIL THE LEDs FLASH ALTERNATELY. WHEN R1 IS ADJUSTED TO ITS FULL RESISTANCE OF 1M, THE LEDs WILL FLASH ONCE EVERY 2-3 SECONDS.

### ABOUT THE CIRCUIT

THE FIRST TWO INVERTERS FORM AN ASTABLE MULTIVIBRATOR. WHEN ONE INVERTER IS SWITCHED ON, THE OTHER IS SWITCHED OFF. THIS BASIC CIRCUIT WILL FLASH ONE LED. ADDING A THIRD INVERTER ALLOWS A SECOND LED TO GLOW WHEN LED 1 IS SWITCHED OFF.

### GOING FURTHER

WITH OR WITHOUT THE LEDs, THIS SIMPLE CIRCUIT IS HANDY ANY TIME A PULSE GENERATOR IS NEEDED. YOU CAN EASILY BUILD A PERMANENT VERSION OF THIS CIRCUIT. MOUNT THE PARTS ON A SMALL CIRCUIT BOARD AND CONNECT THEM TOGETHER USING WRAPPING WIRE. POWER THE CIRCUIT WITH A 9-VOLT BATTERY. SEE "GETTING STARTED IN ELECTRONICS" (RADIOSHACK)

## 4049 HEX INVERTER: BUILD A PULSATING TONE GENERATOR

TONE GENERATORS CAN BE MORE ATTENTION-GETTING WHEN THEY ARE OPERATED IN PULSES INSTEAD OF CONTINUOUSLY. YOU WILL MAKE A PULSATING TONE GENERATOR BY ADDING A BUZZER TO THE DUAL LED FLASHER CIRCUIT ON PAGE 50.

## PARTS YOU WILL NEED

THIS CIRCUIT REQUIRES THE  
4049 DUAL LED FLASHER PLUS:



R4-1K (BRN-BLK-RED)

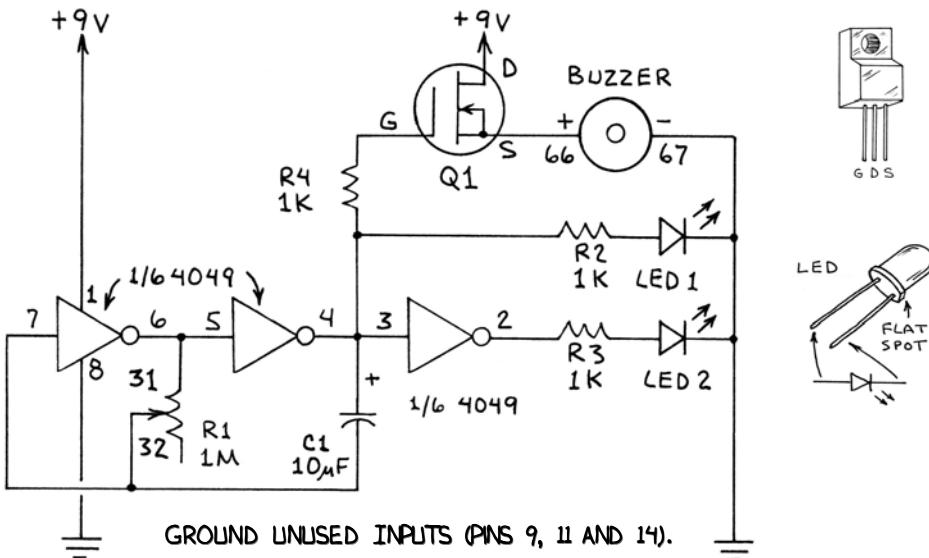


Q1-POWER MOSFET



10

## CIRCUIT DIAGRAM



THIS CIRCUIT WILL  
RESPOND TO LIGHT IF  
YOU CONNECT THE  
PHOTORESISTOR  
ACROSS R1. DO THIS:

- CONNECT SPRING 64 TO K14 (BLU WIRE).
  - CONNECT SPRING 65 AND L14 (BLU WIRE).

CHANGE THE PULSE RATE BY BLOCKING THE PHOTORESISTOR WITH YOUR FINGER.

## 1. MODIFY THE DUAL LED FLASHER CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
  2.  REMOVE WHT WIRE FROM F11 TO V4.
  3.  CONNECT F11 TO V6 (+9V) (RED WIRE).
  4.  INSERT R4 ACROSS H14 AND R16.
  5.  INSERT Q1 AT R18 (G), Q18 (D) AND P18 (S).
  6.  CONNECT Q20 TO V6 (+9V) (RED WIRE).
  7.  CONNECT SPRING 66 TO P20 (BLU WIRE).
  8.  CONNECT SPRING 67 TO GROUND (BLU WIRE).

## 2. TEST THE CIRCUIT

THIS REVISION TO THE DUAL LED FLASHER CIRCUIT CHANGES THE POWER SUPPLY FROM +6 TO +9 VOLTS (TO DRIVE THE BUZZER). SO BE SURE TO REMOVE ALL CONNECTIONS FROM +6 VOLTS WHEN YOU CHECK THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ROTATE THE 1M CONSOLE POTENTIOMETER (R1) UNTIL THE LEDs FLASH ALTERNATELY. THE BUZZER WILL SOUND EACH TIME LED 1 FLASHES. THE TONE FROM THE BUZZER IS LOUD. TO REDUCE ITS VOLUME, PLACE A STICKY LABEL OR PIECE OF TAPE OVER ITS APERTURE.

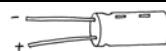
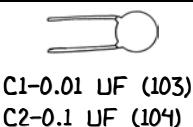
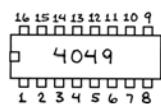
## GOING FURTHER

THE BUZZER IS SWITCHED ON BY Q1. THIS MEANS YOU CAN CONNECT THE BUZZER TO A DIFFERENT VOLTAGE THAN THE FLASHER CIRCUIT. TO REDUCE THE VOLUME OF THE BUZZER SIGNIFICANTLY, MOVE THE RED WIRE BETWEEN Q20 AND +9V TO +3 V. THE CONSOLE BUZZER HAS A BUILT-IN PULSE GENERATOR CIRCUIT. YOU CAN USE THE 4049 TO MAKE A SIMILAR PULSE GENERATOR THAT WILL DRIVE THE SPEAKER. THE ADVANTAGE OF USING THE 4049 IS THAT YOU WILL BE ABLE TO CONTROL THE FREQUENCY OF THE TONE.

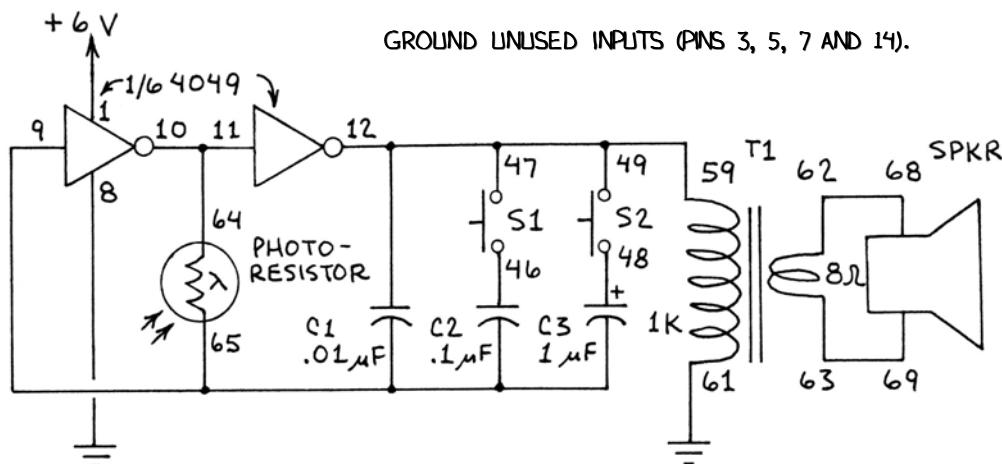
## 4049 HEX INVERTER: BUILD A LIGHT-CONTROLLED AUDIO OSCILLATOR

THE FREQUENCY OF THIS SIMPLE TONE GENERATOR IS CONTROLLED BY LIGHT. YOU WILL BUILD THE CIRCUIT AND EXPERIMENT WITH THE EFFECTS OF LIGHT ON ITS PERFORMANCE. YOU WILL ADD CAPACITORS (USING SWITCHES) TO REDUCE THE FREQUENCY OF THE TONE TO A BUZZ.

### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 3, 5, 7 AND 14).

YOU CAN SUBSTITUTE THE 1M CONSOLE POT FOR THE PHOTORESISTOR. JUST MOVE THE WIRE AT SPRING 64 TO SPRING 31. MOVE THE WIRE AT SPRING 65 TO SPRING 32. ADJUST THE 1M POT TO CHANGE THE TONE.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 ACROSS SLOT 3 (PIN 1 AT F15).
3.  CONNECT M11 TO GROUND (WHT WIRE).
4.  CONNECT F11 TO V4 (+6V) (WHT WIRE).
5.  CONNECT K20 TO L20 (WHT WIRE).
6.  INSERT C1 ACROSS J17 AND M17.
7.  INSERT C2 ACROSS M18 AND O18.
8.  INSERT C3 ACROSS M19 (-) AND P19 (+).
9.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
10.  CONNECT SPRING 47 TO J18 (RED WIRE).
11.  CONNECT SPRING 46 TO O16 (RED WIRE).
12.  CONNECT SPRING 48 TO P16 (RED WIRE).
13.  CONNECT SPRING 64 TO L19 (BLU WIRE).
14.  CONNECT SPRING 65 TO M20 (BLU WIRE).
15.  CONNECT SPRING 59 TO J20 (RED WIRE).
16.  CONNECT SPRING 61 TO GROUND (RED WIRE).
17.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
18.  CONNECT SPRINGS 63 AND 69 (RED WIRE).
19.  CONNECT H11 TO GROUND (WHT WIRE).
20.  CONNECT J11 TO GROUND (WHT WIRE).
21.  CONNECT L11 TO GROUND (WHT WIRE).
22.  CONNECT H17 TO GROUND (WHT WIRE).

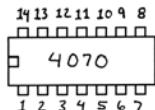
### 2. TEST THE CIRCUIT

CHECK YOUR WIRING. THEN PLACE A FINGER OVER THE PHOTORESISTOR APERTURE AND PUSH THE POWER SWITCH ON. YOU SHOULD HEAR A TONE FROM THE SPEAKER. MOVE YOUR FINGER SLIGHTLY TO ALLOW MORE LIGHT TO STRIKE THE PHOTORESISTOR. THIS WILL REDUCE ITS RESISTANCE AND CAUSE THE FREQUENCY OF THE TONE TO INCREASE NOTICEABLY. EXPERIMENT WITH DIFFERENT LIGHT LEVELS WHILE LISTENING TO THE TONE. NEXT, PRESS PUSHBUTTON S1. THIS WILL INCREASE THE CAPACITY IN THE OSCILLATOR CIRCUIT AND REDUCE THE TONE FREQUENCY SIGNIFICANTLY. PRESS S2 AND THE TONE WILL BECOME A BUZZ OR SERIES OF CLICKS. EXPERIMENT WITH DIFFERENT LIGHT LEVELS WHILE PRESSING S1 AND S2. OPERATE THE CIRCUIT UNDER VARIOUS KINDS OF LIGHTS. DO YOU NOTICE ANY DIFFERENCES? WHY?

## 4070 QUAD EXCLUSIVE-OR GATE: BUILD A BINARY HALF ADDER

THE TRUTH TABLE FOR THE EXCLUSIVE-OR GATE SHOWS THAT THIS GATE CAN DO VERY SIMPLE BINARY ADDITION. THIS PROJECT IS THE SIMPLEST POSSIBLE BINARY ADDER. THE NEXT PROJECT (PAGE 54) WILL ADD MORE CAPABILITY TO THIS BASIC CIRCUIT.

### PARTS YOU WILL NEED

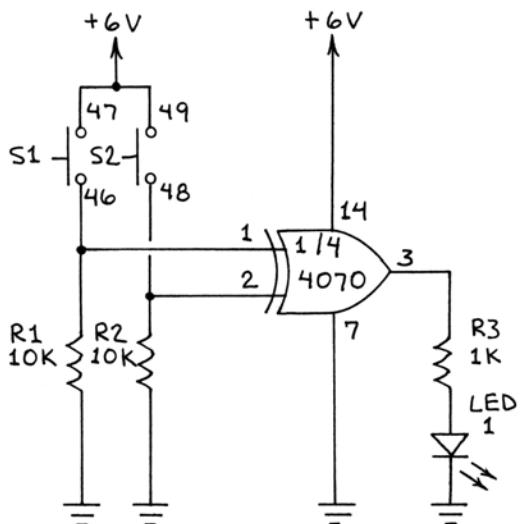


R1, R2-10K (BRN-BLK-ORG)  
R3-1K (BRN-BLK-RED)



LED 1-RED

### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS (PINS 5, 6, 8, 9, 12 AND 13.)

<u>S1</u>	<u>S2</u>	<u>LED 1</u>
LOW (OFF)	LOW (OFF)	LOW (OFF)
LOW (OFF)	HIGH (ON)	HIGH (ON)
HIGH (ON)	LOW (OFF)	HIGH (ON)
HIGH (ON)	HIGH (ON)	LOW (OFF)

LOGICAL 0 = LOW = OFF  
LOGICAL 1 = HIGH = ON

THIS TRUTH TABLE SHOWS THE OPERATION OF THE CIRCUIT. THE ONLY DIFFERENCE BETWEEN THIS GATE AND THE OR GATE IS THAT WHEN BOTH INPUTS ARE HIGH, THE OR GATE OUTPUT IS HIGH AND THE EXCLUSIVE-OR GATE OUTPUT IS LOW. AS YOU CAN SEE BELOW, ASSIGNING THE BINARY BITS 0 FOR LOW AND 1 FOR HIGH CONVERTS THE TRUTH TABLE INTO A SIMPLE BINARY ADDITION TABLE.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT 4070 IC OVER SLOT 3 (PIN 1 AT F15).
3.  INSERT R1 ACROSS F14 AND L14.
4.  INSERT R2 ACROSS G13 AND L13.
5.  INSERT R3 ACROSS Q20 AND H20.
6.  INSERT LED 1 ACROSS T18 (ANODE) AND GROUND (CATHODE).
7.  CONNECT H14 TO Q18 (+6V) (WHT WIRE).
8.  CONNECT L11 TO GROUND (WHT WIRE).
9.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
10.  CONNECT SPRING 46 TO F12 (RED WIRE).
11.  CONNECT SPRING 48 TO G12 (RED WIRE).
12.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
13.  CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).
14.  CONNECT J11 TO K11 (WHT WIRE).
15.  CONNECT K12 TO GROUND (WHT WIRE).
16.  CONNECT G20 TO H20 (WHT WIRE).
17.  CONNECT K20 TO L20 (WHT WIRE).
18.  CONNECT H19 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

MAKE SURE THERE ARE NO ERRORS. THEN PUSH THE POWER SWITCH ON. LED 1 WILL BE OFF. PRESS S1 OR S2 AND LED 1 WILL GLOW. PRESS BOTH S1 AND S2 AND LED 1 WILL SWITCH OFF AGAIN. HERE'S THE BINARY ADDITION TRUTH TABLE:

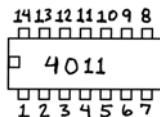
<u>S1</u>	<u>S2</u>	<u>OUT</u>
0	0	$0 + 0 = 0$
0	1	$0 + 1 = 1$
1	0	$1 + 0 = 1$
1	1	$1 + 1 = 10$

1 + 1 = 10 (BINARY).  
BUT 1 + 1 = 0 IN  
THIS CIRCUIT. THERE  
IS ONLY ONE LED—SO  
THE CIRCUIT IS ONLY  
← A "HALF ADDER."

## 4070 QUAD EXCLUSIVE-OR GATE: BUILD A BINARY FULL ADDER

THIS CIRCUIT ADDS TWO BINARY BITS AND INDICATES THE FULL TOTAL USING TWO LEDs. BINARY ADDERS LIKE THIS ARE KEY BUILDING BLOCKS FOR THE ARITHMETIC-LOGIC UNITS OF DIGITAL CALCULATORS AND COMPUTERS. SO BE SURE TO TRY THIS PROJECT.

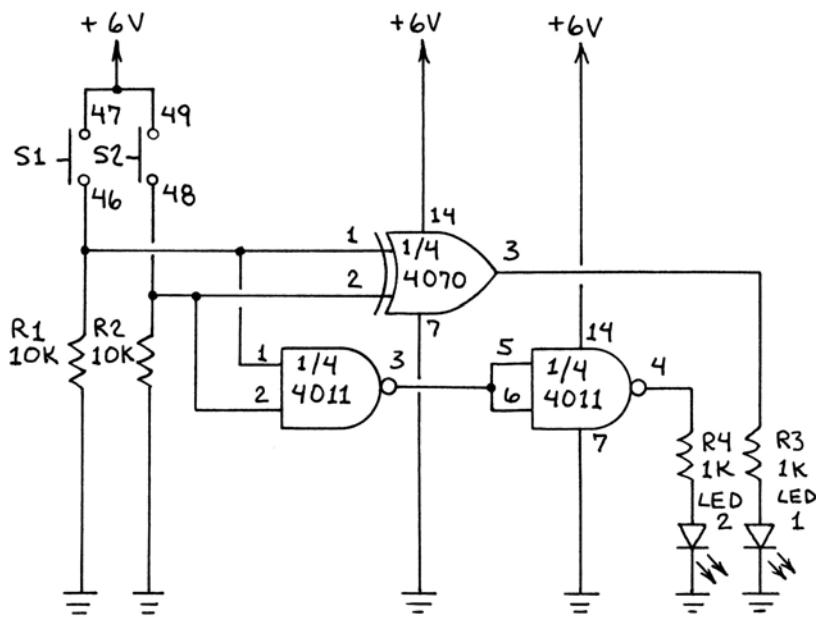
### PARTS YOU WILL NEED



R4-1K (BRN-BLK-RED)

LED 2-GREEN LED

### CIRCUIT DIAGRAM



INPUTS		OUTPUTS	
S1	S2	LED 2	LED 1
OFF	OFF	OFF	OFF
OFF	ON	OFF	ON
ON	OFF	OFF	ON
ON	ON	ON	OFF

LET OFF = 0 AND ON = 1. THE CIRCUIT IS NOW A FULL ADDER:

S1	S2	LED 2	LED 1	ADDER:
0	0	0	0	0 + 0 = 0 0
0	1	0	1	0 + 1 = 0 1
1	0	0	1	1 + 0 = 0 1
1	1	1	0	1 + 1 = 1 0

GROUND UNUSED INPUTS OF 4070 (PINS 5, 6, 8, 9, 12 AND 13) AND 4011 (PINS 8, 9, 12 AND 13).

### 1. CONVERT THE HALF ADDER TO A FULL ADDER

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT 4011 IC OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT R4 ACROSS Q12 AND T12.
4.  INSERT LED 2 ACROSS T15 (ANODE) AND GROUND (CATHODE).
5.  CONNECT F4 TO F11 (WHT WIRE).
6.  CONNECT G4 TO G11 (WHT WIRE).
7.  CONNECT J1 TO K1 (WHT WIRE).
8.  CONNECT H2 TO J2 (WHT WIRE).
9.  CONNECT L1 TO GROUND (WHT WIRE).
10.  CONNECT F10 TO V4 +6V) (WHT WIRE).
11.  CONNECT I4 TO Q11 (WHT WIRE).
12.  CONNECT G7 TO H7 (WHT WIRE).
13.  CONNECT H10 TO GROUND (WHT WIRE).
14.  CONNECT K7 TO L7 (WHT WIRE).
15.  CONNECT L10 TO GROUND (WHT WIRE).

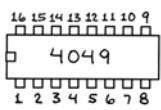
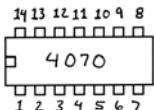
### 2. TEST THE CIRCUIT

CHECK FOR ERRORS AND BE SURE THAT THE HALF ADDER PORTION OF THE CIRCUIT IS OK. PUSH THE POWER SWITCH ON. BOTH LEDs WILL BE OFF. PRESS S1 OR S2, AND LED 1 WILL GLOW. PRESS BOTH S1 AND S2 AND ONLY LED 2 WILL GLOW. THE TRUTH TABLES ABOVE SHOW THE RESULTS THAT YOU SHOULD GET. SEE THE HALF ADDER TRUTH TABLES ALSO. NETWORKS OF CIRCUITS EXACTLY LIKE THIS ONE ARE USED IN DIGITAL COMPUTERS TO ADD AND MULTIPLY. TO MULTIPLY 6 X 4, THE ADDER ADDS 6 TO ITSELF 4 TIMES ( $6 + 6 + 6 + 6 = 24$ ).

## 4070 QUAD EXCLUSIVE-OR GATE: BUILD A PHASE DETECTOR

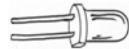
YOU WILL USE AN EXCLUSIVE-OR GATE TO COMPARE THE FLUCTUATING SIGNALS FROM TWO OSCILLATORS AND INDICATE WHEN THEY ARE IN PHASE.

### PARTS YOU WILL NEED



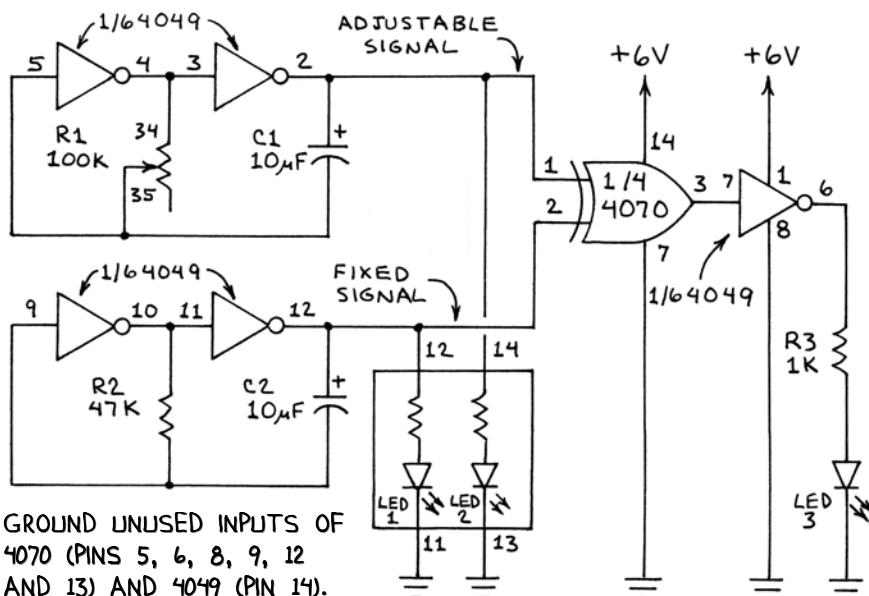
R2-47K (YEL-VIO-ORG)  
R3-1K (BRN-BLK-RED)

C1, C2-10 UF



LED 3-GREEN LED

### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS OF  
4070 (PINS 5, 6, 8, 9, 12  
AND 13) AND 4049 (PIN 10).

### 3. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. LED 1 WILL BLINK ABOUT ONCE PER SECOND. CAREFULLY ADJUST THE 100K CONSOLE POT (R1) UNTIL LED 2 BLINKS AT THE SAME RATE AS LED 1. THIS MAY TAKE A MINUTE OR SO. WHEN BOTH LEDs FLASH IN STEP, LED 3 WILL STOP FLICKERING AND GLOW CONTINUALLY. LED 3 GLOWS STEADILY ONLY WHEN PULSES FROM THE TWO OSCILLATORS ARE IN PERFECT PHASE. SO IT IS TRICKY TO GET LED 3 TO GLOW CONTINUOUSLY.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT 4070 IC OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT 4049 IC OVER SLOT 3 (PIN 1 AT F15).
4.  INSERT R2 ACROSS L18 AND M18.
5.  INSERT R3 ACROSS K14 AND T14.
6.  INSERT C1 ACROSS G13 (+) AND J13 (-).
7.  INSERT C2 ACROSS J19 (+) AND M19 (-).
8.  INSERT LED 3 ACROSS T15 (ANODE) AND GROUND (CATHODE).
9.  CONNECT L1 TO GROUND (WHT WIRE).
10.  CONNECT M11 TO GROUND (WHT WIRE).
11.  CONNECT F10 TO V4 (+6V) (WHT WIRE).
12.  CONNECT F14 TO V4 (+6V) (WHT WIRE).
13.  CONNECT H11 TO I11 (WHT WIRE).
14.  CONNECT K20 TO L20 (WHT WIRE).
15.  CONNECT H4 TO L11 (WHT WIRE).
16.  CONNECT F4 TO G14 (WHT WIRE).
17.  CONNECT G4 TO J17 (RED WIRE).
18.  CONNECT SPRING 34 TO I12 (RED WIRE).
19.  CONNECT SPRING 35 TO J12 (RED WIRE).
20.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
21.  CONNECT SPRING 13 TO GROUND (BLU WIRE).
22.  CONNECT SPRING 12 TO J18 (RED WIRE).
23.  CONNECT SPRING 14 TO G12 (RED WIRE).

### 2. GROUND THE UNUSED INPUTS

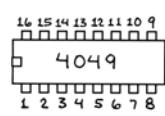
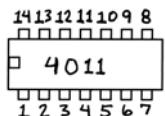
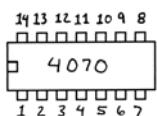
1.  CONNECT J1 TO GROUND (WHT WIRE).
2.  CONNECT K1 TO GROUND (WHT WIRE).
3.  CONNECT K7 TO GROUND (WHT WIRE).
4.  CONNECT L7 TO GROUND (WHT WIRE).
5.  CONNECT G7 TO K8 (WHT WIRE).
6.  CONNECT H7 TO K9 (WHT WIRE).
7.  CONNECT H20 TO GROUND (WHT WIRE).

BE SURE THE WIRES TO THE 100K CONSOLE POT AND OTHER WIRES DO NOT COME LOOSE.

## 4070 QUAD EXCLUSIVE-OR GATE: BUILD A 4-BIT COMPARATOR DIGITAL LOCK

DIGITAL COMPARATORS ARE IMPORTANT BUILDING BLOCKS IN COMPUTERS AND MANY OTHER DIGITAL SYSTEMS. THIS CIRCUIT USES A 4-BIT COMPARATOR AS A DIGITAL COMBINATION LOCK. YOU WILL PROGRAM THE CIRCUIT WITH A 4-BIT BINARY CODE (0000 TO 1111). THE LED GLOWS ONLY WHEN YOU ENTER THE EXACT CODE INTO THE FOUR PUSHBUTTON SWITCHES.

### PARTS YOU WILL NEED

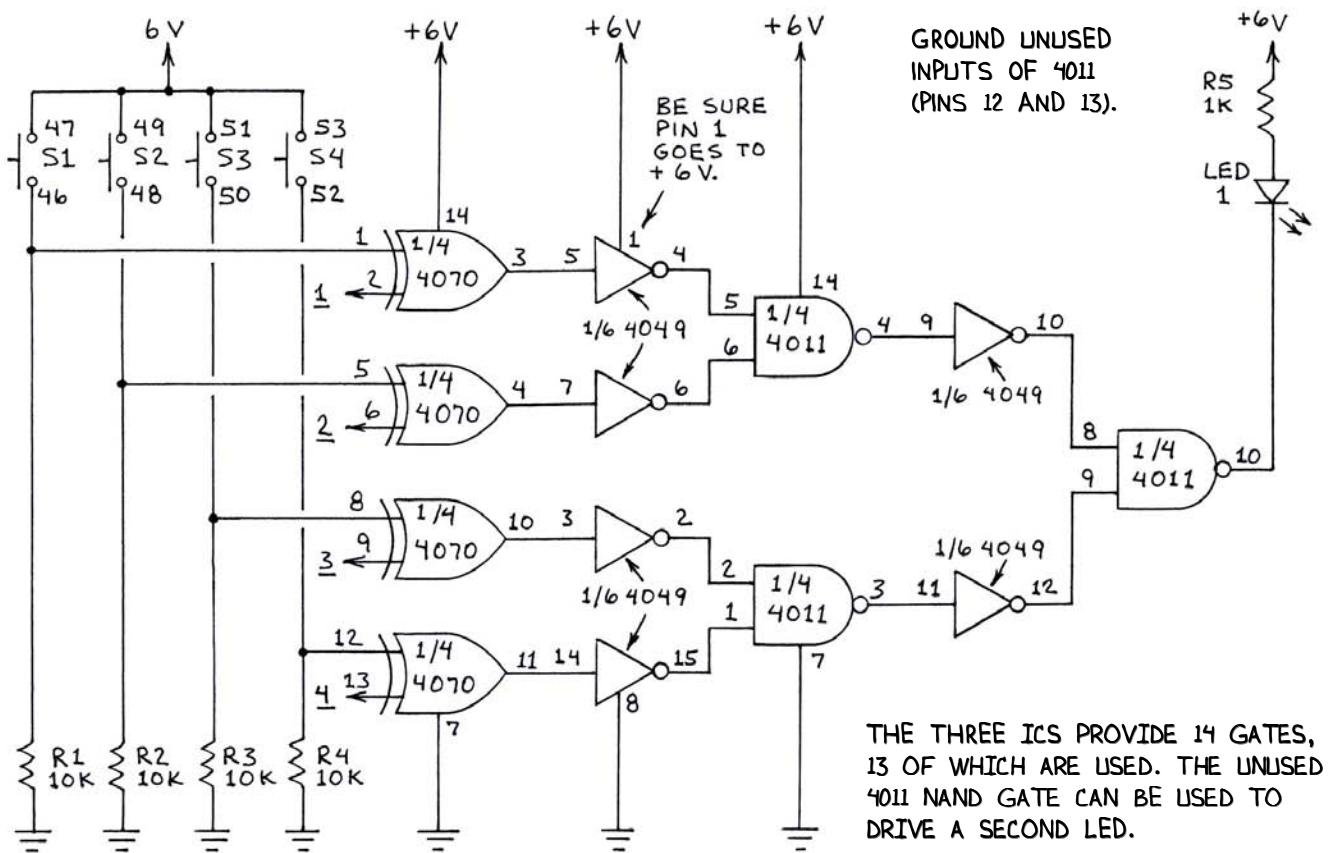


R1-R4-10K (BRN-BLK-ORG)  
R5-1K (BRN-BLK-RED)



LED 1-GREEN

### CIRCUIT DIAGRAM



### ABOUT THE CIRCUIT

A SINGLE EXCLUSIVE-OR GATE CAN FUNCTION BOTH AS A BINARY HALF ADDER AND A 1-BIT COMPARATOR. THE COMPARATOR FUNCTION MAKES THIS 4-BIT COMPARATOR PROJECT POSSIBLE. IN OPERATION, THE EXCLUSIVE-OR GATE COMPARES THE LOGIC STATES AT ITS TWO INPUTS. ONLY WHEN BOTH INPUTS ARE THE SAME DOES THE OUTPUT GO LOW (0). OTHERWISE THE OUTPUT STAYS HIGH (1). AN EXCLUSIVE-NOR GATE DOES THE SAME THING EXCEPT THE OUTPUTS ARE REVERSED SO THAT 0 AND 0 OR 1 AND 1 CAUSE THE OUTPUT TO GO HIGH (1). IN THE 4-BIT COMPARATOR ABOVE, THE EXCLUSIVE-OR GATES ARE CONVERTED TO EXCLUSIVE-NOR GATES WITH 4049 INVERTERS. THE ARROWS MARKED 1-4 AT THE INPUTS OF THE 4 EXCLUSIVE-OR GATES ARE FOR PROGRAMMING THE CIRCUIT.

1-BIT COMPARATOR		
S1	S2	OUT
0	0	0
0	1	1
1	0	1
1	1	0

## 1. INSTALL RESISTORS AND WIRES

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT 4070 IC OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT 4049 IC OVER SLOT 3 (PIN 1 AT F15).
4.  INSERT 4011 IC OVER SLOT 5 (PIN 1 AT F25).
5.  INSERT R1 ACROSS F1 AND L3.
6.  INSERT R2 ACROSS J1 AND GROUND.
7.  INSERT R3 ACROSS L10 AND GROUND.
8.  INSERT R4 ACROSS H7 AND L4.
9.  INSERT R5 ACROSS D30 AND F30.
10.  INSERT LED 1 ACROSS D28 (ANODE) AND J28 (CATHODE).
11.  CONNECT H4 TO J11 (WHT WIRE).
12.  CONNECT I4 TO L11 (WHT WIRE).
13.  CONNECT J10 TO H11 (WHT WIRE).
14.  CONNECT I10 TO H17 (WHT WIRE).
15.  CONNECT I14 TO J21 (WHT WIRE).
16.  CONNECT K14 TO K21 (WHT WIRE).
17.  CONNECT G14 TO G21 (WHT WIRE).
18.  CONNECT G20 TO F21 (WHT WIRE).
19.  CONNECT I21 TO M20 (WHT WIRE).
20.  CONNECT H21 TO K20 (WHT WIRE).
21.  CONNECT L20 TO L27 (WHT WIRE).

## 2. CONNECT POWER AND SWITCHES

1.  CONNECT J20 TO K27 (WHT WIRE).
2.  CONNECT L1 TO GROUND (WHT WIRE).
3.  CONNECT M11 TO GROUND (WHT WIRE).
4.  CONNECT L24 TO GROUND (WHT WIRE).
5.  CONNECT F10 TO V4 (+ 6V) (WHT WIRE).
6.  CONNECT F14 TO V4 (+ 6V) (WHT WIRE).
7.  CONNECT F27 TO V4 (+ 6V) (WHT WIRE).
8.  CONNECT SPRING 46 TO F4 (BLU WIRE).
9.  CONNECT SPRING 48 TO J4 (BLU WIRE).
10.  CONNECT SPRING 50 TO L9 (BLU WIRE).
11.  CONNECT SPRING 52 TO H9 (BLU WIRE).
12.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
13.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
14.  CONNECT SPRINGS 51 AND 53 (WHT WIRE).
15.  CONNECT SPRING 53 TO V4 (+6V) (BLU WIRE).
16.  CONNECT H30 TO GROUND (RED WIRE).
17.  CONNECT G30 TO GROUND (RED WIRE).
18.  INSERT A VERTICAL RED WIRE AT G2.
19.  INSERT A VERTICAL RED WIRE AT K2.
20.  INSERT A VERTICAL RED WIRE AT K7.
21.  INSERT A VERTICAL RED WIRE AT G7.

## 3. PROGRAM THE CIRCUIT

THIS CIRCUIT COMPARES A 4-BIT BINARY WORD THAT YOU MANUALLY PROGRAM INTO THE CIRCUIT WITH THE 4-BIT BINARY WORD ENTERED INTO THE PUSHBUTTON SWITCHES. WHEN THE TWO ARE IDENTICAL, THE LED GLOWS. PROGRAM THE CIRCUIT BY CONNECTING EACH OF THE FOUR VERTICAL RED WIRES TO EITHER 0 (GROUND) OR 1 (+6V). A 4-BIT WORD HAS 16 COMBINATIONS, ANY OF WHICH YOU CAN SELECT. LET'S TRY 1010. THE TRUTH TABLE SHOWS PROGRAM WIRES 1 AND 3 SHOULD GO TO +6V. PROGRAM WIRES 2 AND 4 SHOULD GO TO GROUND. JUST PLUG THE WIRES INTO ANY AVAILABLE +6V AND GROUND POINTS. IF YOU NEED EXTRA +6V POINTS, SOME ARE AVAILABLE ADJACENT TO PIN 1 OF THE 4049 IC.

## 4. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. THEN PUSH THE POWER SWITCH ON. THE LED SHOULD BE OFF (UNLESS YOU PROGRAMMED THE CIRCUIT TO RECOGNIZE 0000). NOW ENTER THE PROGRAMMED WORD (1010) INTO THE PUSHBUTTON SWITCHES (PRESS S1 AND S3). THE GREEN LED WILL GLOW TO INDICATE THAT THE WORD YOU ENTERED MATCHES THE ONE YOU PROGRAMMED INTO THE CIRCUIT.

## GOING FURTHER

THIS CIRCUIT SIMULATES A COMBINATION LOCK. HOW MANY OTHER APPLICATIONS CAN YOU LIST FOR A DIGITAL COMPARATOR?

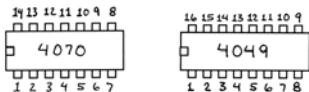
## PROGRAM WIRES

1	2	3	4
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
1	0	0	1
1	0	1	0
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1

## 4070 QUAD EXCLUSIVE-OR GATE: BUILD A SIMPLE ENCRYPTION SYSTEM

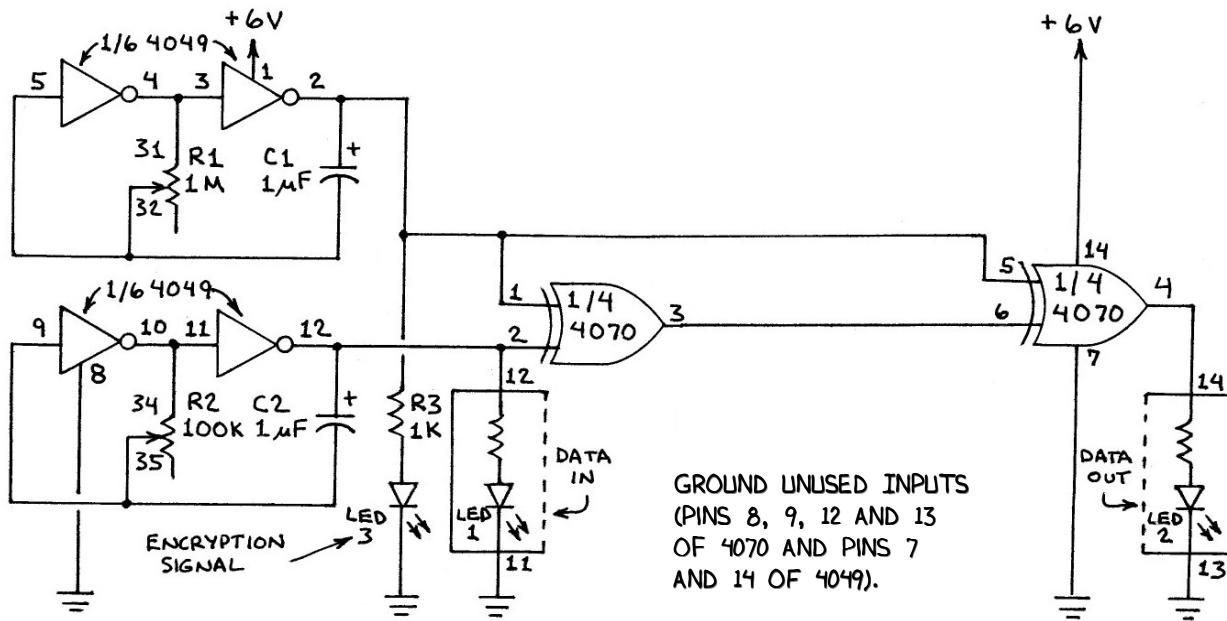
TWO EXCLUSIVE-OR GATES ARE THE KEY TO THIS SIMPLE DATA ENCRYPTION SYSTEM. YOU WILL BUILD TWO OSCILLATORS AND USE ONE AS AN ENCRYPTION KEY AND THE OTHER AS A SIGNAL SOURCE. YOU WILL THEN SEND SIGNALS FROM ONE EX-OR GATE TO THE SECOND EX-OR GATE.

### PARTS YOU WILL NEED



C1, C2-1.0 UF      LED 1-GREEN LED

### CIRCUIT DIAGRAM



### HOW THE ENCRYPTION CIRCUIT WORKS

DATA PULSES COME FROM THE LOWER OSCILLATOR AND ARE INDICATED BY LED 1. ENCODING PULSES COME FROM THE UPPER OSCILLATOR AND ARE INDICATED BY GREEN LED 3. DATA PULSES ARRIVE AT THE RECEIVER OUTPUT AND ARE INDICATED BY LED 2 ONLY WHEN BOTH GATES RECEIVE IDENTICAL ENCODING PULSES. IF SO, THEN LEDS 1 AND 2 FLASH IN PERFECT STEP WITH ONE ANOTHER. IF THE CODE IS SOMEHOW DELAYED OR CHANGED, THEN LED 2 WILL NOT FLASH IN STEP WITH LED 1. THE DATA ARE SAID TO BE SCRAMBLED. IF THE ENCRYPTION LINE IS BROKEN AND PIN 5 OF THE SECOND EXCLUSIVE-OR GATE IS MADE HIGH OR LOW, THE DATA WILL ALSO BE SCRAMBLED. FOR IMPROVED SECURITY IN REAL SYSTEMS, THE DATA AND ENCRYPTION LINES CAN BE REPLACED BY RADIO OR OPTICAL FIBERS.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT 4070 IC OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT 4049 IC OVER SLOT 3 (PIN 1 AT F15).
4.  INSERT R3 ACROSS G13 AND T13.
5.  INSERT C1 ACROSS G14 (+) AND J14 (-).
6.  INSERT C2 ACROSS J17 (+) AND M17 (-).
7.  INSERT LED 3 ACROSS T15 (ANODE) AND GROUND (CATHODE).
8.  CONNECT L1 TO GROUND (WHT WIRE).
9.  CONNECT M11 TO GROUND (WHT WIRE).
10.  CONNECT F10 TO V4 (+6V) (WHT WIRE).
11.  CONNECT F14 TO V4 (+6V) (WHT WIRE).
12.  CONNECT F1 TO J1 (USE A RED WIRE).
13.  CONNECT H1 TO K1 (WHT WIRE).
14.  CONNECT H11 TO I11 (WHT WIRE).
15.  CONNECT K20 TO L20 (WHT WIRE).
16.  CONNECT F4 TO G11 (RED WIRE).
17.  CONNECT G4 TO J18 (RED WIRE).

## 2. CONNECT THE CONSOLE POTENTIOMETERS AND LEDs AND GROUND UNUSED INPUTS

1.  CONNECT SPRING 31 TO H12 (RED WIRE).
2.  CONNECT SPRING 32 TO J11 (RED WIRE).
3.  CONNECT SPRING 34 TO L18 (BLU WIRE).
4.  CONNECT SPRING 35 TO M18 (BLU WIRE).
5.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
6.  CONNECT SPRING 13 TO GROUND (BLU WIRE).
7.  CONNECT SPRING 12 TO G3 (RED WIRE).
8.  CONNECT SPRING 14 TO I3 (RED WIRE).
9.  CONNECT K7 TO GROUND (WHT WIRE).
10.  CONNECT L7 TO GROUND (WHT WIRE).
11.  CONNECT H8 TO L8 (WHT WIRE).
12.  CONNECT G9 TO L9 (WHT WIRE).
13.  CONNECT L11 TO GROUND (WHT WIRE).
14.  CONNECT H20 TO GROUND (WHT WIRE).

## 3. TEST THE CIRCUIT

CHECK FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. ADJUST THE 100K CONSOLE POT (R2) UNTIL LED 1 (INPUT DATA) AND LED 2 (OUTPUT DATA) FLASH TOGETHER A FEW TIMES A SECOND. THIS CONFIRMS THAT DATA PULSES ENTERING THE SYSTEM ARE EXITING THE SECOND COMPARATOR UNCHANGED. NOW CHANGE THE ENCRYPTION CODE BY ADJUSTING THE 1M CONSOLE POT (R1). THE FLASH RATE OF THE GREEN LED WILL CHANGE AS YOU CHANGE THE CODE (THE PULSE RATE). YET LEDS 1 AND 2 WILL STILL FLASH IN STEP.

CODE		DATA SIGNAL
IN	OUT	
0	0	IN = OUT
1	1	IN = OUT
0	1	SCRAMBLED
1	0	SCRAMBLED

TO PROVE THAT THE CIRCUIT REALLY WORKS, BREAK THE ENCRYPTION LINE AT THE SECOND EX-OR GATE BY REMOVING THE RED WIRE FROM F1. NOW PIN 5 IS FLOATING, AND LED 2 NO LONGER FLASHES IN STEP WITH LED 1. CONNECT THE FREE RED WIRE AT PIN 5 TO +6V AND THEN TO GROUND WHILE WATCHING THE SCRAMBLED RESPONSE OF LED 2.

## COMPUTER SECURITY

THIS SIMPLE ENCRYPTION PROJECT IS DESIGNED TO ACQUAINT YOU WITH THE PROBLEM OF COMPUTER AND COMMUNICATIONS SECURITY. BECAUSE OF THE RAPID GROWTH OF CELLULAR TELEPHONE TECHNOLOGY AND THE INTERNET, THERE IS A VITAL NEED TO PROTECT PERSONAL AND BUSINESS INFORMATION FROM UNAUTHORIZED PEOPLE AND CRIMINALS. DATA SECURITY SYSTEMS USE COMPUTER SOFTWARE, ELECTRONIC HARDWARE OR BOTH. OUR SIMPLE EXCLUSIVE-OR ENCRYPTION SYSTEM IS A HARDWARE DEVICE THAT IS CONTROLLED BY A SERIES OF PULSES FROM AN OSCILLATOR. HERE ARE SOME WAYS TO USE HARDWARE TO PROVIDE A RANDOM OR NEARLY RANDOM ENCRYPTION SIGNAL TO MAKE THIS SYSTEM MORE SECURE:

1. USE A GEIGER COUNTER TRIGGERED BY RANDOM PULSES FROM COSMIC RAYS (NATURAL BACKGROUND RADIATION) TO PROVIDE THE ENCRYPTION SIGNAL.
2. USE A SHIFT-REGISTER RANDOM NUMBER GENERATOR TO PROVIDE THE ENCRYPTION SIGNAL.

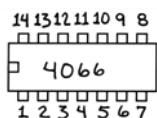
HERE ARE SOME METHODS THAT CAN PROTECT THE ENCRYPTION SIGNAL FROM DETECTION:

1. CUT THE ENCRYPTION LINE BETWEEN THE TWO GATES AND CONNECT A PULSE GENERATOR TRIGGERED BY A RADIO SIGNAL TO THE TWO ENCRYPTION INPUTS. TUNE BOTH RADIOS TO THE SAME STATION TO PROVIDE IDENTICAL ENCRYPTION SIGNALS.
2. CUT THE ENCRYPTION LINE AND PROVIDE A SOFTWARE "KEY" AT EACH END OF THE DATA LINK. THE KEY CAN BE A SPECIAL LISTING OF RANDOMIZED CODE (BINARY PATTERNS) OR EVEN MUSIC OR THE TEXT FROM A BOOK OR TELEPHONE DIRECTORY KNOWN ONLY TO THOSE AUTHORIZED TO RECEIVE THE SIGNAL.

## 4066 QUAD SWITCH: GETTING TO KNOW THE 4066

CMOS SWITCH ICs ARE VERY USEFUL SINCE THEY CAN BE SWITCHED OFF OR ON BY A LOGIC SIGNAL (0 OR 1). YOU WILL BUILD A SIMPLE 4066 DEMONSTRATOR CIRCUIT TO LEARN HOW TO USE THIS HIGHLY USEFUL CHIP. WHILE THE 4066 IS PRIMARILY USED IN DIGITAL LOGIC CIRCUITS, IT CAN ALSO BE USED WITH OPERATIONAL AMPLIFIERS AND OTHER ANALOG ICS.

### PARTS YOU WILL NEED

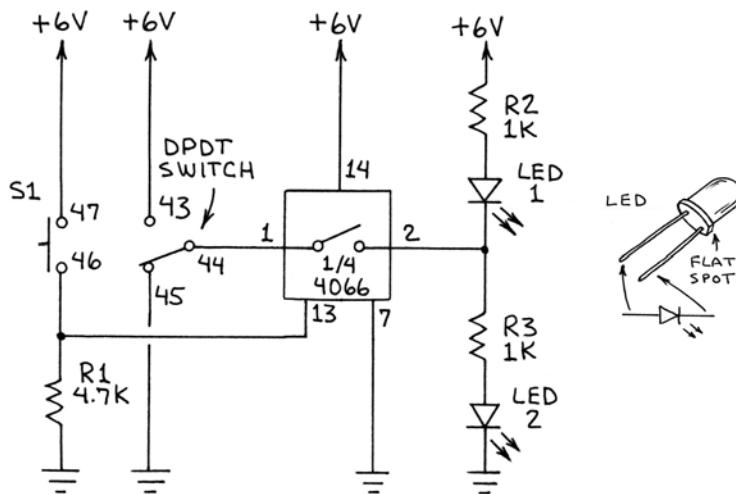


R1-4.7K (YEL-VIO-RED)  
R2, R3-1K (BRN-BLK-RED)



LED 1-RED LED  
LED 2-GREEN LED

### CIRCUIT DIAGRAM



GROUND UNUSED CONTROL INPUTS (PINS 5, 6 AND 12).

DPDT	S1	LED 1	LED 2
DOWN (LOW)	OFF	DIM (4066 OFF)	
UP (HIGH)	ON	ON	OFF
		OFF	ON

NORMALLY THE 4066 SWITCH IS OFF. PRESSING S1 PULLS CONTROL PIN 13 HIGH AND CLOSES THE 4066 SWITCH. DEPENDING ON THE SETTING OF THE DPDT SWITCH, CURRENT WILL NOW BE STEERED THROUGH THE 4066 SWITCH AND EITHER LED 1 OR LED 2.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4066 OVER SLOT 3 (PIN 1 AT F15).
3.  INSERT R1 ACROSS SPRING 46 AND GROUND.
4.  INSERT R2 ACROSS D14 AND F19.
5.  INSERT R3 ACROSS G14 AND N14.
6.  INSERT LED 1 ACROSS D11 (ANODE) AND G11 (CATHODE).
7.  INSERT LED 2 ACROSS N11 (ANODE) AND L11 (CATHODE).
8.  CONNECT L12 TO GROUND (WHT WIRE).
9.  CONNECT F20 TO V4 (+6) (WHT WIRE).
10.  CONNECT SPRING 45 TO GROUND (RED WIRE).
11.  CONNECT SPRING 44 TO F13 (BLU WIRE).
12.  CONNECT SPRING 43 TO V4 (+6V) (BLU WIRE).
13.  CONNECT SPRING 46 TO G20 (RED WIRE).
14.  CONNECT SPRINGS 47 AND 43 (WHT WIRE).

### 2. TEST THE CIRCUIT

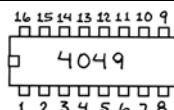
CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE DPDT SWITCH DOWN AND PUSH THE POWER SWITCH ON. BOTH LEDs WILL GLOW DIMLY. THIS IS BECAUSE THEY ARE CONNECTED IN SERIES BETWEEN +6V AND GROUND. (THEY DO NOT NOW RECEIVE ANY CURRENT THROUGH THE 4066 LOGIC SWITCH.) NOW PRESS S1. LED 1 WILL GLOW BRIGHTLY AND LED 2 WILL SWITCH OFF. WHILE KEEPING S1 PRESSED DOWN, PUSH THE DPDT SWITCH UP. NOW LED 2 WILL GLOW BRIGHTLY AND LED 1 WILL SWITCH OFF. RELEASE S1 AND BOTH LEDs WILL GLOW DIMLY AS WHEN THE 4066 SWITCH WAS ORIGINALLY OFF. CHECK YOUR RESULTS AGAINST THE TRUTH TABLE.

## 4066 QUAD SWITCH: HOW TO MAKE A 3-STATE LOGIC GATE

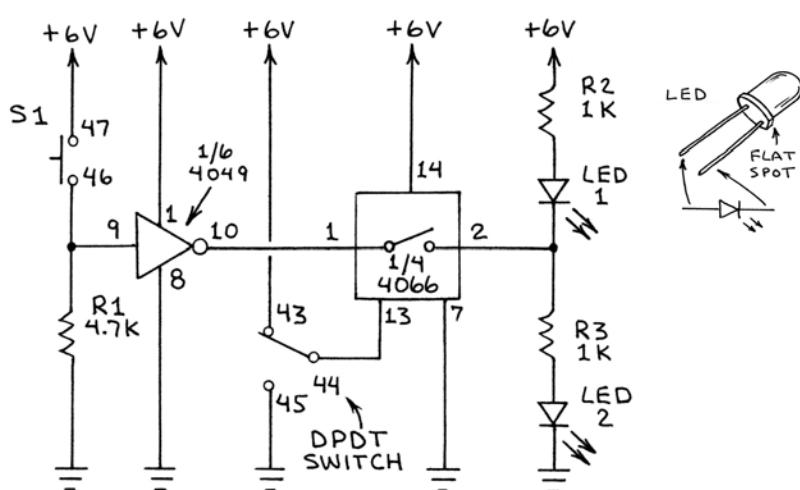
LOGIC GATES HAVE ONLY TWO STATES: LOW (0) AND HIGH (1). MANY ADDITIONAL APPLICATIONS ARE POSSIBLE BY ADDING A THIRD STATE IN WHICH THE OUTPUT OF THE LOGIC GATE IS SIMPLY DISCONNECTED FROM THE OUTSIDE WORLD. SUCH GATES ARE CALLED 3-STATE OR TRI-STATE LOGIC GATES. YOU CAN USE A 4066 TO CONVERT ANY GATE INTO A 3-STATE GATE. THE 4066 WILL ALLOW YOU TO MANUALLY OR ELECTRONICALLY CONTROL WHEN THE GATE IS CONNECTED TO EXTERNAL CIRCUITS.

### PARTS YOU WILL NEED

YOU WILL NEED THE CIRCUIT ON PAGE 60 PLUS:



### CIRCUIT DIAGRAM



DPDT	S1	LED 1	LED 2
DOWN (LOW)	OFF	DIM	(4066 OFF)
	ON		
UP (HIGH)	OFF	OFF	ON
	ON	ON	OFF

YOU CAN CONNECT ANY STANDARD GATE TO A 4066 USING THIS BASIC CIRCUIT. TRIGGER THE 4066 WITH A SWITCH OR WITH ANOTHER GATE.

GROUND UNUSED INPUTS (PINS 5, 6 AND 12 OF 4066 AND 3, 5, 7, 11 AND 14 OF 4049).

### 1. MODIFY THE GETTING ACQUAINTED CIRCUIT ON PAGE 60

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE BLU WIRE FROM SPRING 44 TO F13.
3.  REMOVE RED WIRE FROM SPRING 46 TO G20.
4.  INSERT THE 4049 OVER SLOT 1 (PIN 1 AT F5).
5.  CONNECT M4 TO GROUND (WHT WIRE).
6.  CONNECT F4 TO V4 (+6) (RED WIRE).
7.  CONNECT L10 TO F11 (WHT WIRE).
8.  CONNECT SPRING 46 TO M10 (RED WIRE).
9.  CONNECT SPRING 44 TO G20 (BLU WIRE).
10.  CONNECT H1 TO GROUND (WHT WIRE).
11.  CONNECT J1 TO GROUND (WHT WIRE).
12.  CONNECT L1 TO GROUND (WHT WIRE).
13.  CONNECT H7 TO GROUNND (WHT WIRE).
14.  CONNECT K7 TO GROUND (WHT WIRE).
15.  CONNECT J14 TO GROUND (WHT WIRE).
16.  CONNECT K14 TO GROUND (WHT WIRE).
17.  CONNECT H20 TO GROUND (WHT WIRE).

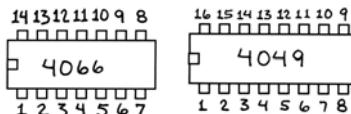
### 2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE DPDT SWITCH DOWN AND PUSH THE POWER SWITCH ON. THE 4066 SWITCH WILL BE IN ITS DISCONNECTED OR HIGH-IMPEDANCE STATE. BOTH LEDs WILL GLOW DIMLY SINCE THEY ARE CONNECTED IN SERIES, ALONG WITH R2 AND R3, TO +6 VOLTS. NOW PUSH THE DPDT SWITCH UP TO PULL THE 4066 CONTROL PIN HIGH. THIS TURNS ON THE 4066 SWITCH. LED 2 WILL GLOW AND LED 1 WILL TURN OFF TO INDICATE THAT THE OUTPUT OF THE 4049 INVERTER IS HIGH. PRESS S1 TO CHANGE THE OUTPUT OF THE 4049 TO LOW. THIS WILL CAUSE LED 1 TO GLOW AND LED 2 TO TURN OFF.

## 4066 QUAD SWITCH: BUILD A 3-STATE DATA BUS CONTROLLER

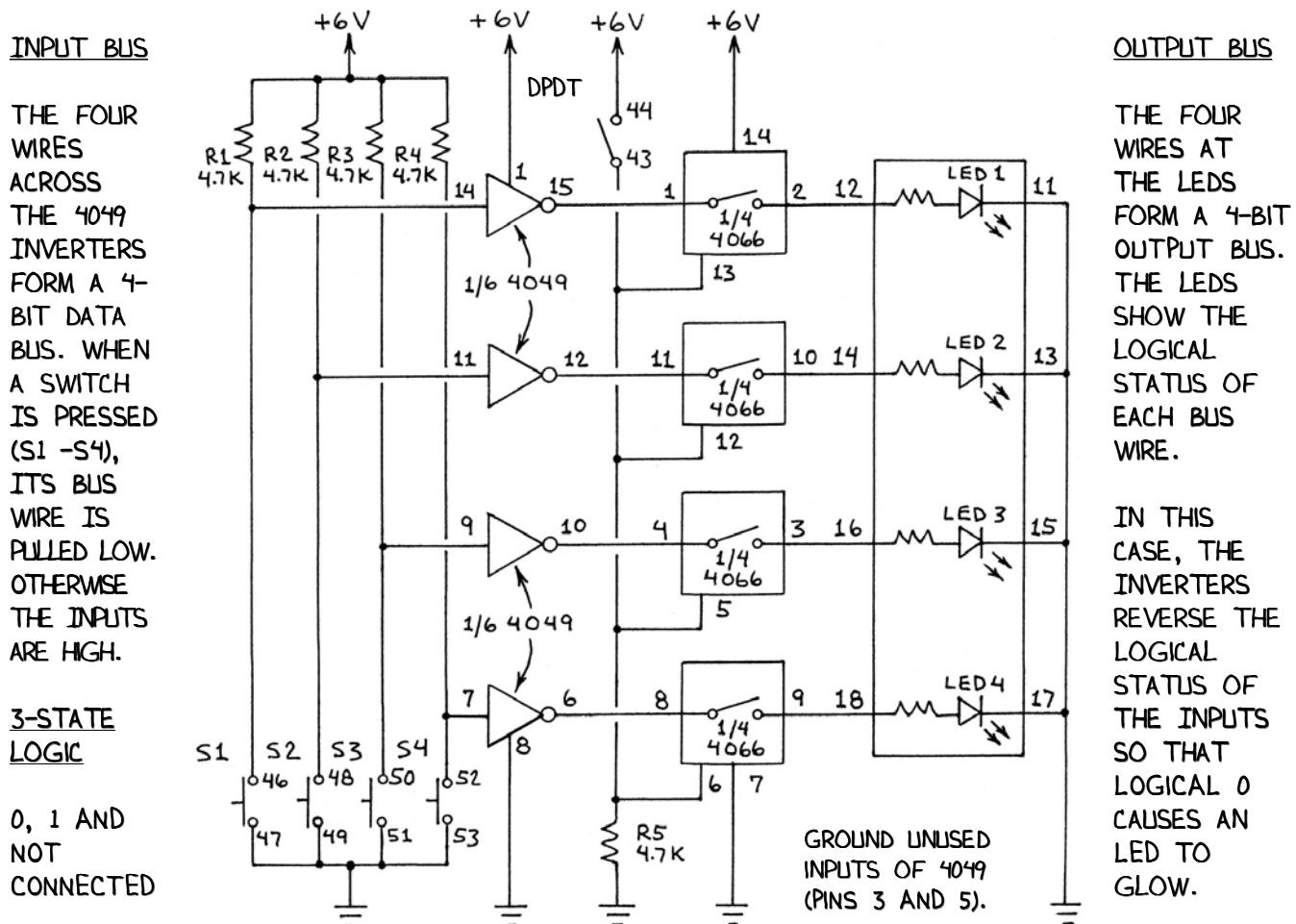
DATA AND INSTRUCTIONS MOVE BETWEEN THE VARIOUS SECTIONS OF A COMPUTER OVER PARALLEL CONDUCTORS OR WIRES CALLED BUSES. YOU WILL USE A 4066 TO DEMONSTRATE HOW A 3-STATE CONTROLLER CAN SWITCH TWO DATA BUSES TOGETHER. FOUR LEDs WILL INDICATE THE 4-BIT LOGIC SIGNALS YOU PLACE ON THE BUS.

### PARTS YOU WILL NEED



R1, R2, R3, R4, R5-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



DPDT 3-STATE CONTROL	INPUT BUS				OUTPUT BUS			
	S1	S2	S3	S4	LED 1	LED 2	LED 3	LED 4
OFF	OFF	OFF	OFF	OFF	LEDS ARE OFF SINCE THE OUTPUT BUS IS NOT CONNECTED TO THEM			
	ON	ON	ON	ON				
ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	ON	ON	ON	ON	ON	ON	ON	ON

## 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT THE 4066 OVER SLOT 3 (PIN 1 AT F15).
4.  CONNECT M4 TO GROUND (WHT WIRE).
5.  CONNECT F1 TO V4 (+6) (RED WIRE).
6.  CONNECT L11 TO GROUND (WHT WIRE).
7.  CONNECT F20 TO V4 (+6 V) (WHT WIRE).
8.  CONNECT G10 TO F11 (WHT WIRE).
9.  CONNECT J10 TO I17 (WHT WIRE).
10.  CONNECT L10 TO I11 (WHT WIRE).
11.  CONNECT J11 TO K11 (WHT WIRE).
12.  CONNECT J14 TO H17 (WHT WIRE).
13.  CONNECT G20 TO H20 (WHT WIRE).
14.  CONNECT K4 TO L17 (RED WIRE).
15.  INSERT R1 ACROSS C7 AND H7.
16.  INSERT R2 ACROSS C8 AND K8.
17.  INSERT R3 ACROSS C9 AND M9.
18.  INSERT R4 ACROSS C6 AND L3.
19.  INSERT R5 ACROSS K12 AND GROUND.
20.  CONNECT C10 TO V4 (+6V) (WHT WIRE).
21.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
22.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
23.  CONNECT SPRINGS 51 AND 53 (WHT WIRE).
24.  CONNECT SPRING 53 TO GROUND (RED WIRE).
25.  CONNECT SPRING 46 TO H10 (BLU WIRE).
26.  CONNECT SPRING 48 TO K10 (BLU WIRE).
27.  CONNECT SPRING 50 TO M10 (BLU WIRE).
28.  CONNECT SPRING 52 TO L1 (BLU WIRE).
29.  CONNECT SPRING 43 TO K14 (RED WIRE).
30.  CONNECT SPRING 44 TO V4 (+6V) (BLU WIRE).
31.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
32.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
33.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
34.  CONNECT SPRING 17 TO GROUND (BLU WIRE).
35.  CONNECT SPRING 12 TO G11 (RED WIRE).
36.  CONNECT SPRING 14 TO J20 (RED WIRE).
37.  CONNECT SPRING 16 TO H11 (RED WIRE).
38.  CONNECT SPRING 18 TO K20 (RED WIRE).
39.  CONNECT H1 TO GROUNND (WHT WIRE).
40.  CONNECT J1 TO GROUND (WHT WIRE).

## 2. TEST THE CIRCUIT

DOUBLE CHECK YOUR WIRING. MAKE SURE ALL THE WIRES ARE INSERTED FIRMLY INTO THE BREADBOARD AND THAT THE BARE LEADS OF ADJACENT RESISTORS DO NOT TOUCH. THEN PUSH THE DPDT SWITCH DOWN AND PUSH THE POWER SWITCH ON. ALL FOUR LEDs SHOULD BE OFF. ALL FOUR WIRES ON THE INPUT BUS ARE HIGH (LOGICAL 1). PRESS SOME PUSHBUTTON SWITCHES TO APPLY LOGICAL 0'S. THE LEDs SHOULD STILL BE OFF, BECAUSE THE 4066 BUS CONTROLLER IS OFF. NEXT, PUSH THE DPDT SWITCH UP TO CONNECT THE INPUT BUS TO THE OUTPUT BUS. THE OUTPUT LEDs WILL STILL BE OFF SINCE EACH IS NOW LOW. WHEN YOU PRESS AN INPUT SWITCH TO GENERATE A LOGICAL 1 ON THE OUTPUT, THE RESPECTIVE LED WILL GLOW.

## ABOUT 3-STATE LOGIC...

THERE ARE ONLY TWO LOGIC STATES: 0 (LOW) AND 1 (HIGH). THREE-STATE LOGIC CIRCUITS FEATURE A SPECIAL CONTROL INPUT. A LOGIC SIGNAL CAN BE APPLIED TO THE CONTROL INPUT TO CONNECT OR DISCONNECT THE OUTPUT OF THE GATE TO OR FROM THE OUTSIDE WORLD. WHEN THE LOGIC GATE IS DISCONNECTED (THE THIRD STATE), THE GATE'S OUTPUT ASSUMES A VERY HIGH IMPEDANCE STATE. WHEN THE LOGIC GATE IS CONNECTED, IT FUNCTIONS AS A NORMAL GATE. SOME ICs DESIGNED SPECIFICALLY FOR CONTROLLING DATA BUSES ARE 3-STATE DEVICES. THE 4066 AND OTHER KINDS OF CMOS SWITCHES ALLOW YOU TO MAKE YOUR OWN 3-STATE LOGIC GATES.

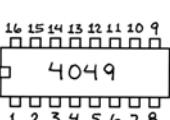
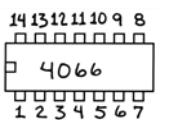
## GOING FURTHER

YOU CAN EASILY CONVERT A STANDARD LOGIC GATE INTO A 3-STATE GATE. JUST CONNECT THE OUTPUT OF A GATE TO ONE OF THE SWITCHES IN A 4066. THE OTHER SIDE OF THE 4066 SWITCH IS NOW THE OUTPUT OF THE GATE. WHEN THE APPROPRIATE CONTROL PIN OF THE 4066 IS LOW, THE GATE WILL ASSUME THE HIGH-IMPEDANCE (DISCONNECTED) STATE. WHEN THE PIN IS HIGH, THE GATE WILL FUNCTION NORMALLY.

## 4066 QUAD SWITCH: BUILD A GATED DUAL FLASHER CIRCUIT

THE 4066 IS HANDY FOR MODIFYING THE OPERATION OF VARIOUS CIRCUITS, LIKE THE DUAL LED FLASHER SHOWN HERE. NORMALLY THE LEDs WOULD FLASH MERRILY ALONG. YOU WILL INSERT TWO SWITCHES IN A 4066 BETWEEN THE LEDs AND THE OSCILLATOR THAT DRIVES THEM. YOU WILL THEN SWITCH THE FLASHER ON AND OFF USING THE 4066 CONTROL INPUTS.

### PARTS YOU WILL NEED

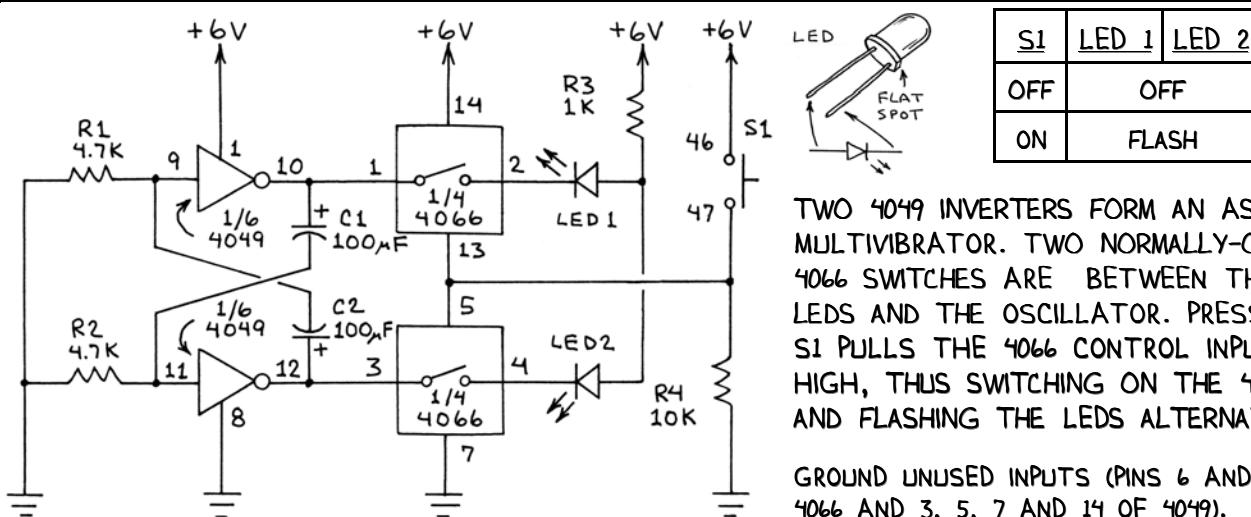


R1, R2-4.7K (YEL-VIO-RED)  
R3-1K (BRN-BLK-RED)  
R4-10K (BRN-BLK-ORG)

C1, C2-100 UF

LED 1-RED LED  
LED 2-GREEN LED

### CIRCUIT DIAGRAM



TWO 4049 INVERTERS FORM AN ASTABLE MULTIVIBRATOR. TWO NORMALLY-OFF 4066 SWITCHES ARE BETWEEN THE LEDs AND THE OSCILLATOR. PRESSING S1 PULLS THE 4066 CONTROL INPUTS HIGH, THUS SWITCHING ON THE 4066 AND FLASHING THE LEDs ALTERNATELY.

GROUND UNUSED INPUTS (PINS 6 AND 12 OF 4066 AND 3, 5, 7 AND 14 OF 4049).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 OVER SLOT 1 (PIN 1 AT F5).
3.  INSERT THE 4066 OVER SLOT 3 (PIN 1 AT F15).
4.  CONNECT M4 TO GROUND (WHT WIRE).
5.  CONNECT F4 TO V4 (+6) (RED WIRE).
6.  CONNECT L11 TO GROUND (WHT WIRE).
7.  CONNECT F20 TO V4 (+6 V) (WHT WIRE).
8.  CONNECT J14 TO G17 (WHT WIRE).
9.  CONNECT J10 TO H11 (WHT WIRE).
10.  CONNECT L10 TO F11 (WHT WIRE).
11.  CONNECT SPRING 47 TO J13 (RED WIRE).
12.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
13.  INSERT R1 ACROSS M10 AND GROUND.
14.  INSERT R2 ACROSS K9 AND GROUND.
15.  INSERT R3 ACROSS E14 AND F17.
16.  INSERT R4 ACROSS J11 AND GROUND.
17.  INSERT C1 ACROSS K7 (-) AND L7 (+).
18.  INSERT C2 ACROSS J8 (+) AND M8 (-).
19.  INSERT LED 1 ACROSS E12 (ANODE) AND G12 (CATHODE).
20.  INSERT LED 2 ACROSS E13 (ANODE) AND I13 (CATHODE).
21.  CONNECT H1 TO GROUND (WHT WIRE).
22.  CONNECT J1 TO GROUND (WHT WIRE).
23.  CONNECT L1 TO GROUND (WHT WIRE).
24.  CONNECT H7 TO GROUND (WHT WIRE).
25.  CONNECT K11 TO GROUND (WHT WIRE).
26.  CONNECT H17 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

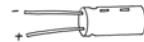
CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. BOTH LEDs WILL BE OFF. PRESS S1. THE LEDs WILL ALTERNATELY FLASH. THE FLASH RATE IS CONTROLLED BY C1 AND C2. EQUAL CAPACITOR VALUES GIVE EQUAL FLASH TIMES. USE A 470 UF CAPACITOR FOR C1 TO GET A 64 LONG-SHORT FLASH CYCLE.

## 4066 QUAD SWITCH: BUILD A PULSATING DUAL FLASHER CIRCUIT

THE 4066 LED DUAL FLASHER IN THE PREVIOUS PROJECT IS CONTROLLED BY PRESSING S1. THIS CIRCUIT EXCHANGES S1 FOR AN INDEPENDENT OSCILLATOR THAT AUTOMATICALLY APPLIES CONTROL PULSES TO THE 4066. YOU WILL ADD THIS SIMPLE CIRCUIT TO THE DUAL LED FLASHER AND ADJUST IT TO CREATE A VARIETY OF EYE-CATCHING EFFECTS.

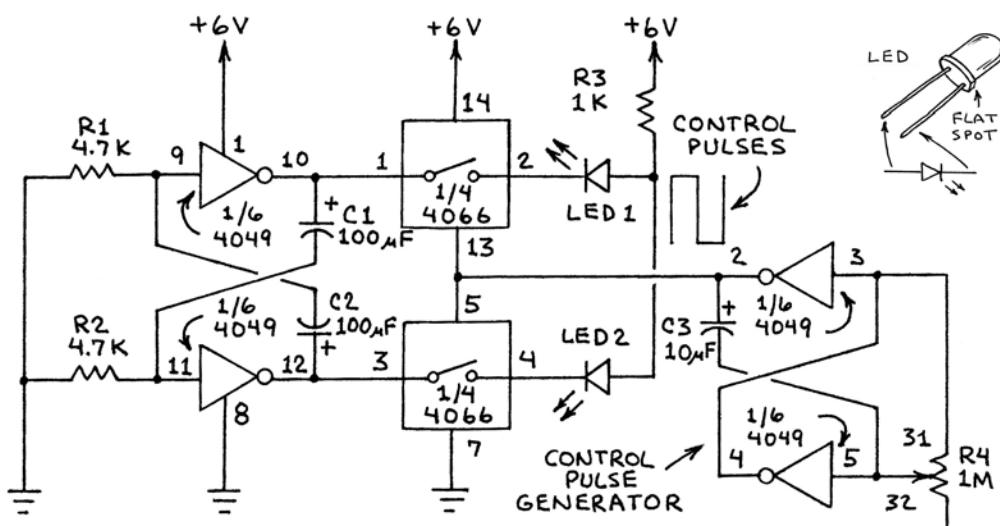
### PARTS YOU WILL NEED

YOU WILL NEED THE GATED DUAL FLASHER CIRCUIT ON PAGE 62 PLUS:



C3-10 UF

### CIRCUIT DIAGRAM



THE FLASHER PORTION OF THIS CIRCUIT IS THE 4066 DUAL LED FLASHER WITHOUT S1 AND R4. THE TWO 4049 INVERTERS ON THE RIGHT SIDE OF THE FLASHER CIRCUIT APPLY THE CONTROL PULSES AT A RATE DETERMINED BY R4.

GROUND UNUSED INPUTS (PINS 6 AND 12 OF 4066 AND 7 AND 14 OF 4049).

### 1. MODIFY THE GATED DUAL FLASHER CIRCUIT ON PAGE 62

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE R4.
3.  REMOVE WIRES BETWEEN S1 AND THE BREADBOARD.
4.  REMOVE WHT WIRE FROM H1 TO GROUND.
5.  REMOVE WHT WIRE FROM J1 TO GROUND.
6.  CONNECT H4 TO I4 (WHT WIRE).
7.  CONNECT G4 TO J12 (RED WIRE).
8.  CONNECT SPRING 31 TO H1 (RED WIRE).
9.  CONNECT SPRING 32 TO J1 (RED WIRE).
10.  INSERT C3 ACROSS G3 (+) AND J3 (-).

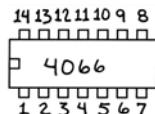
### 2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS AND BE SURE THE ORIGINAL PORTION OF THE CIRCUIT IS STILL CONNECTED PROPERLY. ROTATE THE 1M CONSOLE POT (R4) TO ITS MIDPOINT. THEN PUSH THE POWER SWITCH ON. THE LEDS WILL FLASH ALTERNATELY FOR A FEW SECONDS. BOTH LEDS WILL THEN SWITCH OFF FOR A FEW SECONDS. AFTER THIS PAUSE, THE LEDS WILL CONTINUE TO FLASH, AND THE CYCLE WILL REPEAT INDEFINITELY. WHEN THE CIRCUIT IS WORKING PROPERLY, SLOWLY ROTATE R4'S KNOB WHILE WATCHING THE LEDS. STOP ROTATING R4 WHEN EACH LED FLASHES ONCE BEFORE THE PAUSE INTERVAL. THEN VERY GRADUALLY ADJUST R4 UNTIL EACH LED FLASHES TWICE IN SUCCESSION WITHOUT AN APPARENT PAUSE. NOW THE CONTROL PULSES ARE ARRIVING MUCH FASTER THAN BEFORE. IF YOU ARE CAREFUL, YOU CAN ADJUST R4 SO THAT EACH LED ALTERNATELY EMITS 4-5 VERY BRIEF FLASHES IN RAPID SUCCESSION. THE VISUAL EFFECT IS QUITE CAPTIVATING, ESPECIALLY IN A DARKENED ROOM. 65

## 4066 QUAD SWITCH: BUILD A 1-OF-4 DATA SELECTOR

A MECHANICAL ROTARY SWITCH SELLECTS ONE OF SEVERAL DIFFERENT CIRCUITS. A DATA SELECTOR LOGIC CIRCUIT DOES THE SAME THING WITHOUT ANY MOVING PARTS. YOU WILL USE A 4066 TO MAKE A 1-OF-4 DATA SELECTOR. THE CIRCUIT WILL SELECT 1-OF-4 INPUTS AND APPLY ITS LOGICAL STATE TO AN INDICATOR LED.

### PARTS YOU WILL NEED



R1, R2, R3, R4-4.7K (YEL-VIO-RED)  
R5-1K (BRN-BLK-RED)



LED 1-RED LED

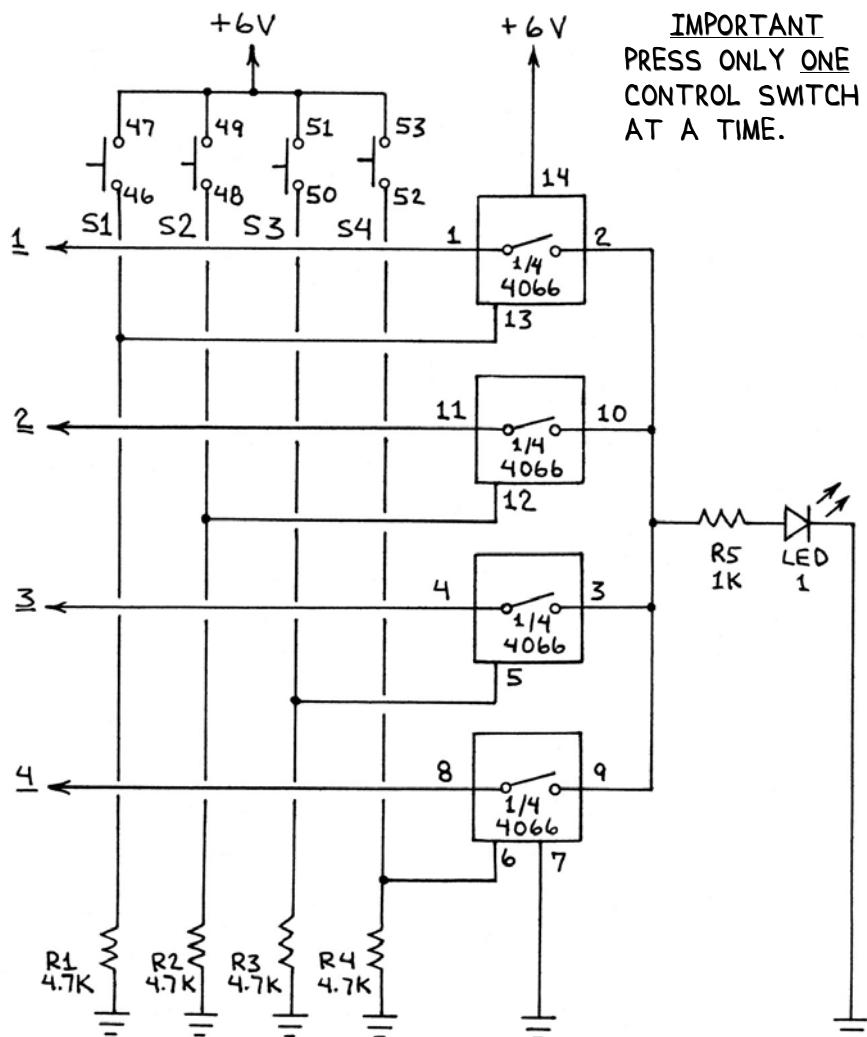
### CIRCUIT DIAGRAM

#### INPUT BUS

INPUTS 1-4 ARE CONNECTED TO EXTERNAL LOGIC CIRCUITS OR TO +6V (HIGH) OR GROUND (LOW). IN THIS PROJECT, THE EXTERNAL SIGNALS ARE PROVIDED BY CONNECTING ANY OR ALL OF 4 INPUT WIRES TO +6V OR GROUND.

#### CONTROL SWITCHES

PUSHBUTTON SWITCHES S1-S4 ARE CONNECTED TO THE CONTROL PINS OF THE 4066. NORMALLY THE CONTROL PIN OF EACH 4066 SWITCH IS PULLED LOW BY R1-R4. Thus THE SWITCHES ARE NORMALLY OFF. PRESSING ONE (AND ONLY ONE) OF SWITCHES S1-S4 PULLS THE RESPECTIVE CONTROL PIN HIGH AND SWITCHES ON THAT SWITCH. THE EXTERNAL CIRCUIT CONNECTED TO THE INPUT OF THAT SWITCH IS THEN CONNECTED DIRECTLY TO THE LED. IF THE INPUT SIGNAL IS HIGH, THE LED WILL THEN GLOW.



#### OUTPUT

SINCE THE OUTPUT SIDES OF THE FOUR 4066 SWITCHES ARE TIED TOGETHER, ONLY ONE SWITCH SHOULD BE ON AT A TIME. THE LED GLOWS ONLY WHEN THE SELECTED INPUT SIGNAL IS HIGH. THE LED IS OFF WHEN THE SELECTED SIGNAL IS LOW OR WHEN NO INPUT HAS BEEN SELECTED.

## 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4066 OVER SLOT 3 (PIN 1 AT F15).
3.  CONNECT L11 TO GROUND (WHT WIRE).
4.  CONNECT F20 TO V4 (+6 V) (WHT WIRE).
5.  CONNECT G11 TO H11 (WHT WIRE).
6.  CONNECT H14 TO J17 (WHT WIRE).
7.  CONNECT J20 TO K20 (WHT WIRE).
8.  INSERT R1 ACROSS G17 AND L13.
9.  INSERT R2 ACROSS H17 AND L14.
10.  INSERT R3 ACROSS J11 AND GROUND.
11.  INSERT R4 ACROSS K12 AND GROUND.
12.  INSERT R5 ACROSS K18 AND T18.
13.  INSERT LED ACROSS T20 (ANODE) AND GROUND (CATHODE).
14.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
15.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
16.  CONNECT SPRINGS 51 AND 53 (WHT WIRE).
17.  CONNECT SPRING 46 TO G20 (BLU WIRE).
18.  CONNECT SPRING 48 TO H20 (BLU WIRE).
19.  CONNECT SPRING 50 TO J13 (BLU WIRE).
20.  CONNECT SPRING 52 TO K13 (BLU WIRE).
21.  CONNECT SPRING 53 TO F19 (BLU WIRE).
22.  INSERT A VERTICAL RED WIRE AT F12.
23.  INSERT A VERTICAL RED WIRE AT I17.
24.  INSERT A VERTICAL RED WIRE AT I12.
25.  INSERT A VERTICAL RED WIRE AT L17.

## 2. PROGRAM THE CIRCUIT

THIS CIRCUIT SELECTS 1-OF-4 INPUT SIGNALS AND APPLIES IT TO THE OUTPUT LED. THE 4 RED VERTICAL WIRES YOU INSERTED INTO THE BREADBOARD ARE THE INPUTS. FOR TEST PURPOSES, CONNECT EACH OF THESE INPUTS TO V4 (+6V). THIS MEANS THAT THE LED WILL GLOW WHEN ANY OF THE 4 INPUTS IS SELECTED BY PUSHBUTTON SWITCHES S1-S4.

## 2. TEST THE CIRCUIT

THIS CIRCUIT HAS SEVERAL CLOSELY SPACED RESISTORS, SO BE SURE NONE OF THEIR BARE LEADS ARE TOUCHING. WHEN YOU ARE SURE THE CIRCUIT IS WIRED CORRECTLY, PUSH THE POWER SWITCH ON. THE LED WILL BE OFF. (IF IT GLOWS WHEN NONE OF THE PUSHBUTTON SWITCHES ARE PRESSED, QUICKLY SWITCH THE POWER OFF AND CHECK YOUR WIRING.) NOW PRESS S1. THE LED WILL GLOW IF YOU CONNECTED INPUT WIRE 1 TO +6V. PRESS S2, S3 AND S4 IN SEQUENCE. EACH TIME A SWITCH IS PRESSED, THE LED WILL GLOW IF YOU CONNECTED THE RESPECTIVE INPUT WIRE TO +6V. BE SURE TO PRESS ONLY ONE PUSHBUTTON SWITCH AT A TIME. PRESSING TWO OR MORE SWITCHES SIMULTANEOUSLY COULD APPLY A SHORT CIRCUIT TO THE RELEVANT INPUTS.

SELECTOR SWITCHES				OUTPUT LED IS CONNECTED TO:
S1	S2	S3	S4	
ON	OFF	OFF	OFF	INPUT 1
OFF	ON	OFF	OFF	INPUT 2
OFF	OFF	ON	OFF	INPUT 3
OFF	OFF	OFF	ON	INPUT 4

CAUTION: PRESS ONLY ONE SWITCH AT A TIME.

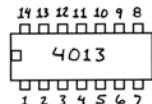
## GOING FURTHER

THE FOUR OUTPUTS IN THIS CIRCUIT ARE WIRED TOGETHER. YOU CAN DISCONNECT THE OUTPUTS FROM ONE ANOTHER AND USE THE CIRCUIT TO CONTROL EACH WIRE IN A BUS OF FOUR WIRES. YOU CAN CONNECT THE FOUR OUTPUTS TO FOUR OF THE CONSOLE LEDs TO PROVIDE LOGIC STATUS INDICATORS. SINCE THE OUTPUTS ARE NOT CONNECTED, YOU CAN ACTIVATE ANY OR ALL THE 4066 INPUTS SIMULTANEOUSLY USING PUSHBUTTON SWITCHES S1-S4.

4013 DUAL FLIP-FLOP: BUILD AND UNDERSTAND A DATA (D) FLIP-FLOP.

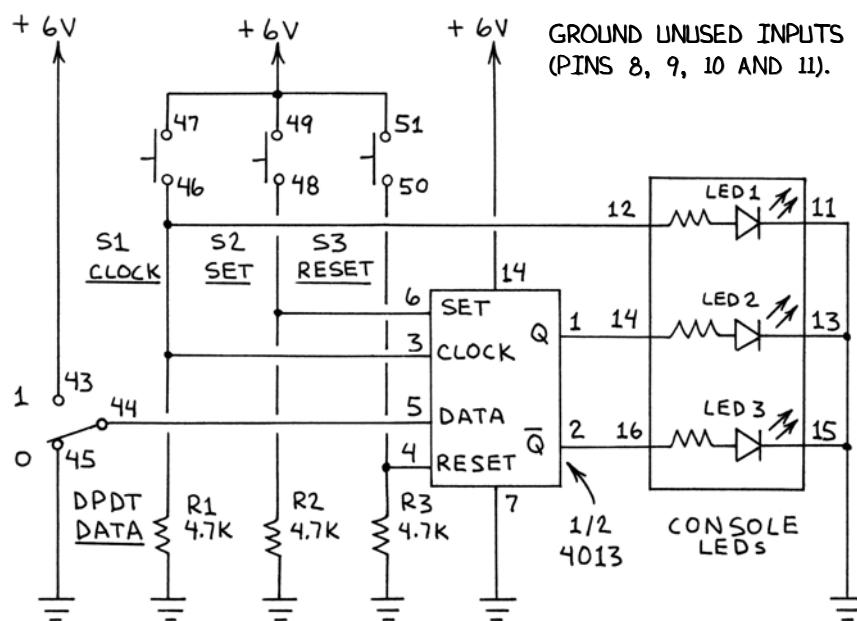
FLIP-FLOPS HAVE TWO OUTPUTS THAT ARE AT OPPOSITE STATES. THE Q OUTPUT OF THE D-TYPE FLIP-FLOP STORES THE BIT AT THE DATA INPUT WHEN TRIGGERED BY A CLOCK PULSE. YOU WILL MAKE AND TEST A D-TYPE FLIP-FLOP THAT STORES A DATA BIT (0 OR 1).

## PARTS YOU WILL NEED



R1, R2, R3-4.7K (YEL-VIO-RED)

## CIRCUIT DIAGRAM



<u>DATA (DPDT SWITCH)</u>	<u>CLOCK (S1 &amp; LED 1)</u>	<u>Q1 (LED 2)</u>	<u>Q2 (LED 3)</u>
DOWN (0)	PRESS (1)	OFF (0)	ON (1)
UP (1)	PRESS (1)	ON (1)	OFF (0)

WHEN THE CLOCK INPUT IS PULSED BY S1, THE D-TYPE FLIP-FLOP STORES THE DATA BIT (0 OR 1) SELECTED BY THE DPDT SWITCH. NORMALLY THE SET AND RESET INPUTS ARE LOW. PRESSING S2 SETS Q TO 1. PRESSING S3 RESETS Q TO 0.

## 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
  2.  INSERT THE 4013 OVER SLOT 3 (PIN 1 AT F15).
  3.  CONNECT L12 TO GROUND (WHT WIRE).
  4.  CONNECT F20 TO V4 (+6) (WHT WIRE).
  5.  INSERT R1 ACROSS H11 AND L11.
  6.  INSERT R2 ACROSS K13 AND GROUND
  7.  INSERT R3 ACROSS I12 AND GROUND.
  8.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
  9.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
  10.  CONNECT SPRING 51 TO V4 (+6V) (BLU WIRE).
  11.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
  12.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
  13.  CONNECT SPRING 15 TO GROUND (BLU WIRE).
  14.  CONNECT SPRING 43 TO V4 (+6V) (BLU WIRE).
  15.  CONNECT SPRING 44 TO J13 (BLU WIRE).
  16.  CONNECT SPRING 45 TO GROUND (RED WIRE).
  17.  CONNECT SPRING 46 TO H14 (RED WIRE).
  18.  CONNECT SPRING 48 TO K14 (RED WIRE).
  19.  CONNECT SPRING 50 TO I14 (RED WIRE).
  20.  CONNECT SPRING 12 TO H12 (RED WIRE).
  21.  CONNECT SPRING 14 TO F12 (RED WIRE).
  22.  CONNECT SPRING 16 TO G12 (RED WIRE).
  23.  CONNECT L20 TO GROUND (WHT WIRE).
  24.  CONNECT K19 TO L19 (WHT WIRE).
  25.  CONNECT J20 TO K20 (WHT WIRE).
  26.  CONNECT I19 TO J19 (WHT WIRE).

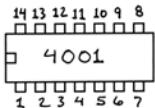
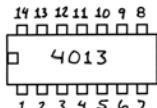
## 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE DPDT SWITCH DOWN AND PUSH THE POWER SWITCH ON. PRESS S2 TO SET THE FLIP-FLOP. LED 2 WILL GLOW. NOW BRIEFLY PRESS CLOCK SWITCH S1. LED 1 WILL FLASH, LED 2 WILL SWITCH OFF AND LED 3 WILL SWITCH ON. PRESS S1 AGAIN, AND LED 2 WILL STAY OFF SINCE IT IS STORING THE 0 INPUT SELECTED BY THE DPDT SWITCH. NOW PUSH THE DPDT SWITCH UP TO SELECT 1. NOW WHAT HAPPENS WHEN YOU PRESS S1? WHY?

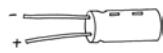
4013 DUAL FLIP-FLOP: BUILD AND UNDERSTAND A TOGGLE (T) FLIP-FLOP

A TOGGLE FLIP-FLOP CHANGES STATES WHEN A CLOCK PULSE ARRIVES. YOU WILL BUILD A TOGGLE FLIP-FLOP AND LEARN WHY A FLIP-FLOP CAN CHANGE STATES MORE THAN ONCE WHEN TRIGGERED BY A SWITCH. YOU WILL ADD A DEBOUNCE CIRCUIT TO ELIMINATE SWITCH BOUNCE.

## PARTS YOU WILL NEED



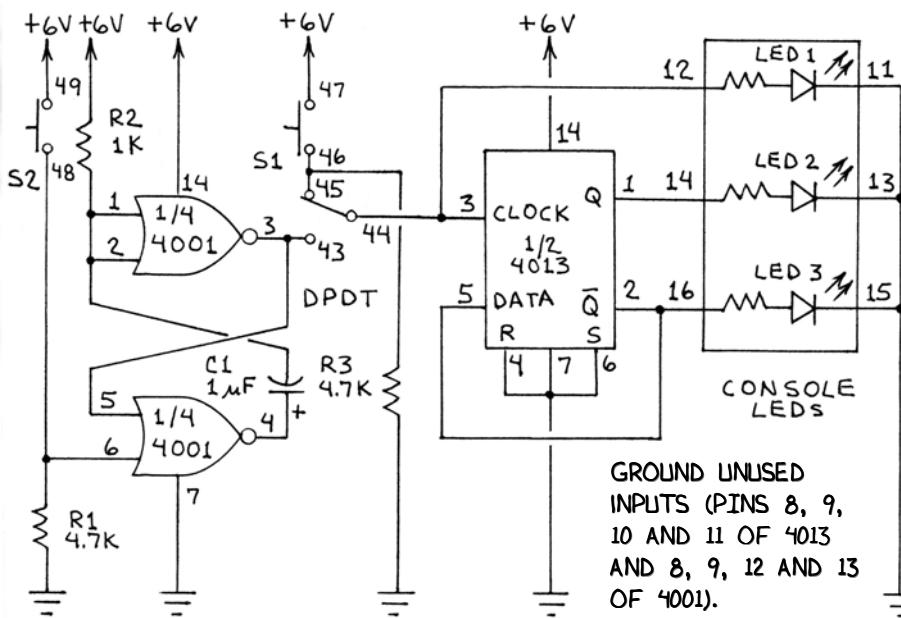
R1, R3-4.7K (YEL-VIO-RED)  
R2-1K (BRN-BLK-RED)



C1-1 11F

## CIRCUIT DIAGRAM

## 2. TEST THE CIRCUIT



CHECK FOR ERRORS. THEN PUSH THE DPDT SWITCH DOWN AND PUSH THE POWER SWITCH ON. PRESS S1. LED 1 WILL GLOW, AND LEDs 2 AND 3 WILL GLOW ALTERNATELY EACH TIME YOU PRESS S1. BUT SWITCH BOUNCE MAY CAUSE THE LEDs TO SWITCH MORE THAN ONCE PER INPUT PULSE. END THE BOUNCE BY PUSHING THE DPDT SWITCH UP. PRESS S2 TO DELIVER CLEAN PULSES FROM THE 4001 "ONE-SHOT" TO THE T-FLIP-FLOP. LED 1 WILL BRIEFLY FLASH WHEN YOU PRESS S2. DIM THE ROOM LIGHTS TO SEE THE FLASHES.

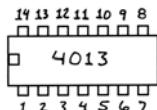
## 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
  2.  INSERT THE 4001 OVER SLOT 1 (PIN 1 AT F5).
  3.  INSERT THE 4013 OVER SLOT 3 (PIN 1 AT F15).
  4.  CONNECT L1 TO GROUND (WHT WIRE).
  5.  CONNECT F10 TO V4 (+6) (RED WIRE).
  6.  CONNECT F1 TO G1 (WHT WIRE).
  7.  CONNECT H1 TO J1 (WHT WIRE).
  8.  CONNECT G11 TO J11 (WHT WIRE).
  9.  CONNECT K12 TO L12 (WHT WIRE).
  10.  CONNECT I14 TO K14 (WHT WIRE).
  11.  CONNECT F20 TO V4 (+6) (WHT WIRE).
  12.  CONNECT L11 TO GROUND (WHT WIRE).
  13.  INSERT R1 ACROSS SPRING 48 AND GROUND.
  14.  INSERT R2 ACROSS F4 AND F7.
  15.  INSERT R3 ACROSS SPRING 46 AND GROUND.
  16.  INSERT C1 ACROSS I2 (+) AND G2 (-).
  17.  CONNECT SPRING 43 TO H4 (RED WIRE).
  18.  CONNECT SPRING 44 TO H13 (BLU WIRE).
  19.  CONNECT SPRINGS 45 AND 46 (WHT WIRE).
  20.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
  21.  CONNECT SPRING 48 TO K4 (RED WIRE).
  22.  CONNECT SPRING 49 TO V4 (+6) (BLU WIRE).
  23.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
  24.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
  25.  CONNECT SPRING 15 TO GROUND (BLU WIRE).
  26.  CONNECT SPRING 12 TO H14 (RED WIRE).
  27.  CONNECT SPRING 14 TO F14 (RED WIRE).
  28.  CONNECT SPRING 16 TO G14 (RED WIRE).
  29.  CONNECT I19 TO J19 (WHT WIRE).
  30.  CONNECT J20 TO K20 (WHT WIRE).
  31.  CONNECT K19 TO L19 (WHT WIRE).
  32.  CONNECT L20 TO GROUND (WHT WIRE).
  33.  CONNECT G10 TO H10 (WHT WIRE).
  34.  CONNECT H9 TO K9 (WHT WIRE).
  35.  CONNECT K10 TO L10 (WHT WIRE).
  36.  CONNECT L9 TO GROUND (WHT WIRE).

## 4013 DUAL FLIP-FLOP: BUILD A TWO-BIT STORAGE REGISTER OR LATCH

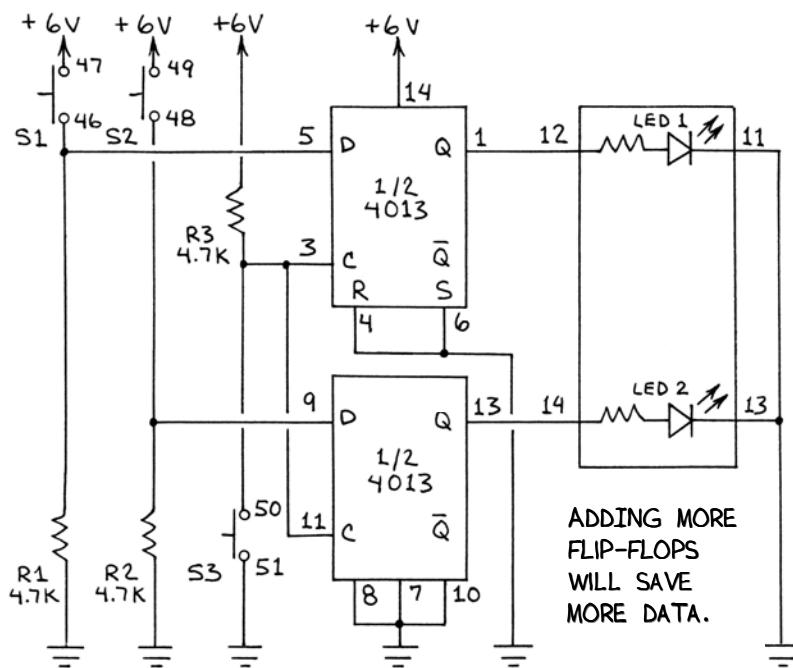
ARRAYS OF FLIP-FLOPS STORE TEMPORARY DATA AND INSTRUCTIONS IN COMPUTERS AND SIMPLER DIGITAL LOGIC SYSTEMS. YOU WILL BUILD A 2-BIT STORAGE REGISTER (OR LATCH). DATA YOU ENTER AT TWO PUSHBUTTON SWITCHES WILL BE STORED WHEN YOU PRESS A THIRD PUSHBUTTON. THE DATA WILL BE SAVED UNTIL YOU PRESS THE STORE PUSHBUTTON AGAIN.

### PARTS YOU WILL NEED



R1, R2, R3-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



DATA IN		LOAD	DATA OUT	
S1	S2	S3	LED 1	LED 2
OFF (0)	OFF (0)	OFF (0)	OFF (0)	OFF (0)
OFF (0)	OFF (0)	ON-OFF (0-1-0)	OFF (0)	OFF (0)
OFF (0)	ON (1)	CHANGE OF STATE OCCURS WHEN S3 IS RELEASED	OFF (0)	ON (1)
ON (1)	OFF (0)		ON (1)	OFF (0)
ON (1)	ON (1)		ON (1)	ON (1)

LOAD IS THE CLOCK INPUT.

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4013 OVER SLOT 3 (PIN 1 AT F15).
3.  INSERT R1 ACROSS J12 AND L12.
4.  INSERT R2 ACROSS K20 AND GROUND.
5.  INSERT R3 ACROSS H12 AND V4 (+6V).
6.  CONNECT L11 TO GROUND (WHT WIRE).
7.  CONNECT K13 TO L13 (WHT WIRE).
8.  CONNECT I14 TO K14 (WHT WIRE).
9.  CONNECT H14 TO I17 (WHT WIRE).
10.  CONNECT J19 TO L19 (WHT WIRE).
11.  CONNECT L17 TO GROUND (WHT WIRE).
12.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
13.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
14.  CONNECT SPRING 46 TO J14 (RED WIRE).
15.  CONNECT SPRING 48 TO K19 (RED WIRE).
16.  CONNECT SPRING 50 TO I12 (RED WIRE).
17.  CONNECT SPRING 49 TO V4 (+6V) (BLU WIRE).
18.  CONNECT SPRING 51 TO GROUND (RED WIRE).
19.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
20.  CONNECT SPRING 13 TO GROUND (BLU WIRE).
21.  CONNECT SPRING 12 TO F11 (RED WIRE).
22.  CONNECT SPRING 14 TO G20 (RED WIRE).

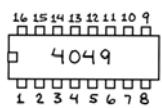
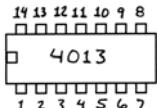
### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ENTER SOME DATA AT S1 AND S2 (PRESS FOR 1 AND DON'T PRESS FOR 0). WITH S1 AND/OR S2 STILL PRESSED, PRESS AND RELEASE S3. THIS LOADS THE DATA INTO THE REGISTER. THE LEDS WILL THEN DISPLAY

## 4013 DUAL FLIP-FLOP: BUILD A DIVIDE-BY-TWO CIRCUIT

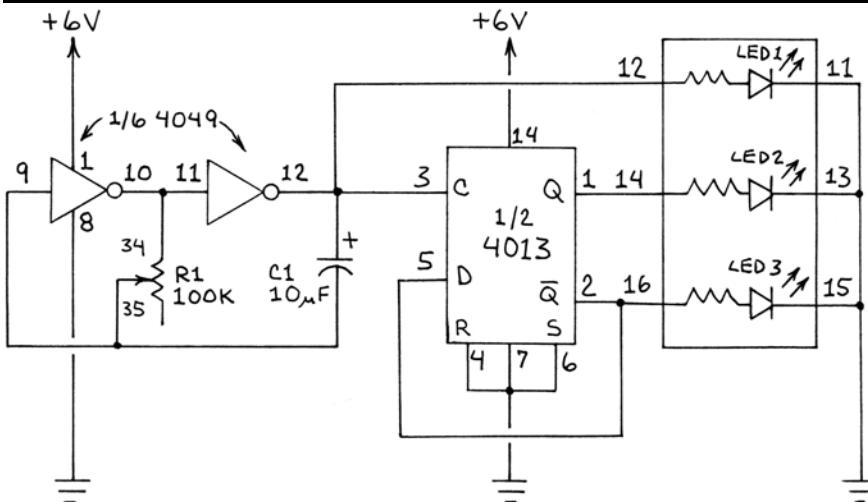
INCOMING CLOCK PULSES CAUSE THE OUTPUTS OF A FLIP-FLOP TO SWITCH BACK AND FORTH BETWEEN 0 AND 1. THIS MEANS THAT EACH OUTPUT CHANGES STATES AT HALF THE RATE OF THE INCOMING PULSES. YOU WILL BUILD A SIMPLE CLOCK AND FLIP-FLOP CIRCUIT THAT NICELY DEMONSTRATES THIS VERY USEFUL APPLICATION.

### PARTS YOU WILL NEED



C1-10  $\mu$ F

### CIRCUIT DIAGRAM



<u>CLOCK</u>	<u>LED 1</u>	<u>LED 2</u>	<u>LED 3</u>
0	OFF	OFF	ON
1	ON	ON	OFF
0	OFF	ON	OFF
1	ON	OFF	ON

LEDS 2 AND 3 CHANGE STATES EACH TIME A POSITIVE CLOCK PULSE (1) ARRIVES. GROUND UNUSED INPUTS (PINS 8, 9, 10 AND 11 OF 4013 AND 3, 5, 7 AND 14 OF 4049).

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 OVER SLOT 1 (PIN 1 AT K5).
3.  INSERT THE 4013 OVER SLOT 3 (PIN 1 AT F15).
4.  INSERT C1 ACROSS O9 (+) AND R9 (-).
5.  CONNECT R1 TO GROUND (WHT WIRE).
6.  CONNECT K1 TO V4 (+6) (RED WIRE).
7.  CONNECT L11 TO GROUND (WHT WIRE).
8.  CONNECT F20 TO V4 (+6) (WHT WIRE).
9.  CONNECT P8 TO Q8 (WHT WIRE).
10.  CONNECT O10 TO H11 (WHT WIRE).
11.  CONNECT K12 TO L12 (WHT WIRE).
12.  CONNECT G14 TO J14 (WHT WIRE).
13.  CONNECT I14 TO K14 (WHT WIRE).
14.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
15.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
16.  CONNECT SPRING 15 TO GROUND (BLU WIRE).
17.  CONNECT SPRING 12 TO H12 (RED WIRE).
18.  CONNECT SPRING 14 TO F12 (RED WIRE).
19.  CONNECT SPRING 16 TO G12 (RED WIRE).
20.  CONNECT SPRING 34 TO Q7 (RED WIRE).
21.  CONNECT SPRING 35 TO R7 (RED WIRE).
22.  CONNECT M7 TO GROUND (WHT WIRE).
23.  CONNECT M1 TO O1 (WHT WIRE).
24.  CONNECT O2 TO Q2 (WHT WIRE).
25.  CONNECT Q1 TO GROUND (WHT WIRE).
26.  CONNECT I20 TO L13 (WHT WIRE).
27.  CONNECT J20 TO L14 (WHT WIRE).
28.  CONNECT K20 TO GROUND (WHT WIRE).
29.  CONNECT L20 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ADJUST THE 100K CONSOLE POT (R1) UNTIL THE LEDS BEGIN FLASHING A FEW TIMES A SECOND. LED 1 WILL FLASH ONCE FOR EACH CLOCK PULSE FROM THE 4049 OSCILLATOR. LEDS 2 AND 3 WILL FLASH ALTERNATELY. NOTE THAT LEDS 2 AND 3 FLASH AT HALF THE RATE OF LED 1 (LOOK AT ONE OR THE OTHER LED TO SEE THIS.) **THUS THE CIRCUIT DIVIDES THE INCOMING CLOCK PULSES BY TWO.**

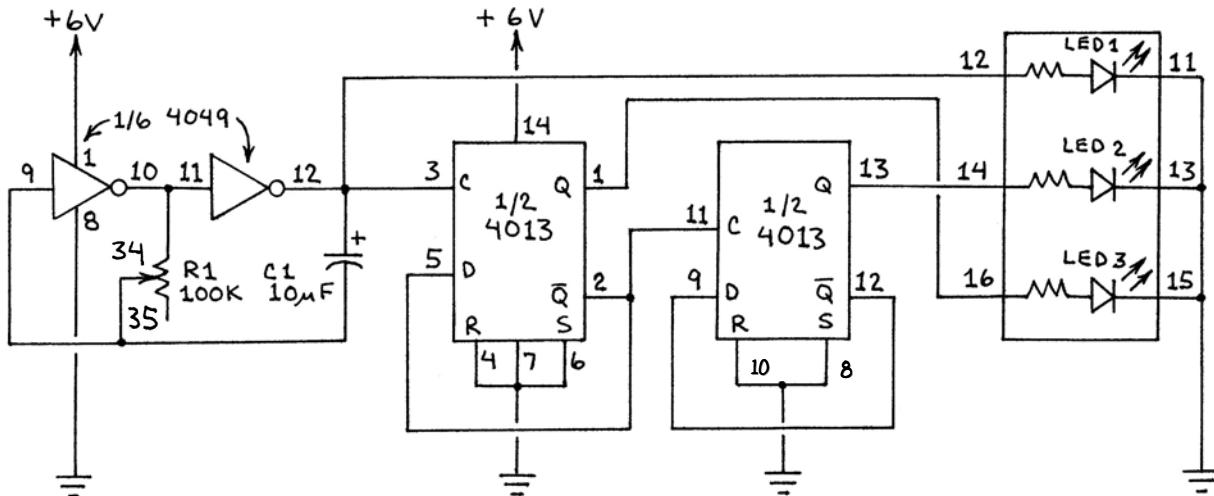
## 4013 DUAL FLIP-FLOP: BUILD A BINARY 2-BIT COUNTER

CONNECT ONE OUTPUT OF A T-TYPE FLIP-FLOP TO THE CLOCK INPUT OF A SECOND FLIP-FLOP AND YOU HAVE A BINARY COUNTER. YOU WILL MODIFY THE DIVIDE-BY-2 CIRCUIT ON THE FACING PAGE BY ADDING A SECOND FLIP-FLOP TO FORM A 2-BIT BINARY COUNTER.

### PARTS YOU WILL NEED

THIS IS A MODIFICATION OF THE DIVIDE-BY-2 CIRCUIT ON PAGE 71. NO ADDITIONAL PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



GROUND UNUSED 4049 INPUTS (PINS 3, 5, 7 AND 14).

#### 1. MODIFY THE DIVIDE-BY-2 CIRCUIT ON PAGE 71

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE THE 2 RED WIRES BETWEEN SPRINGS 14 AND 16 AND THE BREADBOARD.
3.  REMOVE WHT WIRE FROM L13 TO I20.
4.  REMOVE WHT WIRE FROM K20 TO GROUND.
5.  CONNECT H17 TO K17 (WHT WIRE).
6.  CONNECT G13 TO I17 (WHT WIRE).
7.  CONNECT SPRING 14 TO G17 (RED WIRE).
8.  CONNECT SPRING 16 TO F14 (RED WIRE).

#### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ADJUST THE 100K CONSOLE POT (R1) UNTIL CLOCK LED 1 FLASHES A FEW TIMES A SECOND. LED 1 WILL FLASH ONCE FOR EACH CLOCK PULSE FROM THE 4049 OSCILLATOR. LEDS 2 AND 3 WILL NOW BE COUNTING FROM DECIMAL 0 TO 3 IN BINARY: 00...01...10...11...00... THE COUNT RECYCLES AFTER IT REACHES DECIMAL 3. THE TRUTH TABLE SHOWS THAT THE COUNT ADVANCES WHEN THE CLOCK PULSE CHANGES FROM 0 TO 1. THIS MEANS THE COUNTER IS CLOCKED ON THE RISING EDGE OF THE INCOMING CLOCK PULSES. TO VERIFY THE TRUTH TABLE, SLOW THE CLOCK RATE (R1) AND WATCH LEDS 2 AND 3. A GLOWING LED IS 1 (HIGH). AN LED WHICH IS OFF IS 0 (LOW).

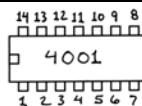
DECIMAL COUNT	BINARY COUNT	CLOCK	LED 1	LED 2	LED 3
0	00	0	OFF	OFF	OFF
1	01	1	ON	OFF	ON
		0	OFF		
2	10	1	ON	ON	OFF
		0	OFF		
3	11	1	ON	ON	ON
		0	OFF		
0	00	1	ON	OFF	OFF
		0	OFF		

## 4013 DUAL FLIP-FLOP: BUILD A 1-OF-4 SEQUENCER (LIGHT CHASER)

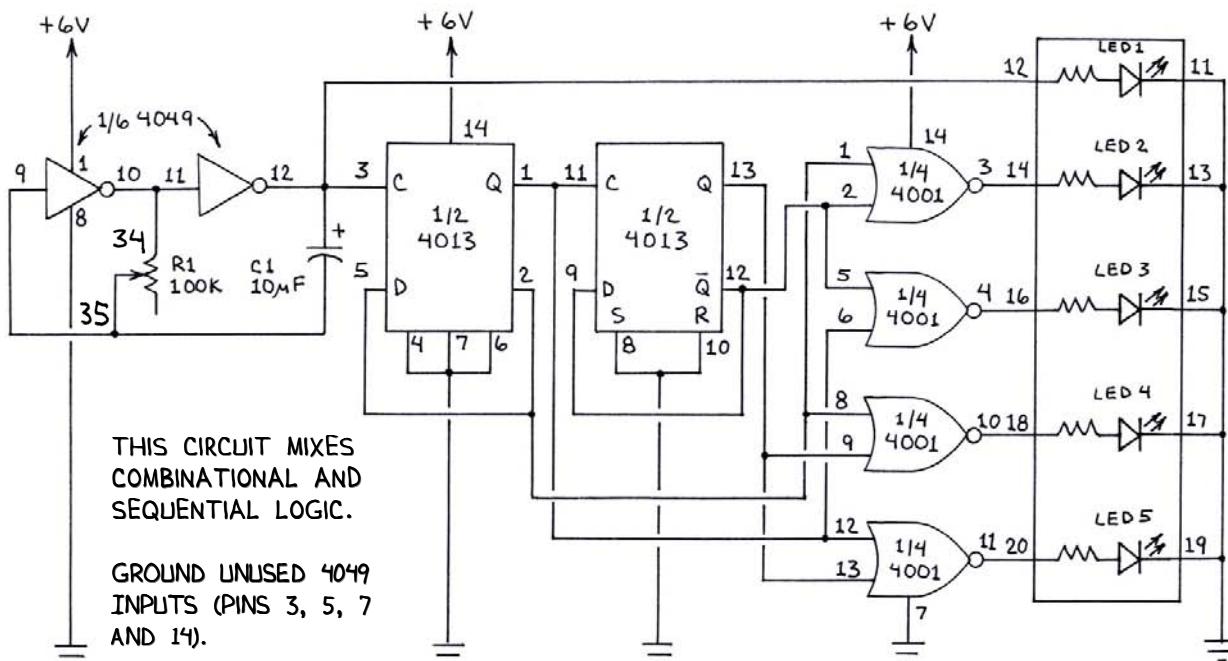
LOGIC CIRCUITS KNOWN AS DECODERS CAN BE ADDED TO THE OUTPUT OF A BINARY COUNTER TO ALTER THE OUTPUT. YOU WILL ADD A NOR GATE DECODER TO CONVERT A 2-BIT BINARY COUNTER INTO A 1-OF-4 SEQUENCER THAT WILL FLASH 1 OF 4 LEDs IN SEQUENCE.

### PARTS YOU WILL NEED

BINARY 2-BIT COUNTER  
CIRCUIT ON PAGE 72 PLUS:



### CIRCUIT DIAGRAM



### 1. MODIFY THE 2-BIT BINARY COUNTER ON PAGE 72

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE THE 2 RED WIRES BETWEEN SPRINGS 14 AND 16 AND THE BREADBOARD.
3.  MOVE WHT WIRE FROM G13 TO F13.
4.  INSERT THE 4001 OVER SLOT 5 (PIN 1 AT F25.)
5.  CONNECT F24 TO L27 (WHT WIRE).
6.  CONNECT G24 TO J24 (WHT WIRE).
7.  CONNECT K24 TO H27 (WHT WIRE).
8.  CONNECT G30 TO K30 (WHT WIRE).
9.  CONNECT L21 TO GROUND (WHT WIRE).
10.  CONNECT F27 TO V4 (+6V) (WHT WIRE).
11.  CONNECT H20 TO G21 (WHT WIRE).
12.  CONNECT I20 TO K21 (WHT WIRE).
13.  CONNECT G11 TO F21 (RED WIRE).
14.  CONNECT G20 TO K29 (RED WIRE).
15.  CONNECT SPRING 14 TO H21 (RED WIRE).
16.  CONNECT SPRING 16 TO I21 (RED WIRE).
17.  CONNECT SPRING 18 TO J30 (RED WIRE).
18.  CONNECT SPRING 20 TO I30 (RED WIRE).
19.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
20.  CONNECT SPRINGS 17 AND 19 (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK FOR LOOSE WIRES AND ERRORS. THEN PUSH THE POWER SWITCH ON. ADJUST THE 100K CONSOLE POT (R1) UNTIL CLOCK LED 1 FLASHES A FEW TIME A SECOND. LEDS 2-5 WILL BEGIN FLASHING ON AND OFF IN SEQUENCE: 1...2...3...4...1...2.3..4...1... ANY OTHER PATTERN MEANS THERE IS A WIRING ERROR OR A MISSING WIRE, PROBABLY IN THE 4001 DECODER SECTION OF THE CIRCUIT. ADJUST R1 WHILE WATCHING HOW THE LEDS REACT. PRETTY NEAT.

## 4013 DUAL FLIP-FLOP: BUILD A 2-STAGE SHIFT REGISTER

A SHIFT REGISTER IS A STRING OF FLIP-FLOPS THAT PASSES THE DATA BIT AT THE FIRST FLIP-FLOP INPUT TO EACH SUBSEQUENT FLIP-FLOP WHEN A CLOCK PULSE ARRIVES. YOU WILL BUILD A SIMPLE 2-STAGE SHIFT REGISTER AND WATCH AS IT SHIFTS DATA.

### PARTS YOU WILL NEED

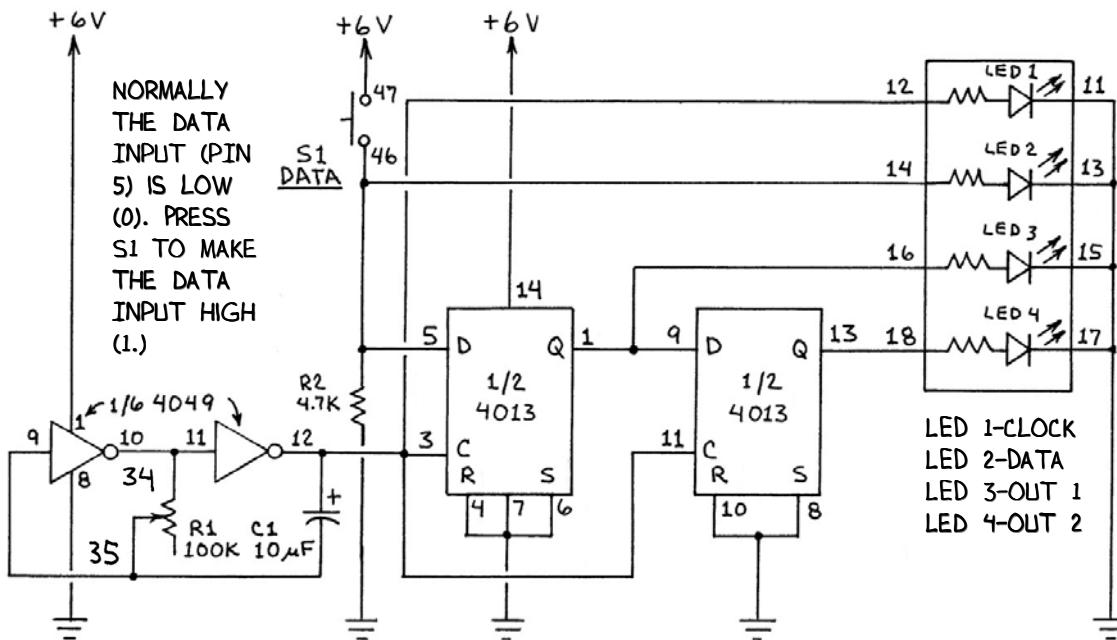
BINARY 2-BIT COUNTER



CIRCUIT ON PAGE 72 PLUS:

R2-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



GROUND UNUSED 4049 INPUTS (PINS 3, 5, 7 AND 14).

### 1. MODIFY THE TWO-BIT BINARY COUNTER ON PAGE 72

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE THE 2 RED WIRES BETWEEN SPRINGS 14 AND 16 AND THE BREADBOARD.
3.  REMOVE WHT WIRE FROM G14 TO J14.
4.  REMOVE WHT WIRE FROM G13 TO I17.
5.  REMOVE WHT WIRE FROM H17 TO K17.
6.  INSERT R2 ACROSS J11 AND GROUND.
7.  CONNECT F14 TO K17 (WHT WIRE).
8.  CONNECT H14 TO I17 (WHT WIRE).
9.  CONNECT SPRING 46 TO J12 (RED WIRE).
10.  CONNECT SPRING 47 TO V4 (+6V) (BLU WIRE).
11.  CONNECT SPRING 14 TO J13 (RED WIRE).
12.  CONNECT SPRING 16 TO F12 (RED WIRE).
13.  CONNECT SPRING 18 TO G20 (RED WIRE).
14.  CONNECT SPRING 15 TO GROUND (BLU WIRE).
15.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON. ADJUST THE 100K CONSOLE POT (R1) UNTIL LED 1 FLASHES A FEW TIMES EACH SECOND. ALL OTHER LEDS WILL BE OFF. PRESS S1 TO APPLY A 1 DATA BIT TO THE INPUT. LED 2 WILL GLOW FOLLOWED BY LEDS 3 AND 4 IN SEQUENCE. RELEASE S1. LED 2 WILL SWITCH OFF FOLLOWED BY LEDS 3 AND 4 IN SEQUENCE.

## 4013 DUAL FLIP-FLOP: BUILD A PSEUDO-RANDOM LED FLASHER

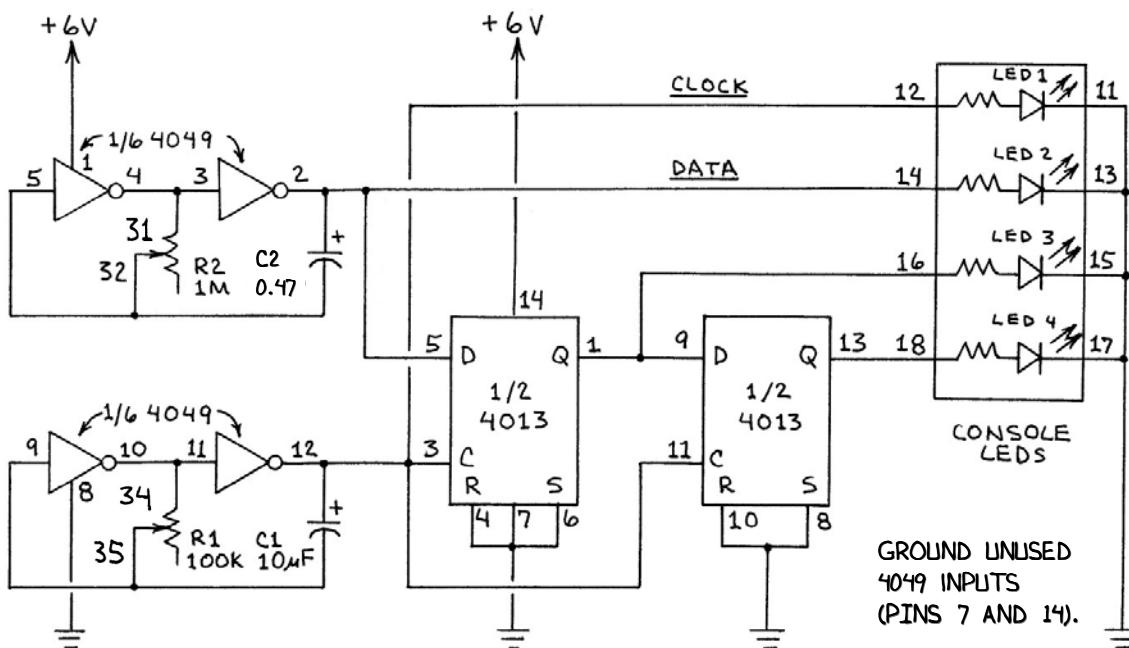
MULTI-STAGE SHIFT REGISTERS CAN PRODUCE SEQUENCES OF "RANDOM" NUMBERS IF THE DATA INPUT IS CONTINUALLY CHANGED. YOU WILL BUILD A SIMPLE 2-STAGE PSEUDO-RANDOM LED FLASHER. YOU WILL CHANGE THE INPUT DATA BY ADDING PULSES FROM A SECOND CLOCK.

### PARTS YOU WILL NEED

2-STAGE SHIFT REGISTER ON  
PAGE 74 PLUS:



### CIRCUIT DIAGRAM



### 1. MODIFY THE SHIFT REGISTER CIRCUIT ON PAGE 74

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHT WIRE FROM M1 TO O1.
3.  REMOVE WHT WIRE FROM O2 TO Q2.
4.  REMOVE R2.
5.  REMOVE WIRES BETWEEN S1 AND BREADBOARD
6.  INSERT C2 ACROSS L3 (+) AND O3 (-).
7.  CONNECT M1 TO N1 (WHT WIRE).
8.  CONNECT L4 TO J12 (RED WIRE).
9.  CONNECT SPRING 31 TO M2 (RED WIRE).
10.  CONNECT SPRING 32 TO O1 (RED WIRE).

### 2. TEST THE CIRCUIT

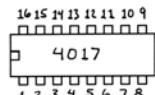
REVIEW YOUR WIRING AND MAKE SURE ALL THE WIRES GO SOMEWHERE. THEN PUSH THE POWER SWITCH ON. CLOCK LED 1 WILL FLASH AT A RATE CONTROLLED BY THE 100K CONSOLE POT (R1). DATA LED 2 WILL FLASH AT A RATE CONTROLLED BY THE 1M CONSOLE POT (R2). OUTPUT LEDs 3 AND 4 WILL FLASH ON AND OFF IN A PATTERN DETERMINED BY THE ARRIVAL RATE OF DATA PULSES. TRY CHANGING THE ADJUSTMENT OF BOTH POTENTS. THE PATTERN IS NOT REALLY RANDOM SINCE THERE ARE ONLY TWO STAGES TO THE SHIFT REGISTER. ADDING MORE STAGES CREATES A PATTERN THAT APPEARS TO THE EYE TO BE RANDOM, SINCE IT TAKES SO LONG TO REPEAT.

A SIMPLE WAY TO INCREASE THE APPARENT RANDOMNESS OF THIS CIRCUIT IS TO REPLACE R2 WITH THE PHOTORESISTOR. NOW THE RATE OF THE DATA PULSES IS CONTROLLED BY CHANGES IN LIGHT. BLOCK THE PHOTORESISTOR WITH A FINGER TO CHANGE THE DATA RATE.

## 4017 DECADE COUNTER: MAKE A SWITCH BOUNCE ANALYZER

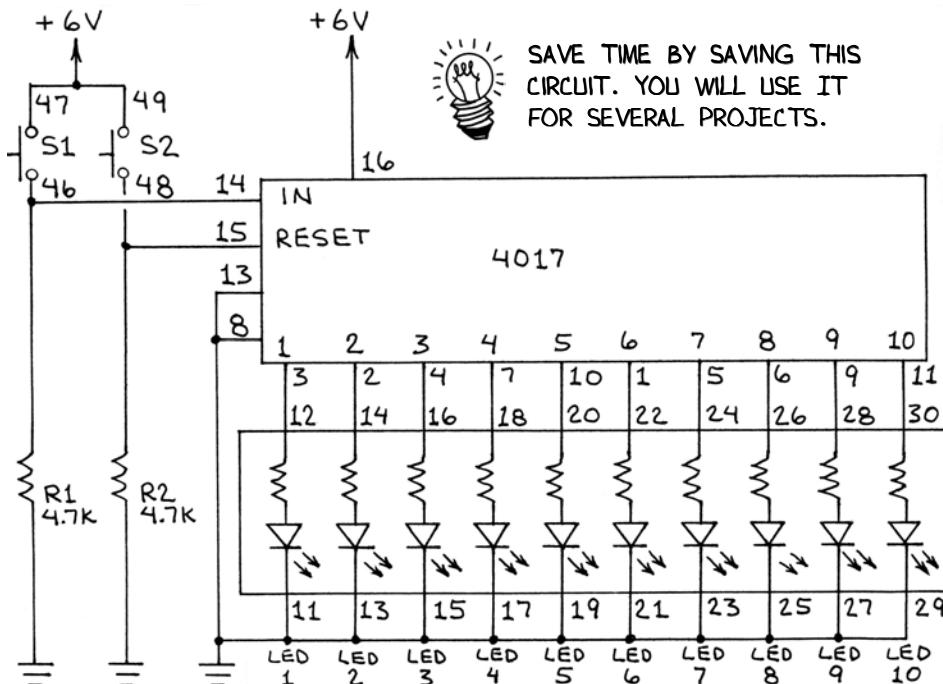
WHEN A SWITCH IS CLOSED OR OPENED, THE CONTACTS OFTEN FAIL TO CONNECT OR SEPARATE CLEANLY. THEY MAY CONNECT SEVERAL TIMES IN QUICK SUCCESSION BEFORE FIRM CONTACT OR COMPLETE SEPARATION OCCURS. THIS IS "SWITCH BOUNCE." YOU WILL USE A 4017 TO EXPERIMENT WITH SWITCH BOUNCE AND TO LEARN WHY IT'S BAD FOR LOGIC CIRCUITS.

### PARTS YOU WILL NEED



R1, R2-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. PUSH THE POWER SWITCH ON AND PRESS S2. LED 1 WILL GLOW. NOW PRESS AND RELEASE S1 TO APPLY A "SINGLE" PULSE TO THE 4017. IDEALLY, LED 2 WILL GLOW. BUT THE COUNT MAY ADVANCE SEVERAL LEDS BEYOND BECAUSE OF UNWANTED PULSES FROM SWITCH BOUNCE. EXPERIMENT TO SEE IF RELEASING S1 CAUSES MORE BOUNCES THAN PRESSING S1. AT ANY TIME YOU CAN PRESS S2 TO RESET THE COUNT.

### 1. BUILD THE CIRCUIT

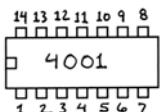
1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4017 IC ACROSS SLOT 5 (PIN 1 AT F25).
3.  INSERT R1 ACROSS H27 AND M23.
4.  INSERT R2 ACROSS G27 AND M22.
5.  CONNECT M21 TO GROUND (WHT WIRE).
6.  CONNECT F27 TO V4 (+6V) (WHT WIRE).
7.  CONNECT M24 TO I27 (WHT WIRE).
8.  CONNECT SPRING 12 TO H21 (RED WIRE).
9.  CONNECT SPRING 14 TO G21 (RED WIRE).
10.  CONNECT SPRING 16 TO I21 (RED WIRE).
11.  CONNECT SPRING 18 TO L21 (RED WIRE).
12.  CONNECT SPRING 20 TO L30 (RED WIRE).
13.  CONNECT SPRING 22 TO F21 (RED WIRE).
14.  CONNECT SPRING 24 TO J21 (RED WIRE).
15.  CONNECT SPRING 26 TO K21 (BLU WIRE).
16.  CONNECT SPRING 28 TO M30 (BLU WIRE).
17.  CONNECT SPRING 30 TO K30 (BLU WIRE).
18.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
19.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
20.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
21.  CONNECT SPRINGS 17 AND 19 (WHT WIRE).
22.  CONNECT SPRINGS 19 AND 21 (WHT WIRE).
23.  CONNECT SPRINGS 21 AND 23 (WHT WIRE).
24.  CONNECT SPRINGS 23 AND 25 (WHT WIRE).
25.  CONNECT SPRINGS 25 AND 27 (WHT WIRE).
26.  CONNECT SPRINGS 27 AND 29 (WHT WIRE).
27.  CONNECT SPRING 29 TO GROUND (BLU WIRE).
28.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
29.  CONNECT SPRING 47 TO V4 (+6V) (BLU WIRE).
30.  CONNECT SPRING 46 TO H28 (RED WIRE).
31.  CONNECT SPRING 48 TO G28 (RED WIRE).

## 4017 DECADE COUNTER: MAKE A TOTALIZER

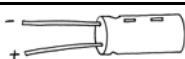
THIS CIRCUIT FEATURES A SWITCH DEBOUNCER THAT PROVIDES CLEAN, NOISE-FREE PULSES. YOU WILL ADD THE DEBOUNCER CIRCUIT TO THE 4017 BOUNCE ANALYZER TO MAKE A TOTALIZER THAT INCREMENTS (ADDS 1 TO THE CURRENT COUNT) EACH TIME A PUSHBUTTON IS PRESSED.

### PARTS YOU WILL NEED

THIS CIRCUIT REQUIRES THE 4017 SWITCH BOUNCE ANALYZER ON PAGE 76 PLUS THESE PARTS:

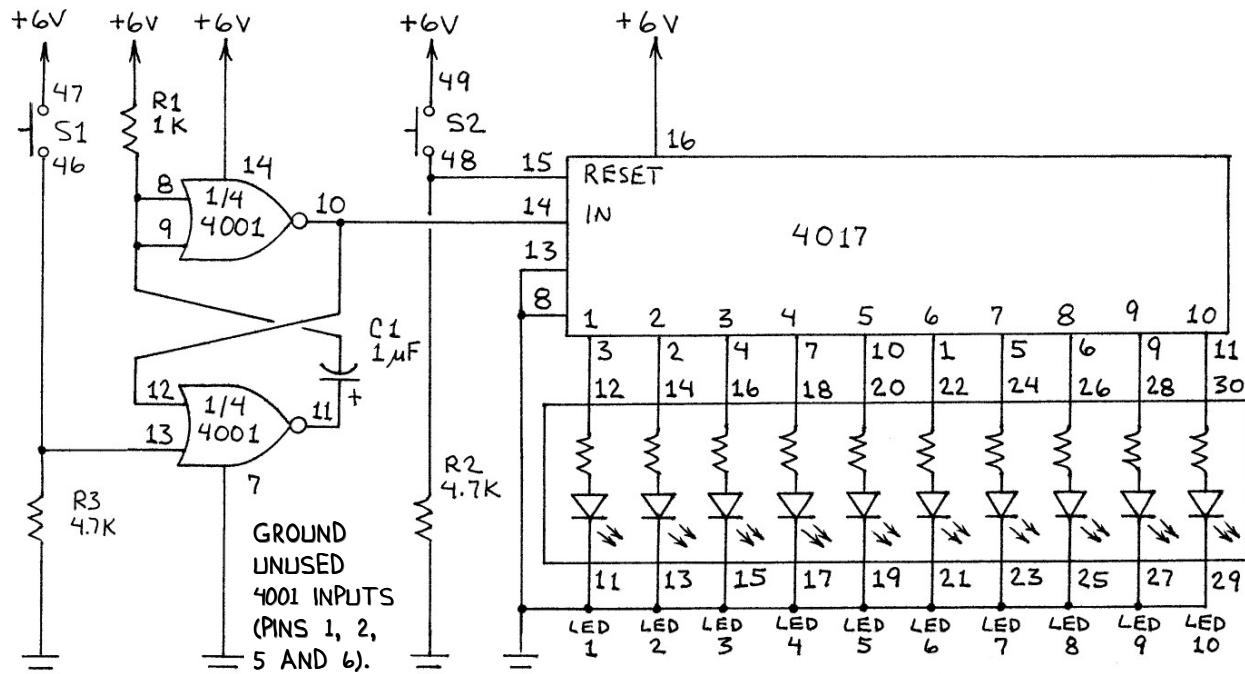


R1-1K (BRN-BLK-RED)  
R2, R3-4.7K (YEL-VIO-RED)



C1-1  $\mu$ F

### CIRCUIT DIAGRAM



### 1. MODIFY THE SWITCH BOUNCE ANALYZER CIRCUIT ON PAGE 76

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE R1 FROM THE 4017 SWITCH BOUNCE ANALYZER CIRCUIT.
3.  INSERT THE 4001 IC ACROSS SLOT 3 (PIN 1 AT F15).
4.  MOVE RED WIRE AT H28 TO G17.
5.  CONNECT L11 TO GROUND (WHT WIRE).
6.  CONNECT F20 TO V4 (+6V) (WHT WIRE).
7.  CONNECT H20 TO J20 (WHT WIRE).
8.  CONNECT K20 TO L20 (WHT WIRE).
9.  CONNECT J19 TO H27 (RED WIRE).
10.  INSERT R1 ACROSS F17 AND K17.
11.  INSERT R3 FROM SPRING 46 TO GROUND.
12.  INSERT C1 ACROSS I18 (+) AND K18 (-).
13.  CONNECT F11 TO L14 (WHT WIRE).
14.  CONNECT G11 TO L13 (WHT WIRE).
15.  CONNECT J11 TO GROUND (WHT WIRE).
16.  CONNECT K11 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE POWER SWITCH ON. PRESS AND RELEASE S2. ONLY LED 1 WILL GLOW. PRESS AND RELEASE S1, AND ONLY LED 2 WILL GLOW. THE LEDS WILL CONTINUE TO GLOW IN SEQUENCE EACH TIME YOU PRESS S1. NOTE THAT THE COUNT IS ALWAYS INCREMENTED BY 1. SINCE S1 IS DEBOUNCED, THERE ARE NO NOISE SPIKES TO CAUSE FALSE TRIGGERING OF THE COUNT. AT ANY TIME YOU CAN RESET THE COUNT BACK TO 1 BY PRESSING S2. THIS CAPABILITY GIVES RISE TO SOME NEAT APPLICATIONS WE'LL LOOK AT SOON.

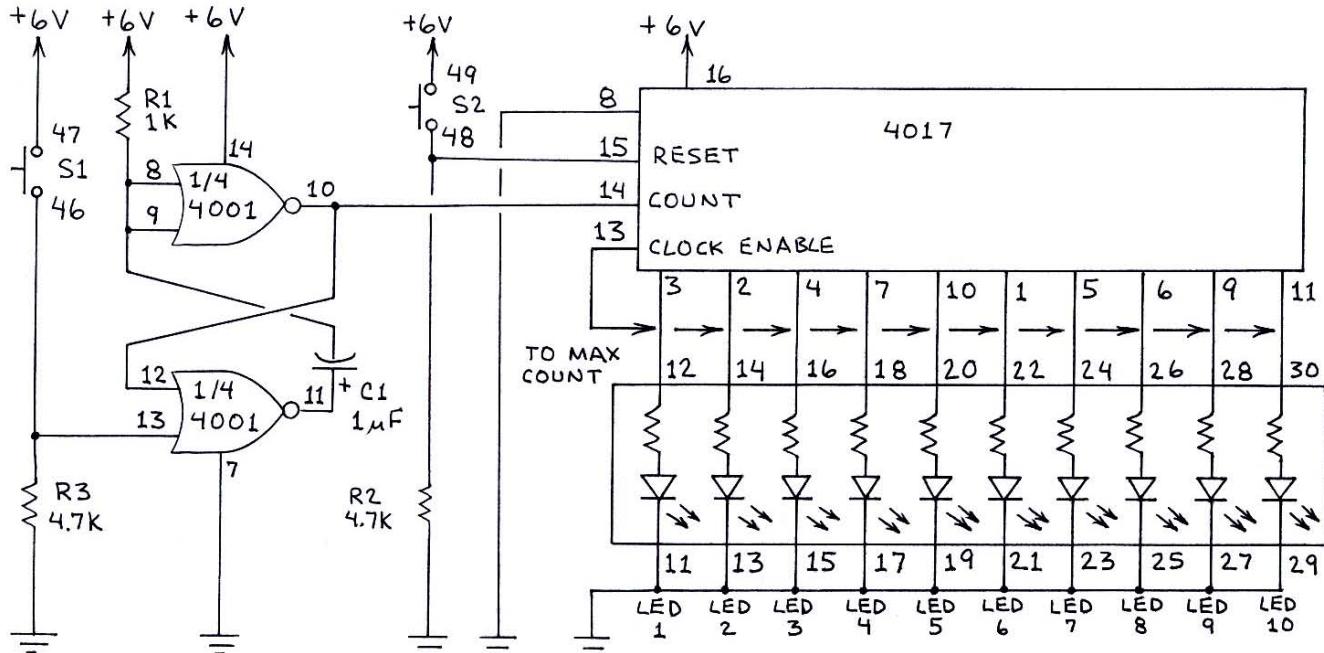
## 4017 DECADE COUNTER: BUILD A COUNT-TO-N-AND-HALT COUNTER

THE 4017 CLOCK-ENABLE (CE) INPUT (PIN 13) HAS MANY USES. YOU WILL CONVERT THE TOTALIZER CIRCUIT ON PAGE 77 INTO A COUNT-TO-2-AND-HALT COUNTER BY CONNECTING THE 4017 CE PIN TO OUTPUT PIN 2. YOU WILL THEN PROGRAM THE CIRCUIT FOR OTHER COUNTS (3 TO 10) BY CONNECTING THE CE PIN TO THE APPROPRIATE 4017 OUTPUT PIN.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE 4017 TOTALIZER CIRCUIT ON PAGE 77. NO ADDITIONAL PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



### 1. MODIFY THE TOTALIZER CIRCUIT ON PAGE 77

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHT WIRE BETWEEN M24 AND J27.
3.  INSERT A PROGRAMMING WIRE AT J27 (BLU WIRE). FOR INITIAL TESTS, CONNECT

THE OPPOSITE END OF THE PROGRAMMING WIRE TO SPRING 14 TO PROVIDE COUNT-TO-2-AND-HALT OPERATION.

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. PUSH THE POWER SWITCH ON. PRESS AND RELEASE S2. LED 1 WILL GLOW. PRESS S1, AND LED 2 WILL GLOW. PRESS S1 AGAIN, AND LED 2 WILL CONTINUE TO GLOW SINCE THE OUTPUT THAT DRIVES LED 2 (PIN 2) IS NOW FORCING THE CE PIN HIGH. THIS DISABLES THE COUNTER AND IT NO LONGER RESPONDS WHEN YOU PRESS S1. PRESS S2 TO RESET THE COUNT TO LED 1.

NOW MOVE THE BLUE PROGRAMMING WIRE FROM SPRING 14 TO SPRING 16. PRESS S2 TO RESET THE CIRCUIT AND BEGIN PRESSING S1. WHEN LED 3 GLOWS, THE COUNT CANNOT BE ADVANCED. REPEAT THIS PROCEDURE FOR VARIOUS OTHER COUNTS.

CE AT:	MAX COUNT
SPRING 14	2
SPRING 16	3
SPRING 18	4
SPRING 20	5
SPRING 22	6
SPRING 24	7
SPRING 26	8
SPRING 28	9
SPRING 30	10

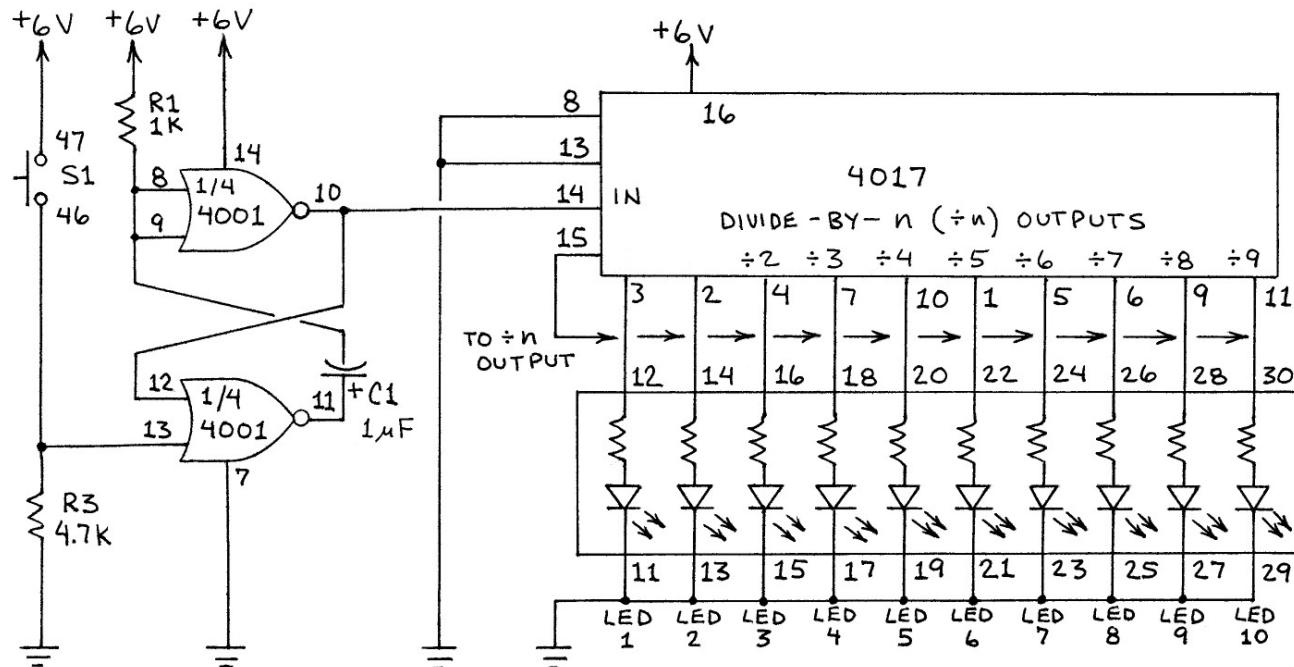
## 4017 DECADE COUNTER: BUILD A PROGRAMMABLE DIVIDE-BY-N COUNTER

THE 4017 RESET INPUT (PIN 15) PERMITS MANY POWERFUL APPLICATIONS. YOU WILL CONVERT THE COUNT-TO-N-AND-HALT CIRCUIT ON THE PRECEDING PAGE INTO A DIVIDE-BY-2 COUNTER BY CONNECTING THE RESET INPUT TO OUTPUT PIN 4. YOU WILL THEN PROGRAM THE CIRCUIT TO DIVIDE BY 3 TO 9 BY CONNECTING THE RESET PIN TO THE APPROPRIATE OUTPUTS.

### PARTS YOU WILL NEED

THIS CIRCUIT IS A MODIFIED VERSION OF THE 4017 COUNT-TO-N-AND-HALT CIRCUIT ON PAGE 78. NO ADDITIONAL PARTS ARE REQUIRED.

### CIRCUIT DIAGRAM



### 1. MODIFY THE COUNT-TO-N-AND-HALT CIRCUIT ON PAGE 78

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE R2 AND THE PROGRAMMING WIRE FROM THE 4017 COUNT-TO-N-AND-HALT CIRCUIT.
3.  DISCONNECT S2 FROM THE 4017 COUNT-TO-N-AND-HALT CIRCUIT.
4.  CONNECT M24 AND I27 (WHT WIRE).
5.  INSERT A PROGRAMMING WIRE AT G27 (BLU WIRE). FOR INITIAL TESTS, CONNECT THE OPPOSITE END OF THE PROGRAMMING WIRE TO SPRING 16 (DIVIDE-BY-2).

### 2. TEST THE CIRCUIT

CHECK FOR ERRORS. PUSH THE POWER SWITCH ON. PRESS S1 UNTIL LED 1 GLOWS. PRESS S1 AGAIN, AND LED 2 WILL GLOW. PRESS S1 AGAIN, AND LED 1 WILL GLOW. LED 2 GLOWS ONCE FOR EVERY TWO SWITCH CLOSURES. THIS THE CIRCUIT IS A DIVIDE-BY-2 COUNTER.

NOW MOVE THE BLUE PROGRAMMING WIRE FROM SPRING 16 TO SPRING 18. LED 3 WILL GLOW FOR EVERY THREE CLOSURES OF S1. THIS THE CIRCUIT IS NOW A DIVIDE-BY-3 COUNTER. REPEAT THIS PROCEDURE FOR EACH OF THE REMAINING OUTPUTS (SEE THE TRUTH TABLE OR THE CIRCUIT DIAGRAM).

RESET AT:	DIVIDES-BY
SPRING 16	2
SPRING 18	3
SPRING 20	4
SPRING 22	5
SPRING 24	6
SPRING 26	7
SPRING 28	8
SPRING 30	9

## 4017 DECADE COUNTER: BUILD A BARGRAPH READOUT

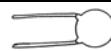
SOME VERY CREATIVE APPLICATIONS ARE MADE POSSIBLE BY CONNECTING PULSE GENERATORS TO THE CLOCK AND RESET INPUTS OF THE 4017. YOU WILL USE THIS APPROACH TO CONVERT THE 4017 SWITCH BOUNCE ANALYZER ON PAGE 76 INTO A HIGHLY VERSATILE ANALOG-TO-DIGITAL BARGRAPH READOUT CIRCUIT WITH APPLICATIONS LIMITED ONLY BY YOUR IMAGINATION.

### PARTS YOU WILL NEED

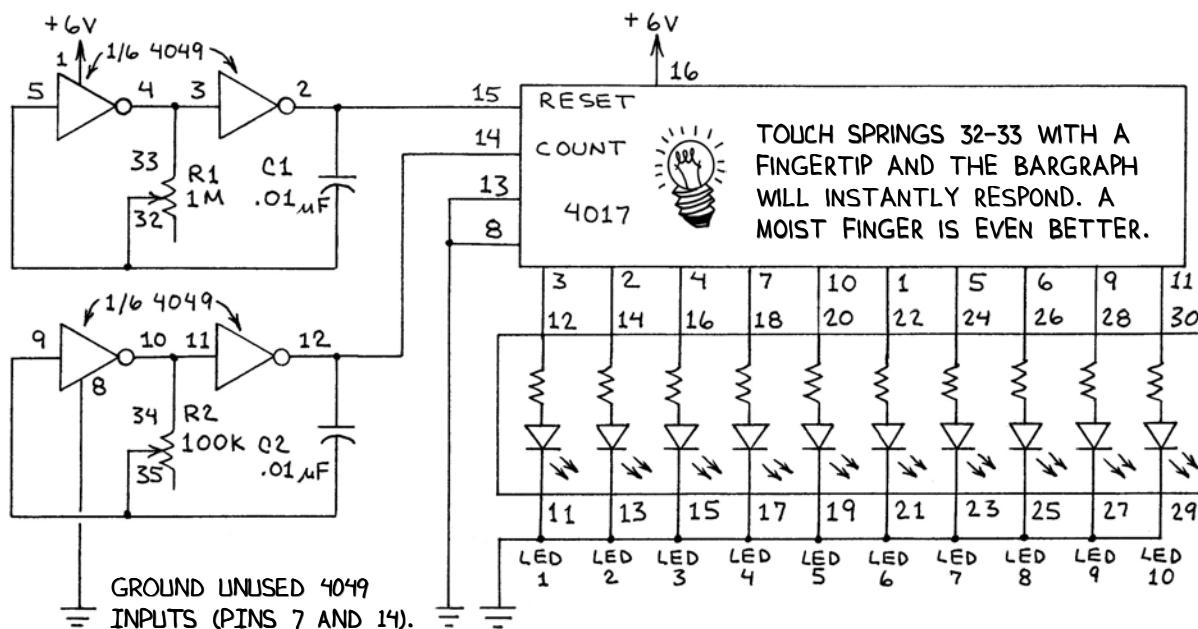
THIS CIRCUIT REQUIRES THE BASIC 4017 SWITCH BOUNCE ANALYZER ON PAGE 76 CIRCUIT PLUS THESE PARTS:



C1, C2-0.01 uF (103)



### CIRCUIT DIAGRAM



### 1. MODIFY THE SWITCH BOUNCE ANALYZER ON PAGE 76

1.  PUSH THE POWER SWITCH TO OFF.
2.  ASSEMBLE THE SWITCH BOUNCE ANALYZER WITHOUT USING R1, R2, S1 AND S2.
3.  INSERT THE 4049 IC ACROSS SLOT 1 (PIN 1 AT K5).
4.  CONNECT BREADBOARD HOLE R1 TO GROUND (WHT WIRE).
5.  CONNECT K1 TO V4 (+6V) (RED WIRE).
6.  CONNECT M1 TO N1 (WHT WIRE).
7.  INSERT C1 ACROSS L4 AND O4.
8.  INSTALL C2 ACROSS O8 AND R8.
9.  CONNECT P10 TO Q10 (WHT WIRE).
10.  CONNECT O10 TO H27 (BLU WIRE).
11.  CONNECT L1 TO G30 (BLU WIRE).
12.  CONNECT SPRING 32 TO O2 (RED WIRE).
13.  CONNECT SPRING 33 TO M2 (RED WIRE).
14.  CONNECT SPRING 34 TO Q7 (RED WIRE).
15.  CONNECT SPRING 35 TO R7 (RED WIRE).
16.  CONNECT Q4 TO GROUND (WHT WIRE).
17.  CONNECT M7 TO GROUND (WHT WIRE).

### 2. TEST THE CIRCUIT

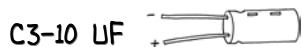
CHECK YOUR WIRING FOR ERRORS. SET THE 1M (R1) AND 100K (R2) CONSOLE POTTS TO THEIR MID-POINTS AND PUSH THE POWER SWITCH ON. SLOWLY ADJUST THE 100K POT UNTIL ALL TEN LEDS GLOW. NOW ROTATE THE 1M POT KNOB TO THE LEFT. THE LEDS WILL SWITC OFF IN SEQUENCE UNTIL ONLY LED 1 GLOWS. EXPERIMENT WITH DIFFERENT SETTINGS OF R1 AND R2. THE CIRCUIT IS A TYPE OF ANALOG-TO-DIGITAL CONVERTER SINCE A VARIABLE RESISTANCE IS CONVERTED INTO A DIGITAL FORMAT ON THE LED BARGRAPH. YOU CAN MAKE A SIMPLE BARGRAPH LIGHT METER BY SUBSTITUTING THE PHOTORESISTOR FOR R1. TRY IT. VERY NEAT APPLICATION.

## 4017 DECADE COUNTER: HOW TO ENHANCE THE BARGRAPH READOUT

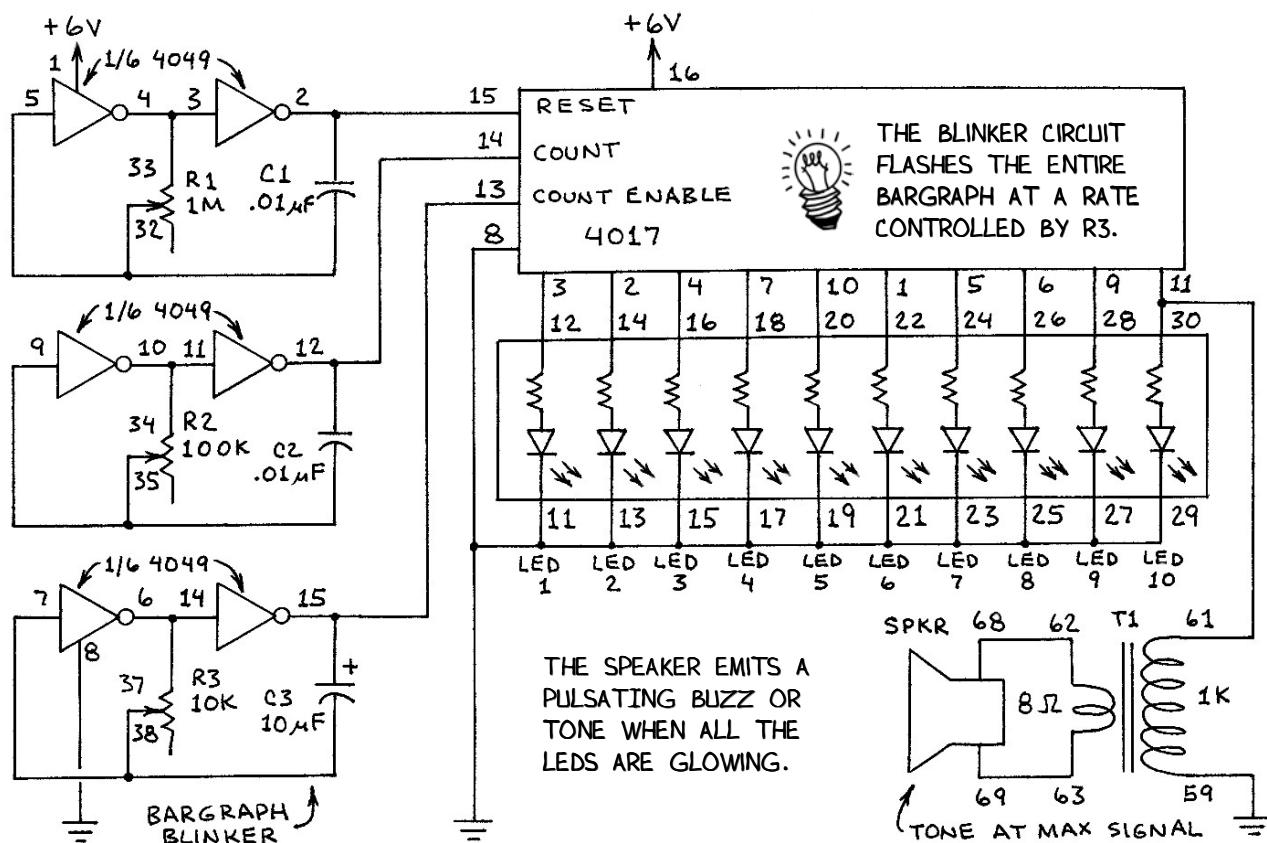
YOU WILL ADD SOME "BELLS AND WHISTLES" TO ENHANCE THE BASIC BARGRAPH CIRCUIT ON PAGE 80. A THIRD PULSE GENERATOR WILL FLASH THE BARGRAPH AND THE SPEAKER WILL EMIT A TONE TO ALERT YOU WHEN THE BARGRAPH READING REACHES LED 10.

### PARTS YOU WILL NEED

THIS CIRCUIT REQUIRES THE 4017 BARGRAPH READOUT ON PAGE 80 PLUS:



### CIRCUIT DIAGRAM



### 1. MODIFY THE BARGRAPH CIRCUIT ON PAGE 80

1.  PUSH THE POWER SWITCH TO OFF.
2.  REMOVE WHT WIRE BETWEEN M24 AND I27.
3.  REMOVE WHT WIRE FROM Q4 TO GROUND.
4.  REMOVE WHT WIRE FROM M7 TO GROUND.
5.  CONNECT P4 AND M10 (WHT WIRE).
6.  CONNECT L10 AND I30 (BLU WIRE).
7.  CONNECT SPRING 37 TO P1 (RED WIRE).
8.  CONNECT SPRING 38 TO Q1 (RED WIRE).
9.  INSERT C3 ACROSS L7 (+) AND Q4 (-).
10.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
11.  CONNECT SPRINGS 63 AND 69 (RED WIRE).
12.  CONNECT SPRING 59 TO GROUND (RED WIRE).
13.  CONNECT SPRINGS 30 AND 61 (RED WIRE).

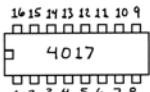
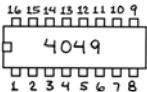
### 2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON AND ADJUST THE 1M CONSOLE POT (R1) UNTIL SOME LEDs ARE GLOWING. THEN ADJUST THE 10K CONSOLE POT UNTIL THE LEDs FLASH AT THE RATE YOU PREFER. NOW ADJUST R1 UNTIL ALL 10 LEDs GLOW. THE SPEAKER IS CONNECTED TO LED 10, AND IT WILL EMIT A PULSATING BUZZ OR TONE. THE TONE WILL STOP WHEN LED 10 IS OFF. R3 CONTROLS THE BARGRAPH FLASH RATE AND THE PULSING TONE. YOU CAN ADD THE DPDT SWITCH TO SWITCH BETWEEN BLINKING AND NON-BLINKING OPERATION. MOVE THE BLUE WIRE AT L10 TO SPRING 44. CONNECT L10 AND SPRING 43 (RED WIRE).

## 4017 DECADE COUNTER: BUILD A RANDOM NUMBER GENERATOR

RANDOM NUMBER GENERATORS ARE USED IN COMPUTER GAMES AND IN MANY SCIENTIFIC AND MATHEMATICS APPLICATIONS. YOU WILL BUILD AND EXPERIMENT WITH A SIMPLE RANDOM NUMBER GENERATOR. YOU WILL THEN MODIFY THE CIRCUIT TO IMPROVE ITS PERFORMANCE.

### PARTS YOU WILL NEED

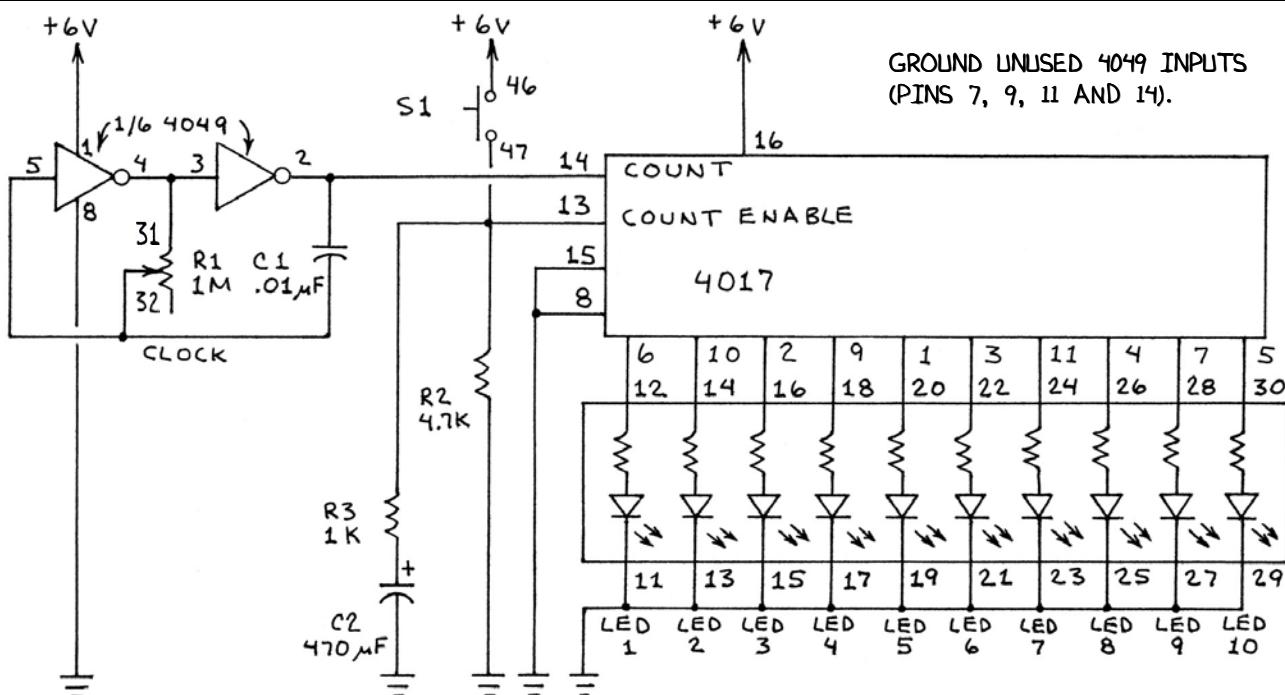


R2-4.7K (YEL-VIO-RED)  
R3-1K (BRN-BLK-RED)

C1-0.01 uF (103)

C2-470 uF

### CIRCUIT DIAGRAM



### ABOUT THE CIRCUIT

A FAST SERIES OF CLOCK PULSES IS GENERATED BY A PAIR OF 4049 INVERTERS AND SENT TO A 4017 COUNTER-DECODER. NORMALLY THE COUNT ENABLE INPUT IS PULLED LOW BY R2. WHEN S1 IS PRESSED, C2 QUICKLY CHARGES TO THE SUPPLY VOLTAGE THROUGH R3. PRESSING S1 ALSO PULLS THE COUNT ENABLE INPUT HIGH, WHICH STOPS THE COUNT. ONLY THE LED GLOWING AT THAT MOMENT STAYS ON. AFTER A SECOND OR SO, C2 DISCHARGES THROUGH R2 AND R3, AND ALL THE LEDs GLOW AGAIN. THE CLOCK PULSES OCCUR TOO FAST TO GUESS HOW MANY HAVE OCCURRED. THEREFORE THE LED THAT GLOWS WHEN S1 IS PRESSED IS RANDOMLY SELECTED.

### 1. BUILD THE CLOCK AND CONTROL CIRCUITS FIRST

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 IC ACROSS SLOT 1 (PIN 1 AT K5).
3.  CONNECT R1 TO GROUND (WHT WIRE).
4.  CONNECT K1 TO V4 (+6V) (RED WIRE).
5.  CONNECT M1 TO N1 (WHT WIRE).
6.  CONNECT SPRING 31 TO M2 (RED WIRE).
7.  CONNECT SPRING 32 TO O2 (RED WIRE).
8.  INSERT C1 ACROSS L4 AND O4.
9.  INSERT R3 ACROSS A16 AND D16.
10.  INSERT C2 ACROSS D17 (+) AND F17 (-).
11.  CONNECT F20 TO GROUND (RED WIRE).
12.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
13.  CONNECT SPRING 47 TO A20 (BLU WIRE).
14.  CONNECT Q1 TO GROUND (WHT WIRE).
15.  CONNECT M10 TO GROUND (WHT WIRE).
16.  CONNECT P10 TO GROUND (WHT WIRE).
17.  CONNECT R10 TO GROUND (WHT WIRE).

## 2. NOW BUILD THE COUNTER CIRCUIT

1.  INSERT THE 4017 IC ACROSS SLOT 5 (PIN 1 AT F25).
2.  INSERT R2 ACROSS M24 AND I27.
3.  CONNECT G30 TO GROUND (RED WIRE).
4.  CONNECT A19 TO I30 (RED WIRE).
5.  CONNECT M21 TO GROUND (WHT WIRE).
6.  CONNECT F27 TO V<sup>4</sup> (+6V) (WHT WIRE).
7.  CONNECT H30 TO L3 (BLU WIRE).
8.  CONNECT SPRING 12 TO K21 (RED WIRE).
9.  CONNECT SPRING 14 TO L30 (BLU WIRE).
10.  CONNECT SPRING 16 TO G21 (RED WIRE).
11.  CONNECT SPRING 18 TO M30 (RED WIRE).
12.  CONNECT SPRING 20 TO F21 (RED WIRE).
13.  CONNECT SPRING 22 TO H21 (RED WIRE).
14.  CONNECT SPRING 24 TO K30 (RED WIRE).
15.  CONNECT SPRING 26 TO I21 (BLU WIRE).
16.  CONNECT SPRING 28 TO L21 (BLU WIRE).
17.  CONNECT SPRING 30 TO J21 (BLU WIRE).
18.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
19.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
20.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
21.  CONNECT SPRINGS 17 AND 19 (WHT WIRE).
22.  CONNECT SPRINGS 19 AND 21 (WHT WIRE).
23.  CONNECT SPRINGS 21 AND 23 (WHT WIRE).
24.  CONNECT SPRINGS 23 AND 25 (WHT WIRE).
25.  CONNECT SPRINGS 25 AND 27 (WHT WIRE).
26.  CONNECT SPRINGS 27 AND 29 (WHT WIRE).
27.  CONNECT SPRING 29 TO GROUND (BLU WIRE).

## 3. TEST THE CIRCUIT

CAREFULLY CHECK YOUR WIRING. NOTE THAT THE CONNECTIONS FROM THE 4017 OUTPUTS TO THE LEDs ARE "SCRAMBLED" (OUT OF ORDER) TO ENHANCE THE APPARENT RANDOMNESS OF THE CIRCUIT. PUSH THE POWER SWITCH ON. THEN ADJUST THE 1M CONSOLE POTENTIOMETER (R1) UNTIL THE ROW OF 10 LEDs IS FLICKERING VERY RAPIDLY. PRESS S1, AND ONLY ONE LED WILL GLOW. IT WILL CONTINUE TO GLOW FOR A SECOND OR SO AFTER YOU RELEASE S1. WHEN C2 IS DISCHARGED, THE ROW OF LEDs WILL RESUME FLICKERING.

## EXPERIMENTING WITH THE CIRCUIT

THE CIRCUIT MIGHT SEEM MORE RANDOM WHEN THE CLOCK IS ADJUSTED FOR THE FASTEST POSSIBLE FREQUENCY. BUT YOU MIGHT PREFER A SLOWER CLOCK SPEED THAT CAUSES A FLICKERING DISPLAY. IF YOU GENERATE A STRING OF 50 OR MORE NUMBERS, YOU MAY FIND THAT SOME NUMBERS OCCUR MUCH MORE FREQUENTLY THAN OTHERS. IF SO, THE CIRCUIT IS NOT TRULY RANDOM. YOU MAY BE ABLE TO IMPROVE THE CIRCUIT'S RANDOMNESS BY MODIFYING THE CIRCUIT.

## MODIFYING THE CIRCUIT

C2 KEEPS THE "RANDOM" LED GLOWING FOR A SECOND OR SO WHEN YOU TAKE YOUR FINGER OFF S1. THE CIRCUIT MAY PROVIDE BETTER RANDOMNESS IF YOU REMOVE C2 AND R3. THEN WHEN YOU PRESS S1, THE COUNTER WILL IMMEDIATELY STOP COUNTING.

AN EVEN BETTER SOLUTION IS TO CONNECT PUSHBUTTON S2 BETWEEN THE CLOCK AND THE COUNTER ALONG WITH A PULL DOWN RESISTOR TO KEEP THE COUNT FROM BEING TRIGGERED BY ELECTRICAL NOISE BETWEEN CLOCK PULSES. PUSH THE POWER SWITCH OFF AND DO THIS:

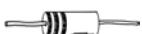
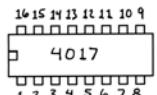
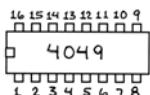
1.  REMOVE THE BLUE WIRE ACROSS L3 AND H30.
2.  INSERT A 4.7K RESISTOR (YEL-VIO-RED) ACROSS H27 AND M23.
3.  CONNECT SPRING 48 TO L3 (BLU WIRE).
4.  CONNECT SPRING 49 TO H30 (BLU WIRE).

PUSH THE POWER SWITCH ON AND ONLY ONE LED WILL GLOW. PRESS AND RELEASE S2 TO GENERATE A RANDOM NUMBER. THE SELECTED LED WILL GLOW UNTIL YOU PRESS S2 AGAIN. IS THE CIRCUIT TRULY RANDOM? GENERATE 50 NUMBERS TO SEE IF SOME OCCUR MORE OR LESS FREQUENTLY THAN OTHERS.

## 4017 DECADE COUNTER: BUILD A DIGITAL-TO-ANALOG CONVERTER

AT SOME POINT, MOST DIGITAL CIRCUITS HAVE TO DEAL WITH AN ANALOG WORLD. YOU WILL BUILD A BASIC 4017 COUNTER CIRCUIT AND ADD RESISTORS TO EACH OUTPUT TO PRODUCE A PROGRAMMABLE SEQUENCE OF STEPPED SIGNALS.

### PARTS YOU WILL NEED

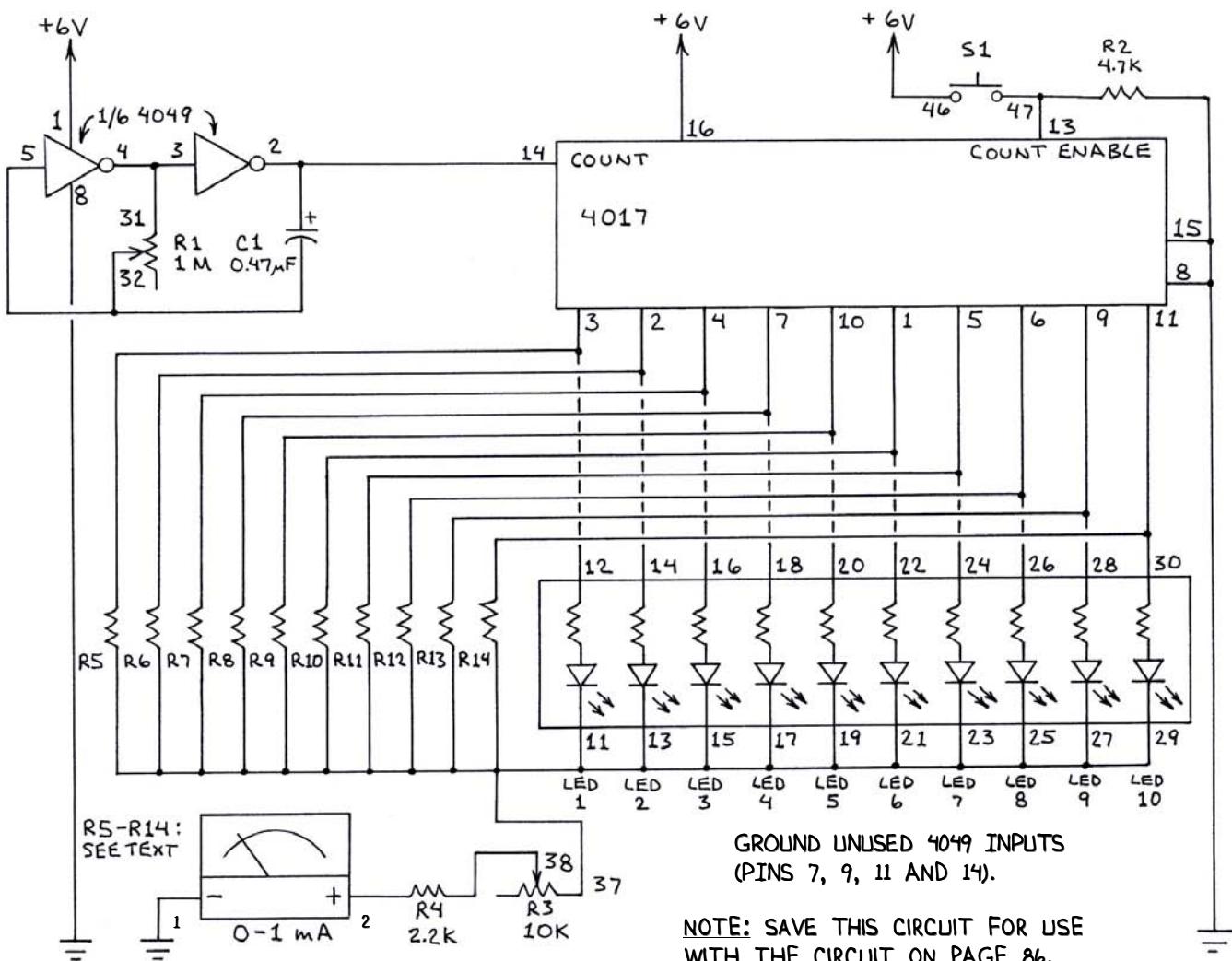


R2-4.7K (YEL-VIO-RED)  
R4-2.2K (RED-RED-RED)  
R5-R14-SEE TEXT



C1-0.47 uF

### CIRCUIT DIAGRAM



### 1. BUILD THE CLOCK CIRCUIT FIRST (OR MODIFY ONE OF THE PREVIOUS 4017 CIRCUITS)

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 IC ACROSS SLOT 1 (PIN 1 AT K5).
3.  CONNECT R1 TO GROUND (WHT WIRE).
4.  CONNECT K1 TO V4 (+6V) (RED WIRE).
5.  CONNECT M1 TO N1 (WHT WIRE).
6.  INSERT C1 ACROSS L4 (+) AND O4 (-).
7.  CONNECT SPRING 31 TO M2 (RED WIRE).
8.  CONNECT SPRING 32 TO O2 (RED WIRE).
9.  CONNECT Q1 TO GROUND (WHT WIRE).
10.  CONNECT M10 TO GROUND (WHT WIRE).
11.  CONNECT P10 TO GROUND (WHT WIRE).
12.  CONNECT R10 TO GROUND (WHT WIRE).

## 2. NOW BUILD THE COUNTER CIRCUIT AND METER INTERFACE

1.  INSERT THE 4017 IC ACROSS SLOT 5 (PIN 1 AT F25).
2.  INSERT R2 ACROSS M24 AND I27.
3.  INSERT R4 ACROSS SPRINGS 38 AND 42.
4.  CONNECT M21 TO GROUND (WHT WIRE).
5.  CONNECT F27 TO V4 (+6V) (WHT WIRE).
6.  CONNECT M22 TO G27 (WHT WIRE).
7.  CONNECT L3 TO H30 (BLU WIRE).
8.  CONNECT SPRING 12 TO H21 (RED WIRE).
9.  CONNECT SPRING 14 TO G21 (RED WIRE).
10.  CONNECT SPRING 16 TO I21 (RED WIRE).
11.  CONNECT SPRING 18 TO L21 (RED WIRE).
12.  CONNECT SPRING 20 TO L30 (RED WIRE).
13.  CONNECT SPRING 22 TO F21 (RED WIRE).
14.  CONNECT SPRING 24 TO J21 (RED WIRE).
15.  CONNECT SPRING 26 TO K21 (BLU WIRE).
16.  CONNECT SPRING 28 TO M30 (BLU WIRE).
17.  CONNECT SPRING 30 TO K30 (BLU WIRE).
18.  CONNECT SPRINGS 11 AND 13 (WHT WIRE).
19.  CONNECT SPRINGS 13 AND 15 (WHT WIRE).
20.  CONNECT SPRINGS 15 AND 17 (WHT WIRE).
21.  CONNECT SPRINGS 17 AND 19 (WHT WIRE).
22.  CONNECT SPRINGS 19 AND 21 (WHT WIRE).
23.  CONNECT SPRINGS 21 AND 23 (WHT WIRE).
24.  CONNECT SPRINGS 23 AND 25 (WHT WIRE).
25.  CONNECT SPRINGS 25 AND 27 (WHT WIRE).
26.  CONNECT SPRINGS 27 AND 29 (WHT WIRE).
27.  CONNECT SPRINGS 11 AND 37 (BLU WIRE).
28.  CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
29.  CONNECT SPRING 47 TO I30 (BLU WIRE).
30.  CONNECT SPRING 1 TO GROUND (BLU WIRE).
31.  CONNECT SPRINGS 2 AND 42 (YEL WIRE).

## 3. INSTALL THE DIGITAL-TO-ANALOG RESISTORS

FOR INITIAL TESTING, SELECT ANY 10 RESISTORS WITH VALUES BETWEEN 1K AND 10K. (LATER YOU CAN CONNECT RESISTORS IN SERIES FOR OTHER VALUES). INSTALL THE RESISTORS ACROSS EACH OF THE CONSOLE LED SPRINGS, EITHER IN INCREASING ORDER OF RESISTANCE OR RANDOMLY. FOR EXAMPLE, INSTALL A 10K RESISTOR ACROSS SPRINGS 11 AND 12, A 4.7K RESISTOR ACROSS SPRINGS 13 AND 14, AND SO FORTH. FINALLY, INSTALL A 1K RESISTOR ACROSS SPRINGS 29 AND 30. BE SURE THE RESISTOR LEADS DO NOT TOUCH ADJACENT SPRINGS OR RESISTORS.

## 4. TEST THE CIRCUIT

RECHECK YOUR WIRING FOR POSSIBLE ERRORS. PAY SPECIAL ATTENTION TO THE 0-1 MA METER. THE YELLOW WIRE AT SPRING 2 SHOULD GO ONLY TO SPRING 42, WHICH IS AN UNUSED DPDT SWITCH TERMINAL BORROWED AS A CONNECTION POINT FOR THE METER AND R4. WHEN YOU ARE SURE EVERYTHING IS CORRECT, PUSH THE POWER SWITCH ON WHILE WATCHING THE METER.

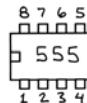
IF THE NEEDLE "SLAMS," IMMEDIATELY SWITCH THE POWER OFF AND RECHECK YOUR WIRING. IF THE NEEDLE DOES NOT SLAM, ADJUST THE 1M CONSOLE POT UNTIL THE LEDs FLASH ON AND OFF IN A SLOW SEQUENCE. PRESS S1 TO STOP THE COUNT WHEN THE LED AT THE 1K RESISTOR GLOWS (LED 10 IN THE EXAMPLE ABOVE). THEN ADJUST THE 10K CONSOLE POT UNTIL THE METER NEEDLE IS PAST THE CENTER POINT BUT LESS THAN FULL SCALE. RELEASE S1. THE COUNTER WILL RESUME COUNTING. AS THE COUNTER'S DECODER SELECTS EACH OF THE 10 OUTPUTS IN TURN, THE METER NEEDLE WILL JUMP UPWARD IN DISTINCT INCREMENTS IF YOU INSTALLED THE 10 RESISTORS IN DECREASING ORDER OF RESISTANCE. OTHERWISE IT WILL JUMP RANDOMLY BACK AND FORTH EACH TIME THE COUNT ADVANCES.

WHEN THE CIRCUIT IS WORKING PROPERLY, SLOWLY ADJUST THE 1M CONSOLE POT TO SPEED UP THE CLOCK FREQUENCY. IF YOU INSTALLED THE RESISTORS IN INCREASING (OR DECREASING) ORDER OF RESISTANCE, ABOVE A CERTAIN FREQUENCY THE METER NEEDLE WILL MOVE MUCH MORE SMOOTHLY THAN BEFORE. AS YOU KEEP INCREASING THE FREQUENCY, THE NEEDLE WILL BEGIN TO BOUNCE RAPIDLY BACK AND FORTH. YOU HAVE NOW DEMONSTRATED THE CONVERSION OF A SEQUENCE OF DISCRETE DIGITAL LOGIC SIGNALS INTO A VARIABLE ANALOG FORMAT.

## 4017 DECADE COUNTER: BUILD THE INCREDIBLE MUSIC MACHINE

THE 4017 DIGITAL-TO-ANALOG CONVERTER PROJECT HAS SOME FASCINATING APPLICATIONS. AMONG THE MOST VERSATILE IS THE "MUSIC MACHINE" DESCRIBED HERE. YOU WILL BUILD A VOLTAGE-CONTROLLED OSCILLATOR (VCO) USING A 555 TIMER IC. YOU WILL THEN CONNECT THE VCO TO THE A/D CONVERTER TO MAKE A PROGRAMMABLE SEQUENTIAL TONE GENERATOR THAT CAN SOUND LIKE A CHIRPING BIRD, A SIREN AND MANY OTHER SOUNDS.

### PARTS YOU WILL NEED



R2, R3, R4-1K (BRN-BLK-RED)

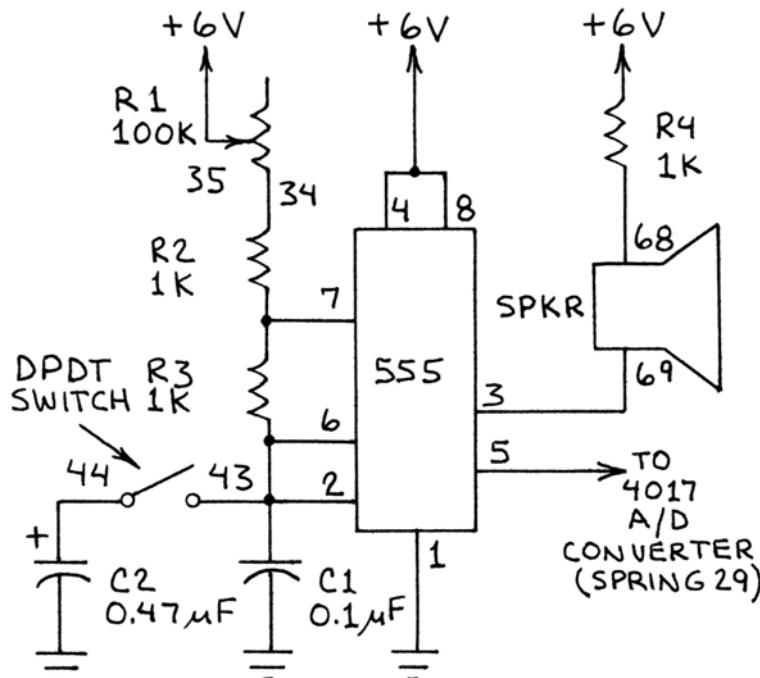


C1-0.1 UF (104)



C2-0.47 UF

### CIRCUIT DIAGRAM



### HOW IT WORKS

THE D/A CONVERTER CIRCUIT SELECTS 1 OF 10 PROGRAMMING RESISTORS AT A RATE CONTROLLED BY THE 1M CONSOLE POT (R1). EACH RESISTOR CAUSES A DIFFERENT VOLTAGE TO APPEAR AT THE CONTROL INPUT OF A 555 VCO. THE VCO IS THE CIRCUIT'S MASTER OSCILLATOR. ITS FREQUENCY IS CONTROLLED BY THE 100K CONSOLE POT (R1) AND C1. CLOSING THE DPDT SWITCH CONNECTS C2 ACROSS C1 AND SLOWS THE FREQUENCY. PRESS S1 TO STOP THE COUNTER SO YOU CAN ADJUST SPECIFIC TONES BY CHANGING TONE-CONTROL RESISTORS R5-R14. WANT MORE VOLUME? REDUCE R4 TO 470 OR 220 OHMS. AN AMAZING VARIETY OF SOUNDS CAN BE PROGRAMMED AND ALTERED. HAVE FUN!

### 1. BUILD THE CIRCUIT

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 555 IC ACROSS SLOT 3 (PIN 1 AT K15).
3.  CONNECT K11 TO GROUND (WHT WIRE).
4.  CONNECT L14 TO M19 (WHT WIRE).
5.  CONNECT N14 TO K17 (WHT WIRE).
6.  CONNECT K20 TO V4 (+6V) (RED WIRE).
7.  INSERT C1 ACROSS K12 AND L12.
8.  INSERT C2 ACROSS T12 (+) AND GROUND (-).
9.  INSERT R2 ACROSS P15 AND L18.
10.  INSERT R3 ACROSS L20 AND M20.
11.  INSERT R4 ACROSS N13 AND T16.
12.  CONNECT SPRING 34 TO P11 (RED WIRE).
13.  CONNECT SPRING 35 TO N11 (RED WIRE).
14.  CONNECT SPRING 43 TO L11 (RED WIRE).
15.  CONNECT SPRING 44 TO T11 (RED WIRE).
16.  CONNECT SPRING 68 TO T18 (BLU WIRE).
17.  CONNECT SPRING 69 TO M14 (BLU WIRE).
18.  CONNECT SPRING 29 TO N20 (BLU WIRE).

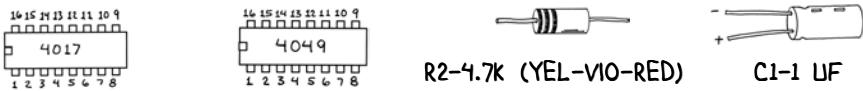
### 2. TEST THE CIRCUIT

CHECK THE WIRING CAREFULLY SINCE SOME OF THE D/A CIRCUIT WIRES MAY HAVE COME LOOSE WHEN YOU ADDED THE 555. PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A TONE SEQUENCE. ADJUST ALL THREE POTENTS TO CONTROL THE TONE SEQUENCE AND FREQUENCY.

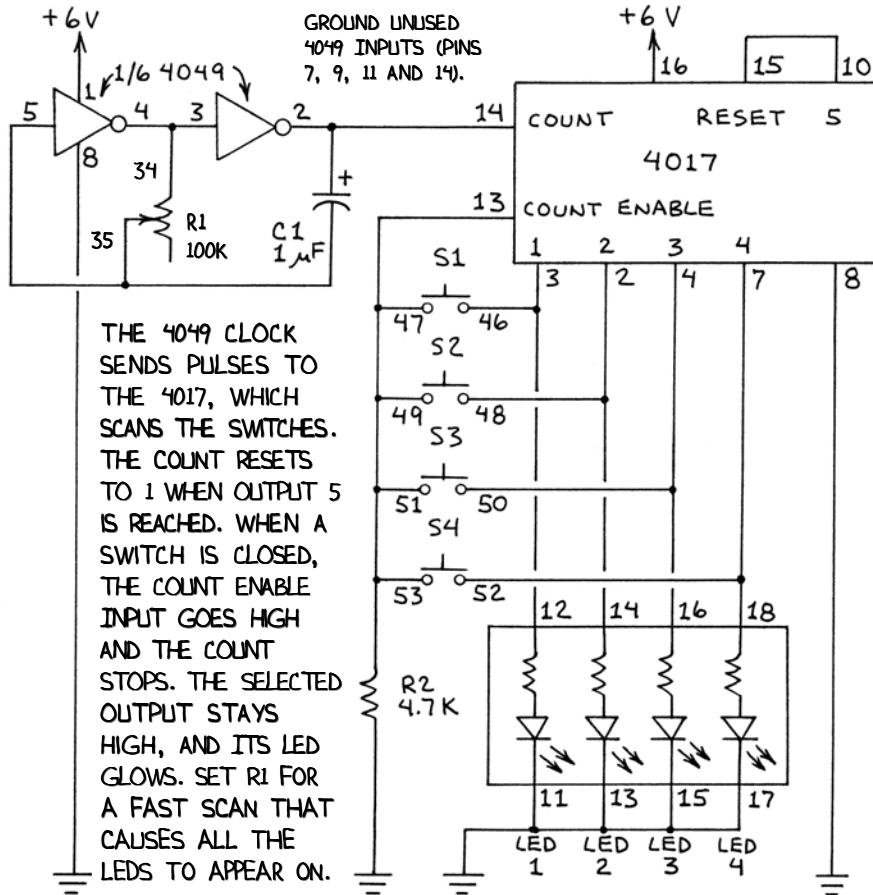
## 4017 DECADE COUNTER: BUILD A KEYBOARD ENCODER

THERE ARE SEVERAL WAYS TO DESIGN KEYBOARD CIRCUITS FOR ENTERING DATA INTO COMPUTERS. YOU WILL BUILD A 4-DIGIT KEYBOARD ENCODER THAT DEMONSTRATES ONE SIMPLE METHOD.

### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM



### 1. BUILD THE CLOCK FIRST

- PUSH THE POWER SWITCH TO OFF.
- INSERT THE 4049 IC ACROSS SLOT 1 (PIN 1 AT K5).
- CONNECT BREADBOARD HOLE R1 TO GROUND (WHT WIRE).
- CONNECT K1 TO V4 (+6V) (RED WIRE).
- CONNECT M1 TO N1 WHT WIRE).
- INSERT C1 ACROSS L3 (+) AND O3 (-).
- CONNECT SPRING 34 TO M2 (RED WIRE).
- CONNECT SPRING 35 TO O2 (RED WIRE).
- CONNECT Q1 TO GROUND (WHT WIRE).
- CONNECT M10 TO GROUND (WHT WIRE).
- CONNECT P10 TO GROUND (WHT WIRE).
- CONNECT R10 TO GROUND (WHT WIRE).
- INSERT THE 4017 IC ACROSS SLOT 5 (PIN 1 AT F25).
- CONNECT M21 TO GROUND (WHT WIRE).

### 2. NOW BUILD THE ENCODER

- CONNECT F27 TO V4 (+6V) (RED WIRE).
- CONNECT G27 TO L27 (WHT WIRE).
- INSERT R2 ACROSS M24 AND I29.
- CONNECT SPRINGS 47 AND 49 (WHT WIRE).
- CONNECT SPRINGS 49 AND 51 (WHT WIRE).
- CONNECT SPRINGS 51 AND 53 (WHT WIRE).
- CONNECT SPRING 53 TO I30 (RED WIRE).
- CONNECT SPRING 46 TO H23 (RED WIRE).
- CONNECT SPRING 48 TO G23 (RED WIRE).
- CONNECT SPRING 50 TO I23 (RED WIRE).
- CONNECT SPRING 52 TO L23 (RED WIRE).
- CONNECT SPRINGS 11 AND 13 (WHT WIRE).
- CONNECT SPRINGS 13 AND 15 (WHT WIRE).
- CONNECT SPRINGS 15 AND 17 (WHT WIRE).
- CONNECT SPRING 17 TO GROUND (BLU WIRE).
- CONNECT SPRING 12 TO H21 (RED WIRE).
- CONNECT SPRING 14 TO G21 (RED WIRE).
- CONNECT SPRING 16 TO I21 (RED WIRE).
- CONNECT SPRING 18 TO L21 (RED WIRE).
- CONNECT L4 (CLOCK) TO H30 (BLU WIRE).

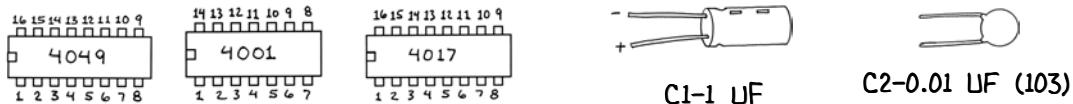
### 3. TEST THE CIRCUIT

CHECK YOUR WIRING. PUSH THE POWER SWITCH ON, AND LEDS 1-4 WILL ALL GLOW. PRESS S1, AND ONLY LED 1 WILL GLOW. PRESS S2, S3 OR S4, AND ONLY LEDS 2, 3 OR 4 WILL GLOW.

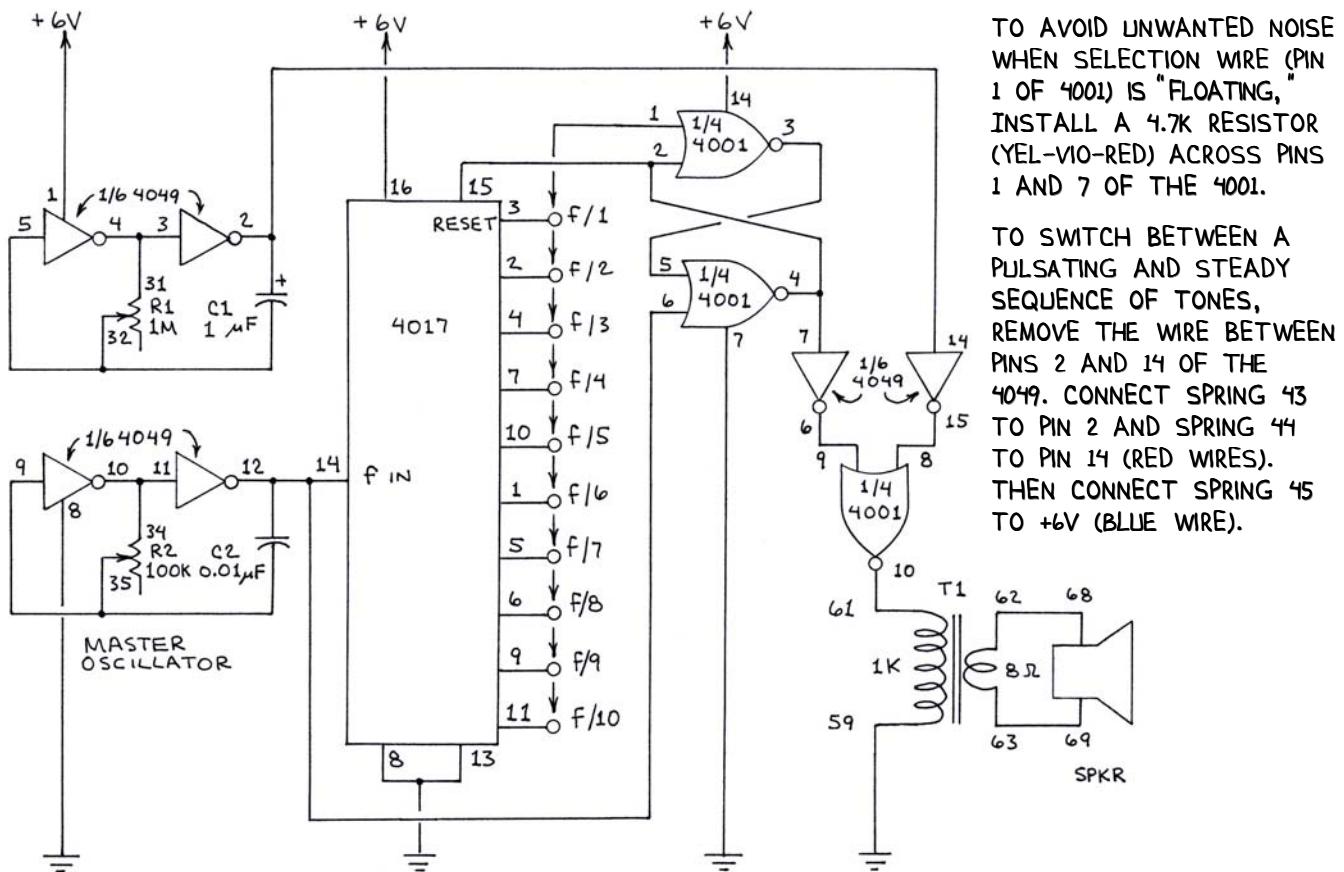
## 4017 DECADE COUNTER: BUILD A FREQUENCY SYNTHESIZER

THIS CIRCUIT EXPLOITS THE ABILITY OF A 4017 TO DIVIDE AN INCOMING CLOCK SIGNAL BY 1 TO 10. YOU WILL BUILD A FREQUENCY SYNTHESIZER THAT PROVIDES 10 SPECIFIC FREQUENCIES SCALED DOWN FROM AN INPUT FREQUENCY PROVIDED BY A MASTER OSCILLATOR. THE OUTPUT FREQUENCIES RANGE FROM THE MASTER INPUT FREQUENCY ( $F$ ) DIVIDED BY 1 ( $F/1$ ) TO 10 ( $F/10$ ). BESIDES THE MASTER OSCILLATOR, THE CIRCUIT INCLUDES A SECOND OSCILLATOR THAT PULSES THE OUTPUT FREQUENCY.

### PARTS YOU WILL NEED



### CIRCUIT DIAGRAM



GROUND UNUSED INPUTS OF THE 4001 (PINS 12 AND 13).

### 1. BUILD THE TWO OSCILLATOR CIRCUITS FIRST

1.  PUSH THE POWER SWITCH TO OFF.
2.  INSERT THE 4049 IC ACROSS SLOT 1 (PIN 1 AT K5).
3.  CONNECT R1 TO GROUND (WHT WIRE).
4.  CONNECT K1 TO V4 (+6V) (RED WIRE).
5.  CONNECT M1 TO N1 (WHT WIRE).
6.  CONNECT L2 TO M7 (WHT WIRE).
7.  CONNECT P10 TO Q10 (WHT WIRE).
8.  INSERT C1 ACROSS L3 (+) AND O3 (-).
9.  INSERT C2 ACROSS O8 AND R8.
10.  CONNECT SPRING 31 TO N2 (RED WIRE).
11.  CONNECT SPRING 32 TO O2 (RED WIRE).
12.  CONNECT SPRING 34 TO Q7 (RED WIRE).
13.  CONNECT SPRING 35 TO R7 (RED WIRE).

## 2. NOW BUILD THE DIVIDER AND LOGIC CIRCUITS

1.  INSERT THE 4001 IC ACROSS SLOT 3 (PIN 1 AT K15).
2.  CONNECT Q11 TO GROUND (WHT WIRE).
3.  CONNECT L11 TO N11 (WHT WIRE).
4.  CONNECT M11 TO O11 (WHT WIRE).
5.  CONNECT K20 TO V4 (+6V) (WHT WIRE).
6.  CONNECT O10 TO P11 (WHT WIRE).
7.  CONNECT P4 TO P17 (RED WIRE).
8.  CONNECT Q4 TO N12 (RED WIRE).
9.  CONNECT L10 TO Q17 (RED WIRE).
10.  CONNECT SPRING 59 TO GROUND (WHT WIRE).
11.  CONNECT SPRING 61 TO O20 (BLU WIRE).
12.  CONNECT SPRINGS 62 AND 68 (RED WIRE).
13.  CONNECT SPRINGS 63 AND 69 (RED WIRE).
14.  INSERT THE 4017 IC ACROSS SLOT 5 (PIN 1 AT F25).
15.  CONNECT M21 TO GROUND (WHT WIRE).
16.  CONNECT F27 TO V4 (+6V) (WHT WIRE).
17.  CONNECT M24 TO I27 (WHT WIRE).
18.  CONNECT SPRING 12 TO H21 (RED WIRE).
19.  CONNECT SPRING 14 TO G21 (RED WIRE).
20.  CONNECT SPRING 16 TO I21 (RED WIRE).
21.  CONNECT SPRING 18 TO L21 (RED WIRE).
22.  CONNECT SPRING 20 TO L30 (RED WIRE).
23.  CONNECT SPRING 22 TO F21 (RED WIRE).
24.  CONNECT SPRING 24 TO J21 (BLU WIRE).
25.  CONNECT SPRING 26 TO K21 (BLU WIRE).
26.  CONNECT SPRING 28 TO M30 (BLU WIRE).
27.  CONNECT SPRING 30 TO K30 (BLU WIRE).
28.  CONNECT L20 TO GROUND (WHT WIRE).
29.  CONNECT M20 TO GROUND (WHT WIRE).
30.  CONNECT L14 TO G27 (RED WIRE).
31.  CONNECT O9 TO H27 (RED WIRE).
32.  INSERT A BLUE WIRE AT K11.

## 4. TEST THE CIRCUIT

FOR INITIAL TESTS, CONNECT THE BLUE FREQUENCY SELECTION WIRE TO SPRING 12. CAREFULLY CHECK YOUR WIRING FOR ERRORS AND OMISSIONS. THEN SET THE 1M (R1) AND 100K (R2) CONSOLE POTENTIOMETERS TO THEIR MIDPOINTS AND PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A PULSATING TONE. ADJUST R1 TO CHANGE THE RATE AT WHICH THE TONE IS PULSED FROM A FEW DOZEN TIMES PER SECOND (ROTATE RIGHT) TO ONCE EVERY SECOND OR SO (ROTATE LEFT). ADJUST R2 TO CHANGE THE TONE FROM A LOW FREQUENCY (ROTATE LEFT) TO A HIGH FREQUENCY (ROTATE RIGHT).

WHEN THE CIRCUIT IS WORKING, ADJUST THE TONE TO A FAIRLY HIGH FREQUENCY (R2) AND THE PULSE RATE TO A FEW PULSES PER SECOND (R1). THEN REMOVE THE BLUE FREQUENCY SELECTION WIRE FROM SPRING 12 AND TOUCH IT IN SEQUENCE TO SPRINGS 14, 16, 18 AND SO FORTH UNTIL REACHING SPRING 30. THE TONE FREQUENCY WILL DECREASE, IN OBVIOUS STEPS, AS YOU TOUCH EACH SPRING. YOU CAN BEST CAPTURE THE EFFECT BY SWEEPING THE SELECTION WIRE ACROSS ALL 10 OUTPUT SPRINGS. HERE ARE THE FREQUENCIES THE CIRCUIT PRODUCES WHEN THE MASTER OSCILLATOR IS SET TO 1,000 Hz:

SPRING	FREQUENCY
12 (F/1)	1,000 Hz
14 (F/2)	500 Hz
16 (F/3)	333 Hz
18 (F/4)	250 Hz

SPRING	FREQUENCY
20 (F/5)	200 Hz
22 (F/6)	166 Hz
24 (F/7)	143 Hz
26 (F/8)	125 Hz

SPRING	FREQUENCY
28 (F/9)	111 Hz
30 (F/10)	100 Hz

MAKE THE TONE  
STEADY BY MOVING  
THE WIRE AT  
SPRING 61 FROM  
O20 TO P20.

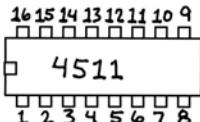
## GOING FURTHER

THE FREQUENCY SELECTION WIRE AT PIN 1 OF THE 4001 IS "FLOATING" WHEN A FREQUENCY IS NOT SELECTED. TO KEEP POWER LINE NOISE FROM CAUSING THE CIRCUIT TO BUZZ, CONNECT A 4.7K RESISTOR BETWEEN PINS 1 (K13) AND 7 (Q13) OF THE 4001. THIS PULL-DOWN RESISTOR IS NOT NEEDED IF THE CIRCUIT IS OPERATED AT ONLY ONE OF THE AVAILABLE FREQUENCIES.

## 4511 SEVEN-SEGMENT DECODER-DRIVER: BUILD A BINARY-TO-DECIMAL KEYPAD

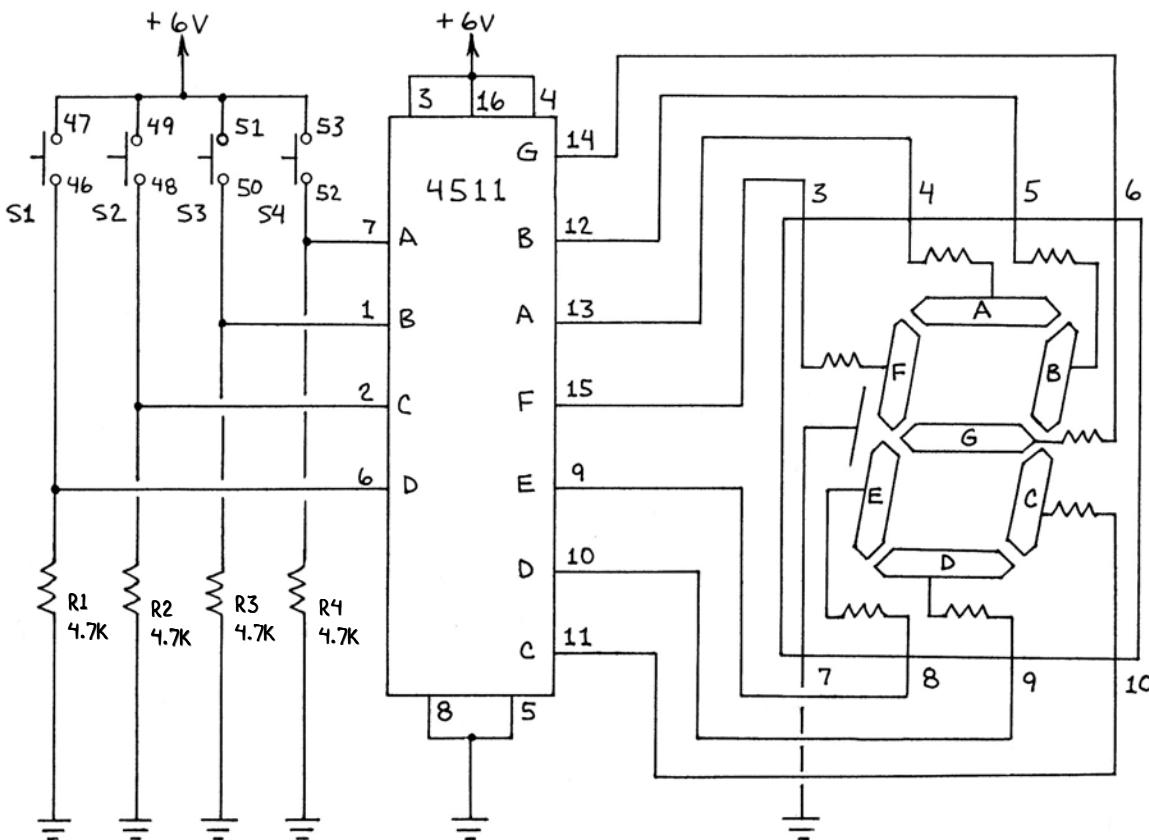
THE 4511 IS USED TO DECODE THE OUTPUT FROM BINARY-CODED DECIMAL (BCD) COUNTER ICs SO THEY CAN ACTIVATE SEVEN-SEGMENT READOUTS. THE 4511 CAN ALSO BE USED BY ITSELF. YOU WILL USE THE 4511 TO MAKE A SIMPLE KEYPAD THAT CONVERTS THE FIRST 10 BINARY NUMBERS INTO THEIR DECIMAL COUNTERPARTS. THIS PROJECT IS AN IDEAL TOOL FOR LEARNING BINARY.

### PARTS YOU WILL NEED



R1, R2, R3, R4-4.7K (YEL-VIO-RED)

### CIRCUIT DIAGRAM



SAVE THIS  
CIRCUIT  
FOR THE  
NEXT  
PROJECT  
(PAGE 92).

### 1. BUILD THE DECODER AND DISPLAY CIRCUIT

1.  PUSH THE POWER SWITCH OFF.
2.  INSERT THE 4511 IC ACROSS SLOT 1 (PIN 1 AT A5).
3.  CONNECT H4 TO GROUND (WHT WIRE).
4.  CONNECT A10 TO V4 (+6V) (WHT WIRE).
5.  CONNECT SPRING 3 TO B7 (BLU WIRE).
6.  CONNECT SPRING 4 TO D7 (BLU WIRE).
7.  CONNECT SPRING 5 TO E7 (BLU WIRE).
8.  CONNECT SPRING 6 TO C7 (BLU WIRE).
9.  CONNECT SPRING 7 TO GROUND (BLU WIRE).
10.  CONNECT SPRING 8 TO H7 (RED WIRE).
11.  CONNECT SPRING 9 TO G7 (RED WIRE).
12.  CONNECT SPRING 10 TO F7 (RED WIRE).
13.  CONNECT SPRINGS 47 AND 49 (WHT WIRE).
14.  CONNECT SPRINGS 49 AND 51 (WHT WIRE).
15.  CONNECT SPRINGS 51 AND 53 (WHT WIRE).
16.  CONNECT SPRING 53 TO V4 (+6V) (BLU WIRE).
17.  CONNECT C4 TO V4 (+6V) (RED WIRE).
18.  CONNECT D4 TO V4 (+6V) (RED WIRE).
19.  CONNECT E4 TO GROUND (RED WIRE).

## 2. NOW ADD THE INPUT SWITCHES

1.  INSTALL R1 ACROSS SPRING 46 AND GROUND.
2.  INSTALL R2 ACROSS SPRING 48 AND GROUND.
3.  INSTALL R3 ACROSS SPRING 50 AND GROUND.
4.  INSTALL R4 ACROSS SPRING 52 AND GROUND.
5.  CONNECT SPRING 46 TO F1 (RED WIRE).
6.  CONNECT SPRING 48 TO B1 (BLU WIRE).
7.  CONNECT SPRING 50 TO A1 (BLU WIRE).
8.  CONNECT SPRING 52 TO G1 (BLU WIRE).

## 3. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THE PUSH THE POWER SWITCH ON. THE LED DISPLAY WILL READ "0" (BINARY 0000). PRESS S4 (BINARY 0001), AND THE DISPLAY WILL READ "1." PRESS S3 (BINARY 0010), AND THE DISPLAY WILL READ 2. FOLLOW THE TRUTH TABLE AT RIGHT TO CHECK EACH INPUT SWITCH COMBINATION. NEXT, TEST THE 4511 CONTROL INPUTS:

- TEMPORARILY MOVE THE RED WIRE AT C4 (PIN 3 OF THE 4511) FROM +6V TO GROUND TO TEST ALL SEVEN DISPLAY SEGMENTS.
- TEMPORARILY MOVE THE RED WIRE AT D4 FROM +6V TO GROUND TO BLANK THE DISPLAY.
- ENTER AND HOLD A NUMBER. THEN MOVE THE RED WIRE AT E4 FROM GROUND TO +6V TO STORE THE NUMBER AFTER YOU RELEASE THE SWITCHES.

BINARY INPUT				DECIMAL READOUT
S1	S2	S3	S4	
OFF (0)	OFF (0)	OFF (0)	OFF (0)	0
		ON (1)	ON (1)	1
		ON (1)	OFF (0)	2
		ON (1)	ON (1)	3
	ON (1)	OFF (0)	OFF (0)	4
		ON (1)	ON (1)	5
		ON (1)	OFF (0)	6
		ON (1)	ON (1)	7
ON (1)	OFF (0)	OFF (0)	OFF (0)	8
ON (1)	OFF (0)	OFF (0)	ON (1)	9

THE COMPLETE TRUTH TABLE FOR THE 4511 IS SHOWN AT RIGHT:

LE (PIN 5):  
LATCH ENABLE  
OR STORE

BI (PIN 4):  
BLANKING INPUT

LT (PIN 3):  
LAMP TEST

0: OFF (LOW)

1: (ON (HIGH))

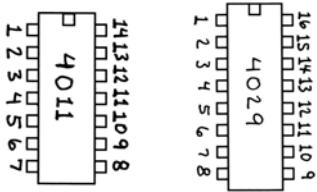
X: "DON'T CARE"

CONTROL			BINARY INPUT				DECIMAL READOUT	SEVEN-SEGMENT READOUT						
LE	BI	LT	S1	S2	S3	S4		A	B	C	D	E	F	G
0	1	1	0	0	0	0	0	1	1	1	1	1	1	0
0	1	1	0	0	0	1	1	0	1	1	0	0	0	0
0	1	1	0	0	1	0	2	1	1	0	1	1	0	1
0	1	1	0	0	1	1	3	1	1	1	1	0	0	1
0	1	1	0	1	0	0	4	0	1	1	0	0	1	1
0	1	1	0	1	0	1	5	1	0	1	1	0	1	1
0	1	1	0	1	1	0	6	0	0	1	1	1	1	1
0	1	1	0	1	1	1	7	1	1	1	0	0	0	0
0	1	1	1	0	0	0	8	1	1	1	1	1	1	1
0	1	1	1	0	0	1	9	1	1	1	0	0	1	1
0	1	1	1	0	1	0	-	ALL SEGMENTS OFF (COUNT > 9)						
0	0	1	X	X	X	X	-	ALL SEGMENTS OFF (BLANK)						
0	X	0	X	X	X	X	8	ALL SEGMENTS ON (LAMP TEST)						
1	1	1	X	X	X	X	0-9	SAVE AND DISPLAY NUMBER						

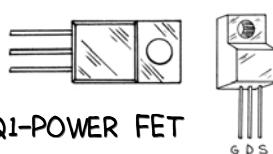
## 4029 UP-DOWN COUNTER: BUILD A PROGRAMMABLE COUNTDOWN TIMER

YOU WILL USE A 4029 COUNTER AND A 4511 7-SEGMENT DECODER TO MAKE A DIGITAL TIMER THAT COUNTS DOWN FROM 9 TO 0 AND THEN ACTIVATES A BUZZER. WHEN THE 4029 COUNT REACHES 0, IT'S CARRY OUTPUT (PIN 7) GOES LOW. YOU WILL SEND THIS SIGNAL TO A NAND GATE TO BLOCK INCOMING CLOCK PULSES. A SECOND GATE WILL ACTIVATE THE BUZZER.

### PARTS YOU WILL NEED



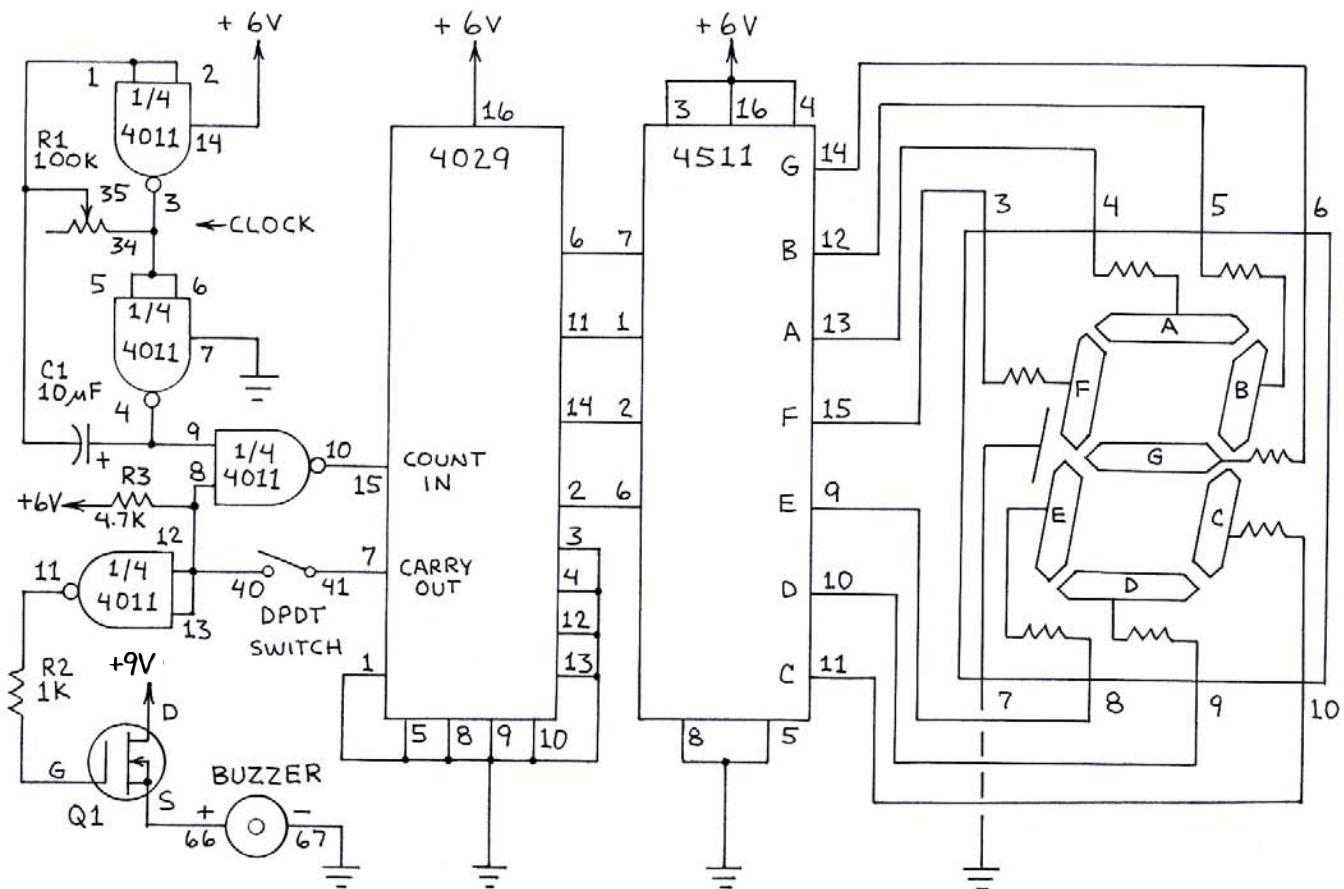
THE 4511 BINARY-TO-DECIMAL KEYPAD ON PAGES 90-91 PLUS:



R2-1K (BRN-BLK-RED)  
R3-4.7K (YEL-VIO-RED)

C1-10 UF

### CIRCUIT DIAGRAM (INPUT SWITCHES S1-S4 ARE NOT SHOWN. SEE DECIMAL KEYPAD CIRCUIT)



### ABOUT THE CIRCUIT

THIS CIRCUIT IS A DIGITAL TIMER. IN OPERATION, AN OSCILLATOR FORMED FROM TWO NAND GATES SENDS A STREAM OF CLOCK PULSES TO A THIRD NAND GATE. THE CARRY OUTPUT OF THE 4029 (PIN 7) IS NORMALLY HIGH. SO WHEN THE DPDT SWITCH IS CLOSED (PUSHED UP), THE THIRD NAND GATE PASSES THE CLOCK PULSES TO THE COUNTER (PIN 15). THE COUNTER COUNTS DOWN FROM 9 TO 0. WHEN 0 IS REACHED, THE CARRY OUTPUT GOES LOW. THIS DISABLES THE THIRD GATE, WHICH THEN BLOCKS THE CLOCK PULSES. THE COUNTER STOPS, AND A NAND GATE CONNECTED AS AN INVERTER SWITCHES ON Q1 AND THE BUZZER. OPENING AND CLOSING THE DPDT SWITCH TURNS OFF Q1 AND THE BUZZER AND ALLOWS THE COUNT TO RESUME FROM 9.

## 1. MODIFY THE BINARY-TO-DECIMAL KEYPAD ON PAGES 90-91

1.  PUSH THE POWER SWITCH OFF.
2.  REMOVE THE WIRES AND RESISTORS R1, R2, R3 AND R4 BETWEEN SWITCHES S1, S2, S3 AND S4 AND THE BREADBOARD.

## 2. ADD THE 4029 COUNTER TO THE BINARY-TO-DECIMAL KEYPAD

1.  INSERT THE 4029 ACROSS SLOT 3 (PIN 1 AT A15).
2.  CONNECT A12 TO C12 (WHT WIRE).
3.  CONNECT B11 TO F4 (WHT WIRE).
4.  CONNECT E11 TO GROUND (RED WIRE).
5.  CONNECT F11 TO G4 (WHT WIRE).
6.  CONNECT H11 TO GROUND (RED WIRE).
7.  CONNECT H14 TO H17 (WHT WIRE).
8.  CONNECT G20 TO GROUND (RED WIRE).
9.  CONNECT F17 TO A1 (RED WIRE).
10.  CONNECT C17 TO B1 (RED WIRE).
11.  CONNECT A19 TO V4 (+6V) (WHT WIRE).
12.  CONNECT D12 TO H12 (WHT WIRE).
13.  CONNECT C13 TO H13 (WHT WIRE).
14.  CONNECT D18 TO H18 (WHT WIRE).
15.  CONNECT E19 TO H19 (WHT WIRE).

## 3. INSTALL THE 4011 NAND GATE CIRCUITS

1.  INSERT THE 4011 ACROSS SLOT 3 (PIN 1 AT K15).
2.  INSERT R3 ACROSS K18 AND M18.
3.  INSERT C1 ACROSS N13 (+) AND L13 (-).
4.  CONNECT K14 TO L14 (WHT WIRE).
5.  CONNECT M12 TO O12 (WHT WIRE).
6.  CONNECT O11 TO P11 (WHT WIRE).
7.  CONNECT Q14 TO GROUND (WHT WIRE).
8.  CONNECT N14 TO P17 (WHT WIRE).
9.  CONNECT K20 TO A20 (WHT WIRE).
10.  CONNECT L20 TO M20 (WHT WIRE).
11.  CONNECT L19 TO Q19 (WHT WIRE).
12.  CONNECT B20 TO O20 (RED WIRE).
13.  CONNECT SPRING 34 TO M11 (RED WIRE).
14.  CONNECT SPRING 35 TO L11 (RED WIRE).
15.  CONNECT SPRING 40 TO Q17 (BLU WIRE).
16.  CONNECT SPRING 41 TO G14 (BLU WIRE).

## 4. INSTALL Q1 AND CONNECT THE BUZZER

1.  INSERT Q1 AT T28 (G), S28 (D) AND R28 (S).
2.  INSERT R2 ACROSS T23 AND T26.
3.  CONNECT N20 TO T21 (WHT WIRE).
4.  CONNECT S30 TO V6 (+9V) (RED WIRE).
5.  CONNECT SPRING 66 TO R30 (BLU WIRE).
6.  CONNECT SPRING 67 TO GROUND (BLU WIRE).

## 5. TEST THE CIRCUIT

THIS CIRCUIT IS FAIRLY COMPLICATED, WITH WIRES GOING EVERYWHERE. SO BE SURE TO MAKE SURE THAT ALL THE WIRES ARE PROPERLY CONNECTED AND THAT NONE CAME LOOSE DURING THE ASSEMBLY STEPS. SET THE 100K CONSOLE POT (R1) TO ITS MIDPOINT AND PUSH THE POWER SWITCH ON. THE LED READOUT WILL IMMEDIATELY BEGIN COUNTING FROM 9 TO 0 AGAIN AND AGAIN. ADJUST R1 TO SLOW THE COUNT TO ABOUT ONE DIGIT PER SECOND. WHEN THE COUNT CYCLES BACK TO 9, PUSH THE DPDT SWITCH UP TO ACTIVATE THE BUZZER. WHEN THE COUNT REACHES 0, THE BUZZER WILL SOUND, AND THE COUNT WILL STOP. TO SWITCH OFF THE BUZZER AND REACTIVATE THE CIRCUIT, PUSH THE DPDT SWITCH DOWN. THE CIRCUIT IS PROGRAMMABLE SINCE YOU CAN BEGIN THE ALARM CYCLE AT ANY POINT IN THE COUNTDOWN. JUST WAIT FOR THE DESIRED DIGIT AND PUSH THE DPDT SWITCH UP. TRY IT.

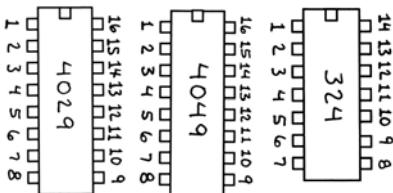
## GOING FURTHER

SOME POWER FETS (Q1) TURN ON AT LOWER VOLTAGES THAN OTHERS. IF YOUR BUZZER SOUNDS WEAK, YOU CAN INCREASE ITS VOLUME BY PUSHING THE POWER SWITCH OFF AND MOVING ALL THE LEADS AT V4 (+6V) TO V6 (+9V). YOU WILL NEED LONGER WIRES FOR SOME OF THE LEADS. JUST BE SURE ALL THE ICS ARE POWERED BY THE SAME VOLTAGE. YOU CAN REPLACE THE BUZZER WITH AN LED. REMOVE R2 AND INSERT R2 ACROSS N19 AND T19. THEN INSERT AN LED ACROSS T20 (ANODE) AND GROUND (CATHODE). AT THE END OF THE COUNTDOWN THE LED WILL GLOW. 93

## 4029 UP-DOWN COUNTER: BUILD A DIGITAL LIGHT METER

THIS FINAL PROJECT NICELY DEMONSTRATES MANY OF THE ELECTRONIC PRINCIPLES THAT YOU HAVE LEARNED WITH YOUR LAB KIT. YOU WILL BUILD AND EXPERIMENT WITH A SINGLE-DIGIT DIGITAL LIGHT METER. YOU WILL ALSO LEARN THE DETAILS ABOUT HOW IT WORKS.

### PARTS YOU WILL NEED



THE 4511 BINARY-TO-DECIMAL KEYPAD CIRCUIT ON PAGES 90-91 PLUS:

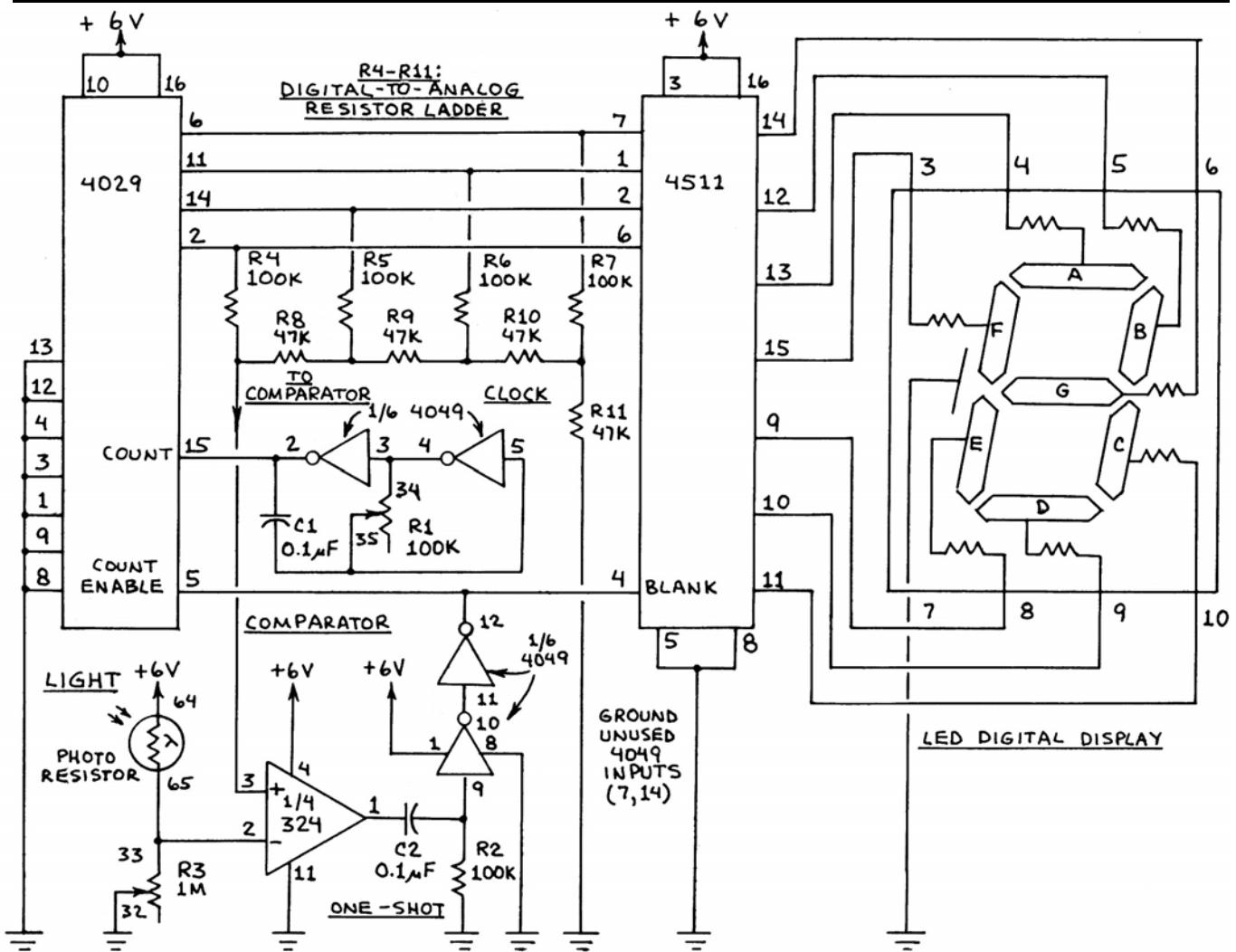


R2, R4, R5, R6, R7-100K (BRN-BLK-YEL)  
R8, R9, R10, R11-47K (YEL-VIO-ORG)



C1, C2-0.1  $\mu$ F (10<sup>4</sup>)

### CIRCUIT DIAGRAM



### ABOUT THE CIRCUIT

THE 4029 COUNTS PULSES FROM THE CLOCK CIRCUIT AND SENDS THE RESULT IN BINARY TO THE 4511 DECODER. THE LED DISPLAY DOES NOT SHOW THE COUNT, SINCE ITS BLANKING INPUT IS PULLED LOW BY A 4049 INVERTER. THE BINARY COUNT IS ALSO SENT TO A DIGITAL-TO-ANALOG (D/A) RESISTOR NETWORK, WHICH CONVERTS IT INTO A PROPORTIONAL VOLTAGE THAT IS SENT TO A 324 OP AMP CONNECTED AS A COMPARATOR. ALSO SENT TO THE COMPARATOR 94 IS THE VOLTAGE FROM A VOLTAGE DIVIDER FORMED FROM THE PHOTORESISTOR AND R3.

## ABOUT THE CIRCUIT (CONTINUED)

THE VOLTAGE FROM THE DIVIDER IS PROPORTIONAL TO LIGHT AT THE PHOTORESISTOR. WHEN THE D/A VOLTAGE EXCEEDS THE DIVIDER VOLTAGE, THE COMPARATOR'S OUTPUT SWITCHES STATES AND TRIGGERS THE ONE-SHOT (C2, R2 AND TWO INVERTERS IN THE 4049), WHICH EMITS A POSITIVE PULSE. THIS PULSE MOMENTARILY DISABLES THE 4029 (PIN 5), THUS STOPPING THE COUNT. THE PULSE ALSO SWITCHES ON THE LED DISPLAY (PIN 4 OF THE 4511). WHEN THE ONE-SHOT PULSE ENDS, THE DISPLAY SWITCHES OFF, AND THE COUNT RESUMES UNTIL THE COMPARATOR AGAIN TRIGGERS THE ONE-SHOT. THIS ONLY THE COUNT AT THE TIME THE ONE SHOT FIRES IS DISPLAYED. IF THE CLOCK IS SUFFICIENTLY FAST, THE DISPLAYED NUMBER APPEARS TO BE CONTINUOUSLY ON. IT'S ACTUALLY BEING PULSED, WHICH YOU CAN CONFIRM BY SLOWING THE CLOCK USING R1.

### 1. MODIFY THE BINARY-TO-DECIMAL KEYPAD ON PAGES 90-91

1.  PUSH THE POWER SWITCH OFF.
2.  REMOVE RED WIRE FROM D4 TO V4 (+6V).
3.  REMOVE WIRES AND R1-R4 BETWEEN SWITCHES S1-S4 AND THE BREADBOARD.

### 2. ADD THE 4029 COUNTER TO THE BINARY-TO-DECIMAL KEYPAD

1.  INSERT THE 4029 ACROSS SLOT 3 (PIN 1 AT A15).
2.  CONNECT A12 TO C12 (WHT WIRE).
3.  CONNECT B11 TO F4 (RED WIRE).
4.  CONNECT F11 TO G4 (WHT WIRE).
5.  CONNECT H11 TO GROUND (WHT WIRE).
6.  CONNECT H14 TO H17 (WHT WIRE).
7.  CONNECT A20 TO V4 (+6V) (WHT WIRE).
8.  CONNECT G19 TO A19 (WHT WIRE).
9.  CONNECT F17 TO A1 (RED WIRE).
10.  CONNECT C17 TO B1 (RED WIRE).
11.  CONNECT D12 TO H12 (WHT WIRE).
12.  CONNECT C13 TO H13 (WHT WIRE).
13.  CONNECT D18 TO H18 (WHT WIRE).
14.  CONNECT E19 TO H19 (WHT WIRE).

### 3. INSTALL THE 4049 INVERTER CLOCK AND ONE-SHOT CIRCUITS

1.  INSERT THE 4049 ACROSS SLOT 1 (PIN 1 AT K5).
2.  CONNECT M1 TO N1 (WHT WIRE).
3.  CONNECT Q3 TO R3 (WHT WIRE).
4.  CONNECT R1 TO GROUND (WHT WIRE).
5.  CONNECT K4 TO A17 (RED WIRE).
6.  CONNECT P7 TO Q7 (WHT WIRE).
7.  CONNECT M7 TO R4 (WHT WIRE).
8.  INSERT C1 ACROSS L1 AND O1.
9.  INSERT C2 ACROSS R8 AND T8.
10.  INSERT R2 ACROSS R10 AND GROUND.
11.  CONNECT SPRING 34 TO N2 (RED WIRE).
12.  CONNECT SPRING 35 TO O2 (RED WIRE).

### 4. INSTALL THE 324 COMPARATOR AND RESISTOR LADDER

1.  INSERT THE 324 ACROSS SLOT 5 (PIN 1 AT K25).
2.  CONNECT N30 TO GROUND (WHT WIRE).
3.  CONNECT N24 TO V4 (+6V) (RED WIRE).
4.  CONNECT A23 TO M23 (WHT WIRE).
5.  CONNECT SPRING 64 TO N23 (BLU WIRE).
6.  CONNECT SPRING 65 TO L24 (BLU WIRE).
7.  CONNECT SPRINGS 65 AND 33 (BLU WIRE).
8.  CONNECT SPRING 32 TO GROUND (RED WIRE).
9.  INSERT R4 ACROSS B14 AND A21.
10.  INSERT R5 ACROSS C20 AND D21.
11.  INSERT R6 ACROSS F20 AND G21.
12.  INSERT R7 ACROSS F14 AND J21.
13.  INSERT R8 ACROSS A25 AND D25.
14.  INSERT R9 ACROSS D24 AND G24.
15.  INSERT R10 ACROSS G25 AND J25.
16.  INSERT R11 ACROSS J22 AND GROUND.

### 5. CONNECT THE CIRCUITS

1.  CONNECT O7 TO D4 (RED WIRE).
2.  CONNECT O10 TO E11 (RED WIRE).
3.  CONNECT T10 TO K21 (RED WIRE).
4.  CONNECT L4 TO B17 (RED WIRE).

## 6. TEST THE CIRCUIT

THIS CIRCUIT HAS A TOTAL OF FOUR ICS CONNECTED BY MORE THAN 40 WIRES. SO INSPECT IT CAREFULLY TO BE SURE THERE ARE NO ERRORS AND THAT ALL THE WIRES ARE FULLY INSERTED INTO THE BREADBOARD. ROTATE THE KNOBS OF BOTH THE 1M (R3) AND 100K (R1) CONSOLE POTS ALL THE WAY TO THE LEFT. THEN PUSH THE POWER SWITCH ON. IF THE CONSOLE IS REASONABLY WELL ILLUMINATED, THE NUMBER 1 WILL BE FLASHING IN THE LED DISPLAY. IF THE CONSOLE IS FAIRLY DARK, THEN PLACE IT WHERE THERE IS MORE LIGHT UNTIL THE NUMBER 1 IS FLASHING IN THE DISPLAY.

NEXT, VERY SLOWLY ROTATE R1'S KNOB TO THE RIGHT WHILE WATCHING THE FLASHING LED DISPLAY. KEEP ROTATING UNTIL THE DISPLAY IS FLASHING SO FAST IT APPEARS CONTINUOUSLY ON AND BECOMES BRIGHTER. IF THE DISPLAY SUDDENLY GOES DARK, YOU WENT TOO FAR. ROTATE R1'S KNOB BACK TO THE LEFT UNTIL THE DISPLAY IS AGAIN GLOWING.

NEXT, BLOCK THE PHOTORESISTOR APERTURE WITH A FINGER OR A PIECE OF OPAQUE TAPE OR PAPER UNTIL THE DISPLAY BECOMES DARK. THEN VERY SLOWLY ROTATE R3 UNTIL THE NUMBER 1 IS AGAIN GLOWING IN THE DISPLAY. UNBLOCK THE PHOTORESISTOR, AND THE NUMBER IN THE DISPLAY SHOULD INCREASE. IF THE LIGHT AT YOUR CONSOLE IS BRIGHT, THE NUMBER WILL GO OFF SCALE, AND THE DISPLAY WILL SWITCH COMPLETELY OFF. PARTIALLY COVER THE PHOTORESISTOR APERTURE WITH YOUR FINGER UNTIL THE NUMBER 9 IS DISPLAYED. AS YOU KEEP DARKENING THE PHOTORESISTOR, THE NUMBER WILL DECREASE.

## GOING FURTHER

YOU CAN MONITOR THE ACTIVITY OF THE LIGHT METER WITH AN LED. CONNECT SPRING 11 TO GROUND (BLU WIRE) AND SPRING 12 TO Q8 (BLU WIRE). WHEN THE ONE-SHOT IS SENDING PULSES TO BOTH THE COUNTER AND THE DECODER, LED 1 WILL GLOW.

THE CLOCK OCILLATES AT AN AUDIO FREQUENCY, WHICH YOU CAN HEAR WITH THE SPEAKER. USE RED WIRES TO CONNECT THE SPEAKER (SPRINGS 68 AND 69) TO THE TRANSFORMER (SPRINGS 62 AND 63). CONNECT SPRING 59 TO GROUND (WHT WIRE). CONNECT SPRING 61 TO B19 (BLU WIRE). THE TONE FROM THE SPEAKER IS THE CLOCK FREQUENCY.

THIS CIRCUIT WILL RESPOND TO THE RESISTANCE OF YOUR SKIN. PULL THE BLUE WIRE FROM SPRING 64 AND HOLD THE BARE END WITH TWO FINGERS WHILE TOUCHING SPRING 65 WITH A THIRD FINGER. TRY THIS WITH YOUR FINGERS DRY AND MOIST. WHAT HAPPENS? WHY?

## GOING FURTHER WITH YOUR ELECTRONICS LEARNING LAB

THIS MAY BE THE FINAL PROJECT IN YOUR TWO ELECTRONICS LEARNING LAB MANUALS, BUT IT IS BY NO MEANS THE END OF WHAT YOU CAN DO WITH YOUR KIT. YOU CAN BEGIN BY TRYING TO SIMPLIFY OR MODIFY THE DESIGN OF SOME OF THE CIRCUITS IN YOUR MANUALS.



ELECTRONICS ENGINEERS AND DIGITAL DESIGNERS CONSIDER SIMPLIFYING CIRCUITS TO BE A MAJOR CHALLENGE—AND LOTS OF FUN. CONSIDER THE DIGITAL LIGHT METER. ARE THERE WAYS THAT YOU CAN SIMPLIFY THE CIRCUIT? FOR EXAMPLE, THE 324 HAS THREE UNUSED OP AMPS. PERHAPS YOU CAN DESIGN AN OSCILLATOR USING ONE OR TWO OF THESE SPARE OP AMPS TO REPLACE THE 4049 CLOCK CIRCUIT. THEN MAYBE YOU CAN USE THE REMAINING OP AMP TO REPLACE THE TWO INVERTERS THAT FORM PART OF THE ONE-SHOT PULSE STRETCHER.

OF COURSE YOU DON'T HAVE TO GET FANCY TO CONTINUE ENJOYING YOUR LAB KIT. MANY VARIATIONS OF THE PROJECTS ARE POSSIBLE USING THE PARTS PROVIDED WITH YOUR KIT. SO LET YOUR IMAGINATION TAKE CHARGE. MAYBE YOU CAN DESIGN SOME PROJECTS OF YOUR OWN.