READ THIS...

This book is for the entertainment and edification of experimenters and hobbyists. While reasonable care has been exercised with regard to the accuracy of the information in this book, the author and publisher assume no responsibility for errors, omissions or suitability for any application. Neither do we assume any liability for any damages resulting from use of this information. It is your responsibility to determine if use, manufacture or sale of any device incorporating one or more circuits in this book infringes any patents, copyrights or other rights.

Due to the large volume of mail received by Radio Shack and the author, it is impossible to answer letters requesting custom circuit designs, technical advice, troubleshooting assistance, etc. But though we cannot acknowledge individual letters, we will nevertheless be delighted to review carefully your comments, impressions and suggestions about this book.

Thanks in advance to those of you who write. We appreciate your comments. But please remember we will be unable to give you a personal reply.
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**NOTE:** Many of these chips are best categorized as analog. Linear is the popular term.

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**NOTE:** The CEX-1200 12-Key Tone Module and the PCIM-161 LCD Clock Module are located in the Linear section although both incorporate CMOS/MOS circuitry.

**NOTE:** TTL and LS chips are generally interchangeable. LS chips consume less power than TTL equivalents. Use LS chips, when possible, for battery powered circuits.
INTRODUCTION

Since the original Engineer's Notebook was published in 1979, Radio Shack has made many changes in its line of integrated circuits. Engineer's Notebook II reflects these changes with the addition of 22 new chips and modules and some 84 new circuits. Chips no longer sold by Radio Shack have been deleted.

Dave Wolf, Radio Shack's parts buyer, and Dave Gunzel, Radio Shack's publications director, have invested many hours reviewing draft versions of the new circuits. I'm appreciative of their many helpful suggestions and the freedom they have allowed me in the selection of circuits.

Speaking of circuits, unless otherwise acknowledged, the circuits in this notebook were designed by me specifically for this publication or were adapted from these sources:

1. Applications information published by the manufacturers of the various integrated circuits.
2. My engineering notebooks.
3. "Experimenter's Corner" and "Project of the Month," two columns I write each month for Popular Electronics magazine.

Thanks to Radio Shack's solderless breadboards, you can assemble most of the circuits very quickly. I hope you have as much fun experimenting with them as I have!

Forrest M. Mims, III

HOW TO USE THIS BOOK

To squeeze the maximum number of circuits into this notebook, only essential information is provided. Therefore you will want to use this notebook in conjunction with Radio Shack's "Semiconductor Reference Handbook" and other data books.

For a quickie review of important components and construction tips, read the next few pages. The remainder of the notebook is divided into two major sections: digital and linear. The digital section is further divided into two major IC families: MOS/CMOS and TTL/LS. The chips in each section are organized according to function, not numerical sequence.

Though most circuits in this book can function on their own, consider them as building blocks you can connect to other circuits to accomplish new applications. Experiment! Change resistors and capacitors in RC circuits to alter frequencies and timing. Add new functions. Above all, work with as many different chips as you can! If you've always used TTL, you'll be impressed with the operating flexibility of CMOS. If your forte is digital logic, you'll be amazed at what you can do with an op-amp. Finally, keep a record of your experiments and circuit designs. A notebook with a grid ruling like this one is best, but a 50¢ spiral notebook is OK.

For beginners only....Be sure to read the next few pages! Begin with simple chips (gate packages, timers, op-amps, etc.), and you'll soon be ready for more advanced circuits and projects. Have fun!
REVIEWING THE BASICS

INTRODUCTION

"Can I use a 0.22 µF capacitor instead of a 0.10 µF unit?"

"Is it OK to substitute a 12,000 ohm resistor for a 10,000 ohm unit?"

This section will tackle these common questions and many others. Master them, and you will be well prepared to tackle the circuits in this book!

RESISTORS

Resistors limit the flow of electrical current. A resistor has a resistance (R) of 1 ohm if a current (I) of 1 ampere flows through it when a potential difference (E) of 1 volt is placed across it. In other words:

\[ R = \frac{E}{I} \text{ (or) } I = \frac{E}{R} \text{ (or) } E = IR \]

These handy formulas form Ohm's law. Memorize them! You'll use them often.

Resistors are identified by a color code:

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>(Multiplier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLACK</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>BROWN</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>RED</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>ORANGE</td>
<td>3</td>
<td>3</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>YELLOW</td>
<td>4</td>
<td>4</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>GREEN</td>
<td>5</td>
<td>5</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>BLUE</td>
<td>6</td>
<td>6</td>
<td>1,000,000</td>
<td></td>
</tr>
<tr>
<td>VIOLET</td>
<td>7</td>
<td>7</td>
<td>10,000,000</td>
<td></td>
</tr>
<tr>
<td>GRAY</td>
<td>8</td>
<td>8</td>
<td>100,000,000</td>
<td></td>
</tr>
<tr>
<td>WHITE</td>
<td>9</td>
<td>9</td>
<td>(none)</td>
<td></td>
</tr>
</tbody>
</table>

A fourth color band may be present. It specifies the tolerance of the resistor. Gold is ± 5% and silver is ± 10%. No fourth band means ± 20%.

Since no resistor has a perfect tolerance, it's often OK to substitute resistors. For example, it's almost always OK to use a 1.8K resistor in place of a 2.0K unit. Just try to stay within 10-20% of the specified value.

What does K mean? It's short for 1,000. 20K means 20 x 1,000 or 20,000 ohms. M is short for meg-ohm or 1,000,000 ohms. Therefore a 2.2M resistor has a resistance of 2,200,000 ohms.

Resistors which resist lots of current must be able to dissipate the heat that's produced. Always use resistors with the specified power rating! No power rating specified? Then it's usually OK to use 1/4 or 1/2 watt units.

Almost every electronic circuit uses resistors. Here are three of the most important applications for resistors:

1. Limit current to LEDs, transistors, speakers, etc.

2. Voltage division. For instance:

\[ \text{The voltage at } \frac{?}{10V} = \frac{I \times R2}{R1} \text{. I means the current through } R1 \text{ and } R2 \text{. So } I = \frac{10V}{R1 + R2} \text{ or } \frac{0.005}{0.005} \text{ amperes.} \]

\[ \text{Therefore, } \frac{?}{10V} = (0.005) \times (1000) \text{ or } 5 \text{ volts.} \]

Note that the total resistance of R1 and R2 is simply R1 + R2. This rule provides a handy trick for making custom resistances.
Voltage dividers are used to bias transistors:

**VOLTAGE DIVIDER**

They're also a convenient source of variable voltage:

**POTENTIOMETER**

(VARIABLE RESISTOR)

And they're useful in voltage sensing circuits. See the comparator circuits in this notebook.

3. They control the charging time of capacitors. Read on...

**CAPACITORS**

Capacitors store electrical energy and block the flow of direct current while passing alternating current. Capacity is specified in farads. One farad represents a huge capacitance so most capacitors have values of small fractions of a farad:

- 1 microfarad (uF) = 10^-6 farad
- 1 picofarad (pF) = 10^-12 farad
- 1 uF = 1,000,000 pF

The value of a capacitor is usually printed on the component. The uF and pF designations may not be present. Small ones marked 1-1000 are rated in pF; larger ones marked .001-1000 are rated in uF.

Electrolytic capacitors provide high capacity in a small space. Their leads are polarized and must be connected into a circuit in the proper direction.

**THESE LEADS MUST GO TO THE MOST POSITIVE CONNECTION POINT.**

Capacitors have a voltage rating. It's usually printed under the capacity marking. The voltage rating must be higher than the highest expected voltage (usually the power supply voltage).

Caution: A capacitor can store a charge for a considerable time after power is removed. This charge can be dangerous! A large electrolytic capacitor charged to only 5 or 10 volts can melt the tip of a screwdriver placed across its leads! High voltage capacitors can store a lethal charge! Discharge a capacitor by carefully placing a resistor (1K or more; use Ohm's law) across its leads. Use only one hand to prevent touching both leads of the capacitor.

Important capacitor applications:

1. Remove power supply spikes. (Place 0.01-0.1 uF across power supply pins of digital ICs. Stops false triggering.)

2. Smooth rectified AC voltage into steady DC voltage. (Place 100-10,000 uF across rectifier output.)
3. Block DC signal while passing AC signal.

4. Bypass AC signal around a circuit or to ground.

5. Filter out unwanted portions of a fluctuating signal.

6. Use with resistor to integrate a fluctuating signal:

   ![Diagram]

7. Or to differentiate a fluctuating signal:

   ![Diagram]

8. Perform a timing function:

   ![Diagram]

   C will quickly charge...then slowly discharge through R.

9. Store a charge to keep a transistor turned off or on.

10. Store a charge to be dumped through a flash tube or LED in a fast and powerful pulse.

Can you substitute capacitors?
In most cases changing the value of a capacitor 10% or even 100% will not cause a malfunction, but circuit operation may be affected. In a timing circuit, for example, increasing the value of the timing capacitor will increase the timing period. Changing the capacitors in a filter will change the filter's frequency response. Be sure to use the proper voltage rating. And don't worry about the difference between 0.47 and 0.5 µF.

**SEMI CONDUCTORS**

Usually made from silicon. Be sure to observe all operating restrictions. Brief descriptions of important semiconductor devices:

**DIODES**

Permit current to flow in but one direction (forward bias). Used to rectify AC, allow current to flow into a circuit but block its return, etc.

**ZENER DIODES**

The zener diode is a voltage regulator. In this typical circuit, voltage exceeding the diode's breakdown voltage is shunted to ground:

![Diagram]

DI = 6 VOLT ZENER DIODE

Zeners can also protect voltage sensitive components and provide a convenient reference voltage.

**LIGHT EMitting DIODES**

LEDs emit green, yellow, red or infrared when forward biased. A series resistor should be used to limit current to less than the maximum allowed:

\[
 R_s = \frac{V_{cc} - V_{LED}}{I_{LED}}
\]

Example: \( V_{LED} \) of red LED is 1.7 volts. For a forward current \( (I\text{LED}) \) of 20 mA at \( V_{cc} = 5 \text{ volts} \), \( R = 330 \text{ ohms} \). Don't exceed \( L\text{LED} \)!!
Infrared LEDs are much more powerful than visible LEDs, but their radiation is totally invisible. Use them for object detectors and communicators.

**TRANSISTORS**

In this notebook, transistors are used as simple amplifiers and switches that turn on LEDs. Any general purpose switching transistors will work.

**INTEGRATED CIRCUITS**

Since an IC is a complete circuit on a silicon chip, you must observe all operating restrictions. Reversed polarity, excessive supply voltage and sourcing or sinking too much current can destroy an IC. Be sure to pay close attention to the location of the power supply pins! Most ICs are packaged in 8, 14 or 16 pin plastic DIPs (Dual In-line Packages). A notch or circle is near pin 1:

When the IC is right side up, pin 1 is at lower left:

**MANUFACTURER**

**PART NUMBER**

(MOTOROLA) (4021)

**DATE CODE:**

78 = 1978
24 = 24th week

Incidentally, a date code may not be present, but other numbers may be...and the date code is not always below the device number:

![](image)

Store ICs in a plastic cabinet if you can afford one. Or insert them in rows in a styrofoam tray (the kind used for meat in a grocery store). CAUTION: Never store MOS/CMOS ICs in ordinary non-conductive plastic. See p. 12.

**CIRCUIT BUILDING**

Build your circuits on a solderless breadboard to make changes and find bugs. Then make permanent versions. Radio Shack plastic modular sockets (276-173, etc.) are ideal. They include two socket rows for power supply connections and snap rails for attaching sockets together. Parts and wires can be inserted directly into the holes in the socket.

For permanent circuits, use Radio Shack PC boards. Catalog numbers 276-024 and 276-151 are ideal for simple IC projects. Use larger universal PC boards for more complex projects (276-152 & 276-157). You can cut them into smaller sections with a nibbler tool or small saw.

I prefer to use wrapping wire for IC projects. Insert wrapping sockets in board and make connections with a Wire-Wrapping tool (such as 276-1570). Apply wrapping wire directly to leads of transistors, resistors, etc. and solder in place.
DIGITAL INTEGRATED CIRCUITS

INTRODUCTION

DIGITAL ICs ARE 2-STATE DEVICES. ONE STATE IS NEAR 0 VOLTS OR GROUND (LOW OR L) AND THE OTHER IS NEAR THE IC's SUPPLY VOLTAGE (HIGH OR H). SUBSTITUTE 0 FOR L AND 1 FOR H AND DIGITAL ICs CAN PROCESS INDIVIDUAL BINARY DIGITS (BITS) OR MULTIPLE BIT WORDS. A 4-BIT WORD IS A NIBBLE AND AN 8-BIT WORD IS A BYTE.

THE BINARY SYSTEM

IT'S VERY HELPFUL TO KNOW THE FIRST 16 BINARY NUMBERS. IF 0=L AND 1=H, THEY ARE:

0 - L L L L    8 - H L L L
1 - L L L H    9 - H L L H
2 - L L H L    10 - H L H L
3 - L L H H    11 - H L H H
4 - L H L L    12 - H H L L
5 - L H L H    13 - H H L H
6 - L H H L    14 - H H H L
7 - L H H H    15 - H H H H

NOTE THAT LLLL (0) IS AS MUCH A NUMBER AS ANY OTHER NUMBER.

LOGIC GATES

LOGIC CIRCUITS ARE MADE BY INTERCONNECTING TWO OR MORE OF THESE BASIC LOGIC GATES:

AND

NAND

OR

NOR

EXCLUSIVE-OR

EXCLUSIVE-NOR

YES (BUFFER)

NOT (INVERTER)

3-STATE LOGIC

CONTROL

CONTROL

CONTROL

HI-Z: OUTPUT IN HIGH IMPEDANCE STATE.
MOS/CMOS INTEGRATED CIRCUITS

INTRODUCTION

MOS IC's can contain more functions per chip than TTL/LS and are very easy to use. Most chips in this section are CMOS (complementary MOS). They consume very little power and operate over a +3-15 volt range. CMOS can be powered by this:

\[ + (V_{DD}) \]

OR YOU CAN USE A LINE POWERED SUPPLY MADE FROM A 7805/7812/7815. SEE THE LINEAR SECTION.

INCIDENTALLY, YOU CAN POWER A CMOS CIRCUIT FROM TWO SERIES CONNECTED PENLIGHT CELLS, BUT A 9-12 VOLT SUPPLY WILL GIVE BETTER PERFORMANCE.

OPERATING REQUIREMENTS

1. THE INPUT VOLTAGE SHOULD NOT EXCEED V_{DD} (TWO EXCEPTIONS: THE 4049 AND 4050.)

2. AVOID, IF POSSIBLE, SLOWLY RISING AND FALLING INPUT SIGNALS SINCE THEY CAN CAUSE EXCESSIVE POWER CONSUMPTION. RISTIMES FASTER THAN 15 MICROSECONDS ARE BEST.

3. ALL UNUSED INPUTS MUST BE CONNECTED TO V_{DD} (+) OR V_{SS} (GND). OTHERWISE ERRATIC CHIP BEHAVIOR AND EXCESSIVE CURRENT CONSUMPTION WILL OCCUR.

4. NEVER CONNECT AN INPUT SIGNAL TO A CMOS CIRCUIT WHEN THE POWER IS OFF.

5. OBSERVE HANDLING PRECAUTIONS.

HANDLING PRECAUTIONS

A CMOS CHIP IS MADE FROM PMOS AND NMOS TRANSISTORS. MOS MEANS METAL-OXIDE-SILICON (OR SEMICONDUCTOR). P AND N REFER TO POSITIVE AND NEGATIVE CHANNEL MOS TRANSISTORS. AN NMOS TRANSISTOR LOOKS LIKE THIS:

\[ \text{Gate (in)} \]

A PMOS TRANSISTOR IS IDENTICAL EXCEPT THE P AND N REGIONS ARE EXCHANGED. THE SiO_{2} (SILICON DIOXIDE) LAYER IS A GLASSY FILM THAT SEPARATES AND INSULATES THE METAL GATE FROM THE SILICON SUBSTRATE. THIS FILM IS WHY A MOS TRANSISTOR OR IC PLACES PRACTICALLY NO LOAD ON THE SOURCE OF AN INPUT SIGNAL. THE FILM IS VERY THIN AND IS THEREFORE EASILY PUNCHED BY STATIC ELECTRICITY.

PREVENT STATIC DISCHARGE!

1. NEVER STORE MOS IC'S IN NONCONDUCTIVE PLASTIC "SNOW," TRAYS, BAGS OR FOAM.

2. PLACE MOS IC'S PINS DOWN ON AN ALUMINUM FOIL SHEET OR TRAY WHEN THEY ARE NOT IN A CIRCUIT OR STORED IN CONDUCTIVE FOAM.

3. USE A BATTERY POWERED IRON TO SOLDER MOS CHIPS. DO NOT USE AN AC POWERED IRON.
INTERFACING CMOS

1. If supply voltages are equal:

\[ R_{pu} : \text{Pullup Resistor.} \]

\[ R_{pu} : 470 \text{--} 4.7 \text{K} \text{ for TTL;} \]
\[ 1 \text{K} \text{--} 10 \text{K} \text{ for LS.} \]

\[ \text{TTL or LS} \rightarrow \text{CMOS} \]

\[ +5 \text{ (V}_{dd}\text{)} \]

\[ \text{R}_{pu} \]

\[ \text{CMOS} \rightarrow \text{TTL or LS} \]

2. Different supply voltages:

\[ +5 \]

\[ +3-15 \]

\[ 10 \text{K} \]

\[ 1 \text{K} \]

\[ R_{S2009} \]

\[ \text{TTL or LS} \rightarrow \text{CMOS} \]

\[ +3-15 \]

\[ +5 \]

\[ \text{CMOS} \rightarrow \text{TTL or LS} \]

3. CMOS LED drivers:

\[ V_{dd} \text{ (+3-5V)} \]

\[ \text{Glow when low.} \]

\[ V_{dd} \text{ (+3-15V)} \]

\[ \text{Glow when high.} \]

\[ R = \frac{V_{dd} - 1.7}{0.01} \text{ (For 10 mA LED current)} \]

Use 1000 ohms for most applications.

CMOS LOGIC CLOCK

Many circuits in this section require a source of pulses. Here's a simple CMOS clock:

\[ \text{TYPICAL VALUES: } R = 100K, \quad C = 0.01 \text{--} 0.1 \mu F \]

OK to use 4049... but much more current will be required.

CMOS TROUBLESHOOTING

1. Do all inputs go somewhere?

2. Are all IC pins inserted into the board or socket?

3. Is the IC hot? If so, see 1-2 above and make sure the output is not overloaded.

4. Does the circuit obey all CMOS operating requirements?

5. Have you forgotten a connection?

Note that CMOS must be powered by at least 5 volts when CMOS is interfaced with TTL. Otherwise the CMOS input will exceed \( V_{dd} \).
QUAD NAND GATE
4011

The basic CMOS building block chip. More applications than TTL 7400/741500 quad NAND gate.

CONTROL GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
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<tr>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

INVERTER

<table>
<thead>
<tr>
<th>A</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

AND GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
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<tr>
<td>L</td>
<td>H</td>
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</table>

OR GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
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</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
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<tr>
<td>H</td>
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<td>H</td>
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</tbody>
</table>

EXCLUSIVE-OR GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
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<tr>
<td>L</td>
<td>H</td>
<td>H</td>
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<td>H</td>
<td>L</td>
<td>H</td>
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<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

AND-OR GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>H</td>
</tr>
<tr>
<td>X</td>
<td>H</td>
<td>H</td>
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<tr>
<td>H</td>
<td>X</td>
<td>H</td>
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<td>H</td>
<td>H</td>
<td>H</td>
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</tbody>
</table>

EXCLUSIVE-NOR GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
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<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

**Important:** Connect all unused inputs to pin 7 or 14!
GATED OSCILLATOR

Output frequency is 1 kHz square wave.

SIMPLE OSCILLATOR

Output not as symmetrical as above circuit.

GATED FLASHER

LED flashes 1-2 Hz when enable is high. LED stays on when enable is low.

TOUCH SWITCH

Output goes high when touch wires are bridged by a finger.

ONE-SHOT TOUCH SWITCH

Output goes high when touch wires are bridged by a finger. Output then returns low after about 1 second.

INCREASED OUTPUT DRIVE

Use this method to increase current. The 4011 can source or sink. OK to add more gates.
QUAD NOR GATE
4001

An important CMOS building block chip, its high impedance input makes possible more applications than the TTL 7402/74LS02 quad nor gate.

BOUNCELESS SWITCH

V_{dd} (+3-15\,\text{V})

**INCREASED OUTPUT DRIVE**

Important: connect all unused inputs to pin 7 or 14.

**GATED TONE SOURCE**

Tone frequency is about 1\,\text{kHz}.

**RS LATCH**

<table>
<thead>
<tr>
<th>R</th>
<th>S</th>
<th>Q</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>NOT ALLOWED</td>
</tr>
</tbody>
</table>

**LED FLASHER**

LED flashes 1-2 times/second.

**OR GATE**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
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<tr>
<td>L</td>
<td>L</td>
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<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
QUAD AND GATE
4081

BUILDING BLOCK CHIP. USE FOR BUFFERING AND LOGIC.
NOT AS VERSATILE AS 4011.

AND GATE BUFFER

NAND GATE

NOR GATE

4-INPUT NAND GATE

4-INPUT AND GATE
QUAD EXCLUSIVE-OR GATE 4070

THE OUTPUT OF EACH GATE GOES LOW WHEN BOTH INPUTS ARE EQUAL. THE OUTPUT GOES HIGH IF THE INPUTS ARE UNEQUAL. MANY APPLICATIONS INCLUDING BINARY ADDITION, COMPARING BINARY WORDS AND PHASE DETECTION.

IMPORTANT: CONNECT UNUSED INPUTS TO PIN 7 OR 14.

1-BIT COMPARATOR

THIS CIRCUIT IS ALSO A HALF-ADDER WITHOUT A CARRY OUTPUT.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

4-BIT COMPARATOR

DETERMINES IF TWO 4-BIT WORDS ARE EQUAL.

HINT: USE 4011 (p. 14) IF 4012 IS UNAVAILABLE.

IF DCBA = D'C'B'A' OUTPUT IS LOW, OTHERWISE OUTPUT IS HIGH. USE 4012 AS INVERTER TO REVERSE OPERATION.

INPUT FREQUENCIES ARE EQUAL.

CONTROLLED INVERTER

BINNARY FULL ADDER

PHASE DETECTOR
QUAD EXCLUSIVE-OR GATE (CONTINUED)

4070

EXCLUSIVE-NOR

$$\begin{array}{ccc}
A & B & \text{OUT} \\
1 & 1 & H \\
1 & 0 & L \\
0 & 1 & L \\
0 & 0 & L \\
\end{array}$$

3-INPUT EX-OR

$$\begin{array}{ccc}
A & B & C & \text{OUT} \\
1 & 0 & 0 & L \\
1 & 0 & 1 & L \\
1 & 1 & 0 & L \\
1 & 1 & 1 & H \\
0 & 1 & 1 & H \\
0 & 1 & 0 & H \\
0 & 0 & 1 & H \\
0 & 0 & 0 & L \\
\end{array}$$

10 MHz OSCILLATOR

V\text{dd} = 3 \text{ to } 15 \text{ volts}

FREQUENCY VARIES WITH V\text{dd}:

<table>
<thead>
<tr>
<th>V\text{dd}</th>
<th>FREQUENCY</th>
<th>AMPLITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.4 MHz</td>
<td>3.5 V</td>
</tr>
<tr>
<td>10</td>
<td>9.4 MHz</td>
<td>8.0 V</td>
</tr>
<tr>
<td>15</td>
<td>11.0 MHz</td>
<td>12.0 V</td>
</tr>
</tbody>
</table>

8-INPUT EX-OR

SQUARE WAVE GENERATOR

V\text{dd} = 3 \text{ to } 15 \text{ volts}

RISETIME = 50 nanoseconds

FREQUENCY = 2 MHz WHEN

V\text{dd} = 10 \text{ volts}
HEX INVERTING BUFFER
4049

IN ADDITION TO STANDARD
LOGIC AND CMOS TO TTL
INTERFACING, OFTEN USED
IN OSCILLATORS AND PULSE
GENERATORS, FOR LOW CURRENT
APPLICATIONS, USE 4011 CONNECTED
AS INVERTER. (OK TO USE 4011 FOR
CIRCUITS ON THIS PAGE.)

CLOCK PULSE GENERATOR

1, 2 = ½ 4049 PULSE RATE = 1.4RC

PHASE SHIFT OSCILLATOR

OUTPUT FREQUENCY = \frac{1}{3.3RC}

1, 2, 3 = \frac{1}{2} 4049

BOUNCELESS SWITCH

1, 2 = \frac{1}{3} 4049

TRIANGLE WAVE SOURCE

FREQUENCY = \frac{1}{1.4 RIC1}

SQUARE WAVE GENERATOR

1, 2 = \frac{1}{3} 4049

LINEAR 10X AMPLIFIER

1, 2, 3 = \frac{1}{2} 4049

NOTE THAT THE
INVERTERS ARE USED
IN A LINEAR MODE. GAIN = R2/R1.
HEX NON-INVERTING BUFFER
4050

PRIMARILY INTENDED FOR INTERFACING CMOS TO TTL. SUPPLIES MORE CURRENT THAN STANDARD CMOS.

IMPORTANT: ALL UNUSED INPUTS MUST GO TO PIN 1 OR 8.

OUTPUT EXPANDER

OUTPUT BUFFER

CMOS TO CMOS AT LOWER V_{DD}

CMOS TO TTL/LS AT LOWER V_{CC}

INCREASED OUTPUT DRIVE

NOTE UNUSUAL LOCATION OF POWER SUPPLY PINS.

LED GLOWS WHEN INPUT IS LOW.

V_{DD} 1 EXCEEDS V_{DD} 2.
1 = \frac{1}{6} 4050
QUAD BILATERAL SWITCH 4066

ONE OF THE MOST VERSATILE CMOS CHIPS. PINS A, B, C AND D CONTROL FOUR ANALOG SWITCHES. CLOSE A SWITCH BY CONNECTING ITS CONTROL PIN TO V_DD. ON RESISTANCE = 80 - 250 OHMS. OPEN A SWITCH BY CONNECTING ITS CONTROL PIN TO GROUND (PIN 7). OFF RESISTANCE = 10^9 OHMS. I/O (INPUT/OUTPUT) AND O/I PINS ARE REVERSIBLE.

DATA BUS CONTROL

DATA SELECTOR

DIGITAL TO ANALOG (D/A) CONVERTER

THIS IS NOT A LINEAR D/A CONVERTER. INSTEAD IT PRODUCES A PSEUDO-RANDOM OUTPUT THAT RANGES FROM 3.06 - 5.62 VOLTS (V_DD = 9 V). USE TO DRIVE 4046 VCO OR PRODUCE UNUSUAL WAVEFORMS. R = 47K AND 2R = 100K.

USE 4518 COUNTER FOR AUTOMATIC OPERATION.
QUAD BILATERAL SWITCH

(continued)

4066

PROGRAMMABLE GAIN AMPLIFIER

\[
V_{\text{OUT}} = \frac{R_F}{R_{\text{IN}}}
\]

0000 to 1111 at DCBA gives
\[R_{\text{IN}}\] of from R to \(R/15\)

PROGRAMMABLE FUNCTION GENERATOR

\[I_C\,1,\,2,\,3 = 4066\quad V_{\text{DD}} = 3-15\text{V}\]

\(R_1 - R_{10}\) = 10K TRIMMER POTS

produces repetitive 10-step waveform.
program height of each step via \(R_1 - R_{10}\).

vary rate via \(R_{11}\) and \(C_1\).
### 1024-BIT STATIC RAM

**2102L**

1024 1-BIT STORAGE LOCATIONS ADDRESSED BY PINS A0-A9. TTL/LS COMPATIBLE. CE (CHIP ENABLE) INPUT CONTROLS R/W (READ/WRITE) OPERATIONS. 3-STATE OUTPUTS.

<table>
<thead>
<tr>
<th>CE</th>
<th>R/W</th>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>WRITE (LOADS BIT AT PIN 11)</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>READ (OUTPUTS BIT AT PIN 12)</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>HI Z (OUTPUT ENTERS THIRD STATE)</td>
</tr>
</tbody>
</table>

---

**2102L ADDRESSING CIRCUIT**

The address inputs must be stable during R/W operations.
1024-BIT STATIC RAM (CONTINUED)
2102L

ADDING PROGRAMMED
OR MANUAL JUMP

ADD THESE CONNECTIONS TO THE
ADDRESSING CIRCUIT ON FACING PAGE.

SA-SJ: USE
8-POSITION DIP
SWITCHES OR
MINIATURE TOGGLES.
OPEN = H; CLOSED = L

SINGLE I/O PORT

Add this circuit to the
addressing circuit on facing
page. When I/O (input/output)
control is H, pin 3 of the
74LS367 enters third state (Hi-Z)
and I/O port accepts input
data. When pin 3 of the
74LS367 is L, I/O port
outputs data. Both these
operations are dependent
upon the status of the
2102L control inputs.

CASCADE 2102L'S

Normally the load input is high,
making load low loads the
address programmed in switches
SA-SJ into the 74193's. This
permits a programmed jump
or a manual jump to any
address.
1024 x 4-BIT RAM
2114L /4045

1024-4-BIT STORAGE LOCATIONS ADDRESSED
BY PINS AO-A9. TTL/LS COMPATIBLE.
FOR READ/WRITE OPERATIONS, CE (CHIP ENABLE,
ALSO CALLED CHIP SELECT) MUST BE LOW.
WE INPUT MUST BE LOW TO WRITE
(LOAD) DATA INTO CHIP. WHEN WE
IS HIGH, DATA IN ADDRESSED
LOCATION APPEARS AT INPUT/OUTPUT
PINS. IDEAL CHIP FOR DO-IT-YOURSELF
MICROCOMPUTERS AND CONTROLLERS.

2114L ADDRESSING CIRCUIT

+5 A7 A0 A9 A B C D WE
18 17 16 15 14 13 12 11 10

INPUT/OUTPUT
PINS

AO-A9: ADDRESS INPUTS
WE: WRITE ENABLE

A6 A5 A4 A3 AO AI A2 CE GND
(cs)

CLEAR
WHEN H)

ADDRESS
LINES TO
OTHER
2114L'S.

THE ADDRESS INPUTS
MUST REMAIN STABLE
DURING R/W OPERATIONS.
1024 x 4-BIT RAM (CONTINUED)
2114L/4045

1024-NIBBLE
DATA LOADING CIRCUIT
(NIBBLE = 4-BIT WORD OR 1/2 8-BIT WORD)

USE THIS CIRCUIT TO MANUALLY
STORE UP TO 1024 4-BIT WORDS
IN A 2114L. AFTER THE DATA
IS LOADED, IT CAN THEN BE READ
BACK AT THE CLOCK SPEED. THE
DATA OUTPUTS ARE PINS 11-14 WHEN
DATA INPUT SWITCHES ARE AT NEUTRAL.

WRITE: 1. SWITCH S2 TO THE
BOUNCELESS PUSHPUTTON.
2. SWITCH SH AND SS TO L.
3. CLOSE S3.
4. INPUT DATA.
5. PRESS BOUNCELESS PUSHPUTTON.
6. REPEAT STEPS 1-5.

READ: 1. OPEN S3.
2. SWITCH SS TO H.
3. CLOSE, THEN OPEN, SI.
4. SELECT CLOCKED OR
MANUAL OUTPUT (S2).

NOTE:
BEST TO OUTPUT DATA
THROUGH 74LS367 HEX
BUFFER.
DUAL D FLIP-FLOP 4013

VERY VERSATILE PAIR OF D-TYPE FLIP-FLOPS. GROUND UNUSED INPUTS.

I-OF-4 SEQUENCER

OUTPUTS GO HIGH IN SEQUENCE. 1, 2, 3, 4: 4001
ALL OTHERS STAY LOW.

DIVIDE-BY-2

MODULO-8 COUNTER

COUNTS LLLL-HLLL AND RECYCLES 5

SERIAL IN/OUT, PARALLEL OUT SHIFT REGISTER

SERIAL DATA IN

CLOCK
DUAL JK FLIP FLOP 4027

Use for dividers, counters and registers. S (set) and R (reset) inputs must be low for clocking to occur. Making S or R high sets or resets flip-flop independent of clock. Important: All inputs must go somewhere!

DIVIDE-BY-2 COUNTER

DIVIDE-BY-3 COUNTER

DIVIDE-BY-4 COUNTER

DIVIDE-BY-5 COUNTER

4-BIT SERIAL SHIFT REGISTER

Vdd (+3-15V)
QUAD LATCH
4042

Four bistable latches. Can be used as a 4-bit data register. All four latches are clocked simultaneously. Polarity pin provides clocking flexibility.

4-BIT DATA LATCH

DATA BUS

VDD

CLOCK POLARITY

D

C

B

A

DATA OUT

4042

VDD

CLOCK

DATA ON BUS APPEARS AT OUT puts. DATA IS LATCHED (SAVED) WHEN CLOCK SWITCHES.

STEPPED WAVE GENERATOR

Typical Values:

R1 = R3 = 22k
R2 = 33k
DUAL ONE-SHOT

4528

Two fully independent monostable multivibrators. Both can be retriggered. Trigger can be rising or falling edge of pulse. T1 and T2 are timing inputs. RST is reset and +IN are trigger inputs.

POSITIVE ONE-SHOT

Pulse Delayer

Stepped Tone Generator

To control with light, use CdS photocell for R1.

Adjust R1 to create unique stepped tone. R2 controls frequency. OK to experiment with C1 and C2. R3 controls gain.
DECcade COUNTER/DIVIDER

4017

Sequentially makes 1-of-10 outputs high (others stay low) in response to clock pulses. Many applications. Count takes place when pins 13 and 15 are low.

RANDom NUMBER GENERATOR

COUNT TO N AND HALT

COUNT TO N AND RECYCLE

OK TO ADD MORE 4017's
DECADE COUNTER/DIVIDER (CONTINUED)

4017

BCD KEYBOARD ENCODER

4017

S0 S1 S2 S3 S4 S5 S6 S7 S8 S9

IC1 = 4049  IC2 = 4011

TOGGLE S10, THEN PRESS S0 - S9.

FREQUENCY DIVIDER

4017

IC1 = 4001

CLOSE S1 - S10 TO DIVIDE FREQUENCY BY FROM 1 TO 10.
3-DIGIT BCD COUNTER
MC14553

COMPLETE 3-DIGIT COUNTER. USE FOR DO-IT-YOURSELF EVENT AND FREQUENCY COUNTERS. BEGINNERS: GET SOME PRACTICAL CIRCUIT EXPERIENCE BEFORE USING THIS CHIP. PIN EXPLANATIONS:

DS (DIGIT SELECT) 1,2,3—SEQUENTIALLY STROBES READOUTS. LE—LATCH ENABLE (WHEN H). DIS—INHIBITS INPUT WHEN H. CLOCK—INPUT. MR—MASTER RESET (WHEN H). OF—OVERFLOW. A, B, C, D—BCD OUTPUTS.

3-DIGIT EVENT COUNTER

OK TO USE LIQUID CRYSTAL DISPLAY OR COMMON CATHODE LED DISPLAY. SEE 14553 FOR DETAILS.

6-DIGIT FREQUENCY COUNTER

LATCH: STORES TOTAL COUNT IN ONE COUNT CYCLE.

RESET: CLEARS COUNT TO 000000 PRIOR TO NEW COUNT CYCLE.

COUNT: COUNT INPUT
3-DIGIT BCD COUNTER (CONTINUED)

MC14553

6-DIGIT COUNTER

THIS CIRCUIT SHOWS HOW TO CASCADE TWO 3-DIGIT COUNTERS. MAXIMUM COUNT Q3 IS 999,999. DISPLAYS ARE COMMON CATHODE (COMMON ANODE CONFIGURATION SHOWN ON PREVIOUS PAGE). NOTE THAT PIN 6 OF 14543 (OR 4543) GOES TO GND INSTEAD OF VDD WHEN COMMON CATHODE DISPLAY IS USED.

FREQUENCY COUNTER:

USE INPUT AND CONTROL CIRCUIT ON PREVIOUS PAGE... INPUT FREQUENCY SHOULD NOT EXCEED VDD. NON-SQUARE WAVE INPUTS MAY REQUIRE INPUT TAILORING. USE COMPARATOR TO SHARPEN SLOW RISING WAVES.
BCD-TO-7-SEGMENT LATCH/DECODER/DRIVER 4511

Converts BCD data into format suitable for producing decimal digits on 7-segment LED display. Includes built-in 4-bit latch to store data to be displayed (when PIN 5 is high). When latch is not used (PINS low), the 7-segment outputs follow the BCD inputs. Make PIN 4 low to extinguish the display and high for normal operation. Make PIN 3 low to test the display and high for normal operation.

DISPLAY FLASHER

DISPLAY FLASHES     E     DISPLAY
ONCE PER SECOND     H     FLASHERS
WHEN E IS HIGH      L     OFF

DECIMAL COUNTING UNIT (DCU)

OPERATION:

TO COUNT, ENABLE IS HIGH AND RESET IS LOW. BLANK SHOULD BE HIGH (LOW TURNS OFF DISPLAY). SAVE SHOULD BE LOW. MAKE SAVE HIGH TO STORE INTERIM COUNT WITHOUT AFFECTING COUNTER.

VDD (+3-15v) f  g  a  b  c  d  e
60-Hz TIMEBASE
MM5369 (276-1769)

Provides precise 60 Hz square wave when used with 3.579545 MHz color TV crystal. Use for most do-it-yourself timers, clocks, controllers, function generators. Install in small cabinet for workbench precision clock.

**60-Hz TIMEBASE**

60 Hz OUT

![Circuit Diagram](image)

RI- use two 10M in series.

*Motorola specifies that C1=30pF and C2=6.36 pF. OK to use six 4.7 pF capacitors in parallel or 47 pF capacitor for C1. Try tunable capacitor (e.g. 5-50pF) for C2. To tune, connect frequency meter to pin 7. Tune C2 until frequency is 3,579,545 Hz. Accuracy fairly good even if you don't tune C2.

**10-Hz TIMEBASE**

10 Hz OUT

![Circuit Diagram](image)

This is a \( \frac{1}{6} \) divider.

**1-Hz TIMEBASE**

10 Hz IN

![Circuit Diagram](image)

This is a \( \frac{1}{10} \) divider.

**DIGITAL STOPWATCH**

![Circuit Diagram](image)

Operation:

1. Toggle SI from CLEAR to READY.
2. Switch S2 from STOP to START.
3. Switch S2 from START to STOP.

1 Hz = 00-99 sec
10 Hz = 0.0-9.9 sec
OK to add more stages.
NOISE GENERATOR
S2688/MM5837N

PRODUCES BROADBAND WHITE
NOISE FOR AUDIO AND
OTHER APPLICATIONS. THE
NOISE QUALITY IS VERY
UNIFORM. IT IS PRODUCED
BY A 17-BIT SHIFT REGISTER
WHICH IS CLOCKED BY AN
INTERNAL OSCILLATOR.

WHITE NOISE SOURCE

CONNECT OUTPUT TO AUDIO
AMPLIFIER TO HEAR NOISE.
USE 7815 VOLTAGE REGULATOR
TO OBTAIN +15 VOLTS.

PINK NOISE SOURCE

CHANGE R AND C TO
ALTER NOISE SPECTRUM.
ALSO, TRY LOWER SUPPLY
VOLTAGES TO CHANGE SPECTRUM.

COIN TOSSEER

PRESS S1; BOTH LEDS GLOW. RELEASE
S1 AND ONLY ONE GLOWS. GROUND
INPUTS OF UNUSED HALF OF 4027
(PINS 9, 10, 11, 12 AND 13).* (OK TO USE
9-VOLT BATTERY AS POWER SUPPLY.)

SNARE/BRUSH NOISE

PRESS S1 TO OPERATE,
INCREASE C2 AND
C3 TO LOWER OUTPUT
FREQUENCY.
TTL/LS INTEGRATED CIRCUITS

INTRODUCTION
TTL is the best established and most diversified IC family. LS is functionally identical to TTL but is slightly faster and uses 80% less power. TTL/LS chips require a regulated 4.75-5.25 volt power supply. Here's a simple battery supply:

```
+-------------------+      +-------------------+      +-------------------+
|                   |      |                   |      |                   |
|       IN4001       |      |                       |      |                       |
|                   |      |       Vcc              |      |                       |
|                   |      |                       |      |                       |
| -10μF             |      | 1μF                   |      | GND                   |
+-------------------+      +-------------------+      +-------------------+
6-Volts            |      |                       |      |                       |
```

The diode drops the battery voltage to a safe level. Both capacitors should be installed on the TTL/LS circuit board. Circuits with lots of TTL/LS chips can use lots of current. Use a commercial 5 volt line powered supply to save batteries or make your own. (See the 7805 on page 94.)

OPERATING REQUIREMENTS
1. Vcc must not exceed 5.25 volts.
2. Input signals must never exceed Vcc and should not fall below GND.
3. Unconnected TTL/LS inputs usually assume the H state... but don't count on it! If an input is supposed to be fixed at H, connect it to Vcc.
4. If an input is supposed to be fixed at L, connect it to GND.
5. Connect unused and/NAND/or inputs to a used input of the same chip.
6. Force outputs of unused gates H to save current (NAND—one input H; NOR—all inputs L).
7. Use at least one decoupling capacitor (0.01-0.1 μF) for every 5-10 gate packages; one for every 2-5 counters and registers and one for each one-shot. Decoupling capacitors neutralize the hefty power supply spikes that occur when a TTL/LS output changes states. They must have short leads and be connected from Vcc to GND as near the TTL/LS ICs as possible.
8. Avoid long wires within circuits
9. If the power supply is not on the circuit board, connect a 1-10 μF capacitor across the power leads where they arrive at the board.

INTERFACING TTL/LS
1. 1 TTL output will drive up to 10 TTL or 20 LS inputs.
2. 1 LS output will drive up to 5 TTL or 10 LS inputs.
3. TTL/LS LED DRIVERS:

```
Vcc
  +-------------------------------+
  |                               |
  |                               |
  |                               |
  |                               |
  +-------------------------------+
```

GLOWS WHEN L
GLOWS WHEN H

TTL/LS TROUBLESHOOTING
1. Do all inputs go somewhere?
2. Are all IC pins inserted into the board or socket?
3. Does the circuit obey all TTL/LS operating requirements?
4. Have you forgotten a connection?
5. Have you used enough decoupling capacitors? Are their leads short?
6. Is Vcc at each chip within range?
QUAD NAND GATE
7400/74LS00
THE BASIC BUILDING BLOCK CHIP
FOR THE ENTIRE TTL FAMILY. VERY
EASY TO USE. HUNDREDS OF APPLICATIONS.

CONTROL GATE
A
B (CONTROL)  

INVERTER

AND GATE

OR GATE

AND-OR GATE

NOR GATE

4-INPUT NAND GATE

EXCLUSIVE-OR GATE

EXCLUSIVE-NOR GATE

NOTE: PIN NUMBERS CAN BE
REARRANGED IF DESIRED.
QUAD NAND GATE (CONTINUED)
7400/74LS00

HALF ADDER

RS LATCH

D FLIP-FLOP

GATED RS LATCH

WHEN ENABLE (E) INPUT IS HIGH,
Q OUTPUT Follows D INPUT. NO
CHANGE WHEN E IS LOW.

FUNCTIONS AS RS LATCH
WHEN ENABLE (E) INPUT IS
HIGH. IGNORES RS INPUTS
WHEN E IS LOW.

LED DUAL FLASHER

SWITCH DEBOUNCER

FLASH RATE IS
2 Hz WHEN C1
AND C2 ARE 47uF.

PROVIDES NOISE FREE OUTPUT FROM
STANDARD SPDT TOGGLE SWITCH.
QUAD NAND GATE (CONTINUED)
7400/74LS00

8-INPUT NAND GATE

BCD DECODER

USE THIS METHOD TO DECODE ANY 4-BIT NIBBLE. JUST ADD OR REMOVE INPUT INVERTERS.

IC1, 2 = 7400/74LS00

UNANIMOUS VOTE DETECTOR

LED GLOWS WHEN ALL INPUT SWITCHES ARE CLOSED.

IC 1, 2 = 7404
IC 3, 4 = 7400/74LS00
QUAD AND GATE
7408/74LS08

One of the basic building block chips. Not as versatile, however, as the 7400/74LS00 Quad NAND gate.

AND GATE BUFFER

Use for interfacing without changing logic states.

NAND GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

NOR GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

4-INPUT NAND GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

4-INPUT AND GATE

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

DIGITAL TRANSMISSION GATE

E = ENABLE

AND-OR-INVERT GATE
QUAD OR GATE
74LS32

Four 2-input or gates. Not as versatile as 7402/74LS02 quad nor gate, but very useful in simple data selectors.

AND-OR CIRCUIT

NOR GATE

NAND GATE

Output goes high when both inputs of either or both and gates are high; otherwise the output is low. This basic circuit is used to make data selectors... as shown below.

2-INPUT DATA SELECTOR

Selects 1-of-2 inputs and transmits its logic state to the output.

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>DATA IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

Note: For 3-input data selector, use 74LS27 nor gate followed by inverter and preceded by 74LS10 3-input and gates.
QUAD NOR GATE
7402/74LS02

JUST AS VERSATILE AS THE
7400/74LS00 QUAD NAND GATE...

BUT NOT USED AS OFTEN.
ADD INVERTER (7404/74LS04)
TO BOTH INPUTS OF A NOR
GATE AND AN AND GATE IS
FORMED.

EXCLUSIVE-OR GATE

THIS CIRCUIT IS EQUIVALENT
TO A BINARY HALF-ADDER.

RS LATCH

4-INPUT NOR GATE

AND GATE

OR GATE
HEX INVERTER
7404/74LS04

VERY IMPORTANT IN ALMOST ALL LOGIC CIRCUITS. CHANGES AN INPUT TO ITS COMPLEMENT (i.e. H → L AND L → H).

BOUNCER FREE SWITCH

OUTPUT FOLLOWS SWITCH POSITION.

1, 2 = 1/2 7404/74LS04

UNIVERSAL EXPANDER

ALLOWS ONE SIGNAL TO OUT(=IN) CONTROL 2 OR MORE INPUTS.

1-OF-2 DEMULTIPLEXER

This circuit steers the input bit to the output selected by the address.

This technique can be used to make multiple output demultiplexers.

<table>
<thead>
<tr>
<th>DATA</th>
<th>ADDRESS</th>
<th>OUT A</th>
<th>OUT B</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

(A ADDRESS)
HEX 3-STATE BUS DRIVER
74LS367

Each gate functions as a non-inverting buffer when its enable input (G1 or G2) is low. Otherwise each gate's output enters the high impedance (Hi-Z) state.

Here's the truth table:

<table>
<thead>
<tr>
<th>G</th>
<th>IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>X</td>
<td>H-Z</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

1-OF-2 DATA SELECTOR

INPUT WORDS

SELECTS 1-OF-2 2-BIT WORDS.

OUTPUT WORD

ADDİNG 3-STATE OUTPUT TO TTL

BIDIRECTIONAL DATA BUS

TWO-WAY (BIDIRECTIONAL) DATA BUS
BCD-TO-7 SEGMENT DECODER/DRIVER

7447 / 74LS47

Converts BCD data into format suitable for producing decimal digits on common anode LED 7-segment display. When lamp test input is low, all outputs are low (on). When BI/RBO (blanking input) is low, all outputs are high (off). When DCBA input is LLLL (decimal 0) and RBI (ripple blanking input) is low, all outputs are high (off). This permits unwanted leading 0s in a row of digits to be blanked.

MANUALLY SWITCHED DISPLAY

0-9 SECOND /MINUTE TIMER

CLOSE SI TO START TIMING CYCLE. CALIBRATE 555 FOR 1 PULSE (COUNT) PER SECOND OR 1 COUNT PER MINUTE BY ADJUSTING RI.

DISPLAY FLASHER

THIS SIMPLE CIRCUIT WILL FLASH DISPLAY TWICE PER SECOND.

TO PIN 4, 7447/74LS47.

I = 3/7404 C1, C2 = 47 µF
BCD-TO-7-SEGMENT
DECODER/Driver
7448

Converts BCD data into format suitable for producing decimal digits on common cathode LED 7-segment display.

Display Dimmer

4.7k

4.7k

TO PIN 4 7448

0-99 Two Digit Counter

Lowest Order Display

Highest Order Display

R1 - R14: 330Ω

Common Cathode LED Display

7490 / 74LS90

7490 / 74LS90

*See 7447 for explanations.
3-LINE TO 8-LINE DECODER
74LS138

Each 3-bit address drives one output low. All others stay high. This chip has three enable inputs. When E2 is high, all outputs are high. When EI is low, all outputs are high. To enable chip, make EI high and E2 low. (Note: E2 = E2A + E2B.)

1-TO-8 DEMULTIPLEXER

Data Out

INPUT: DATA (H or L) IS PASSED TO SELECTED OUTPUT.

2-TO-8 STEP SEQUENCER

Outputs

TO DESIRED SEQUENCE (e.g. connect to output 4 and circuit will cycle from 0 TO 3).

Vcc

VEN

USE TO FLASH LEDs, CONTROL RELAYS, ETC.

RI CONTROLS CYCLE RATE.
4-LINE TO 16-LINE DECODER
74154

Each 4-bit address drives one output low. All others stay high. Enable inputs (E1 and E2) must be low if one or both are high, all outputs go low.

1-TO-16 DEMULTIPLEXER

Selected output is low when data in is low. If data in is high, selected output is high.

BACK AND FORTH FLASHER

Increase R1 to slow flash rate.
DUAL ONE-SHOT
74LS123

TWO FULLY INDEPENDENT MONOSTABLE MULTIVIBRATORS. BOTH ARE RETRIGGERABLE. PINS DESIGNATED R AND R/C ARE FOR EXTERNAL TIMING RESISTOR AND CAPACITOR. SEE RADIO SHACK DATA BOOK FOR INFORMATION ABOUT R AND C.

BASIC ONE-SHOT

TWO WAYS TO TRIGGER:
1. KEEP INPUTS A AND B LOW; THEN MAKE B HIGH.
2. KEEP INPUTS A AND B HIGH; THEN MAKE A LOW.

TO CLEAR:
MAKE PIN 3 LOW. THIS ALSO INHIBITS TRIGGERING.

MISSING PULSE DETECTOR

Q OUTPUT STAYS HIGH SO LONG AS INCOMING PULSES ARRIVE BEFORE ONE-SHOT TIMING PERIOD RUNS OUT.

ADJUST R AND C TO GIVE TIMING PERIOD ABOUT 1/3 LONGER THAN THE INTERVAL BETWEEN INCOMING PULSES.

OPERATION:

TONE STEPPER

THIS CIRCUIT STEPS ACROSS A RANGE OF TONES WHEN R1 AND/OR R3 ARE ADJUSTED. VERY UNUSUAL SOUND EFFECTS.

CHANGE C1 AND C2 FOR OTHER TONE RANGES. ALSO, TRY PHOTORESISTORS FOR R1 AND R3.
DUAL D FLIP-FLOP
7474/74LS74

Two D (DATA) flip-flops in a single package. Data at D input is stored and made available at Q output when clock pulse (φ) goes high. Here's the truth table:

<table>
<thead>
<tr>
<th>PRESET</th>
<th>CLEAR</th>
<th>CLOCK</th>
<th>D</th>
<th>Q</th>
<th>Q̅</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>↑</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>↑</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

2-BIT STORAGE REGISTER

D ← DATA IN → D CLR φ PRESET

PHASE DETECTOR

The LED glows when input frequencies f₁ and f₂ are unequal or out of phase. f₁ and f₂ should be square waves.

WAVE SHAPER

DIVIDE-BY-TWO COUNTER

D ← DATA IN → D CLR φ PRESET
DUAL J-K FLIP-FLOP
7473

Two JK flip-flops in a single package. Note the clear inputs. These flip-flops will toggle (switch output states) in response to incoming clock pulses when both J and K inputs are high. Here's the truth table:

<table>
<thead>
<tr>
<th>CLEAR</th>
<th>CLOCK</th>
<th>J</th>
<th>K</th>
<th>Q</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>TOGGLE</td>
<td></td>
</tr>
</tbody>
</table>

DIVIDE-BY-TWO

Vcc

DIVIDE-BY-THREE

Vcc

DIVIDE-BY-FOUR

Φ IS CLOCK INPUT.

BINARY COUNTERS

The three circuits on this page are binary counters that count up to the maximum count and automatically recycle. Connect a decoder to output of divide-by-three and divide-by-four counters to obtain one-of-three and one-of-four operation. This truth table summarizes operation of these counters:

<table>
<thead>
<tr>
<th>DIVIDE-BY:</th>
<th>TWO</th>
<th>THREE</th>
<th>FOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTPUTS</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

54
DUAL J-K FLIP-FLOP
7476

Two J-K flip-flops in a single package. Similar to 7473/74LS73 but has both preset and clear inputs. Flip-flops will toggle (switch output states) in response to incoming clock pulses when both J and K inputs are high. Here's the truth table:

<table>
<thead>
<tr>
<th>PRE</th>
<th>CLR</th>
<th>CLK</th>
<th>J</th>
<th>K</th>
<th>Q</th>
<th>Q̅</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>TOGGLE</td>
<td></td>
</tr>
</tbody>
</table>

PRE = PRESET
CLR = CLEAR
ϕ = CLOCK (or CLK)

TOGGLE = FLIP-FLOP SWITCHES OUTPUT STATES IN RESPONSE TO CLOCK PULSES.

4-BIT SERIAL SHIFT REGISTER

4-BIT BINARY UP COUNTER
**QUAD LATCH**

**7475/74LS75**

A 4-BIT BISTABLE LATCH. PRIMARILY USED TO STORE THE COUNT IN DECIMAL COUNTING UNITS. NOTE THAT BOTH Q AND Q OUTPUTS ARE PROVIDED. ALSO NOTE THE E (ENABLE) INPUTS. WHEN E IS HIGH, Q FOLLOWS D.

**4-BIT DATA LATCH**

DATA ON BUS APPEARS AT OUTPUTS WHEN LATCH INPUT IS HIGH. DATA ON BUS WHEN LATCH INPUT GOES LOW IS STORED UNTIL LATCH INPUT GOES HIGH. (LATCH INPUT CONTROLS BOTH ENABLE INPUTS.) TWO QUAD LATCHES CAN BE USED AS AN 8-BIT DATA LATCH.

**DECIMAL COUNTING UNIT**

EXPANDABLE DECADE COUNTER. FOR TWO DIGIT COUNT, CONNECT PIN 11 OF 7490/74LS90 OF FIRST UNIT TO INPUT OF SECOND UNIT. A LOW AT THE LATCH INPUT FREEZES THE DATA BEING DISPLAYED.
QUAD D FLIP-FLOP
74LS175

Handy package of four D-type flip-flops. Data at D-inputs is loaded when clock goes high, making clear input low makes all Q outputs low and $\bar{Q}$ outputs high.

4-BIT DATA REGISTER

Data on bus is loaded into 74LS175 when load input goes high. Data is then stored and made available at outputs until new load pulse arrives.

MODULO-8 COUNTER

SERIAL IN/OUT, PARALLEL OUT SHIFT REGISTER
BCD (DECADE) COUNTER
7490/74LS90

One of the most popular decade counters, easily used for divide-by-n counters. Less expensive than more sophisticated counters. RST indicates reset pins. This chip is usually used in decimal counting units, but circuits on this page show many other possibilities.

DIVIDE-BY-5 COUNTER

DIVIDE-BY-8 COUNTER

DIVIDE-BY-6 COUNTER

DIVIDE-BY-9 COUNTER

DIVIDE-BY-7 COUNTER

DIVIDE-BY-10 COUNTER
DIVIDE-BY-12 BINARY COUNTER
7492

Often used to divide conditioned 60 Hz pulses from AC power line into 10 Hz pulses. Other divider applications also. RST indicates reset pins.

DIVIDE-BY-7 COUNTER

DIVIDE-BY-9 COUNTER

DIVIDE-BY-12 COUNTER

10-HZ PULSE SOURCE

DIVIDE-BY-120 COUNTER

This method of cascading counters can be used to create any divide-by-N counter.
BCD UP-DOWN COUNTER
74192

FULLY PROGRAMMABLE BCD COUNTER. OPERATION IS IDENTICAL TO 74193/74LS193 EXCEPT COUNT IS 10-STEP BCD (LLLL-HLLH) INSTEAD OF 16-STEP BINARY. MANY APPLICATIONS FOR 74192/74LS192 AND 74193/74LS193 ARE INTERCHANGEABLE.

CASCADED COUNTERS

SINGLE UP-DOWN INPUT

PROGRAMMABLE COUNT DOWN TIMER

CALIBRATE R1 AND C1 TO PROVIDE DESIRED NUMBER OF CLOCK PULSES PER MINUTE. SET DESIRED N INTO S1-S4 (CLOSED SWITCH = LOW AND OPEN SWITCH = HIGH). PRESS S5 TO LOAD N AND START (OR RESET) COUNT. LED GLOWS AT HALT.

TO COMMON ANODE LED DISPLAY.
4-BIT UP COUNTER
74LS161

General purpose binary counter with programmable inputs. Counter accepts data at inputs when load input goes low. A low at the clear input resets the counter to 0000 upon the next clock pulse. P and T are count enable inputs. Both P and T must be high to count. These enable inputs are not available with the otherwise more advanced 74LS193.

8-BIT COUNTER

RAMP SYNTHESIZER

Output A is lowest order bit.

Remove C1 to obtain this staircase. Frequency of ramp and staircase is 1/16 clock frequency.
4-BIT UP-DOWN COUNTER
74193/74LS193

Very versatile 4-bit counter with up-down capability. Any 4-bit number at the DCBA inputs is loaded into the counter when the load input (pin 11) is made low. The counter is cleared to LLLL when the clear input (pin 14) is made high. The borrow and carry outputs indicate underflow or overflow by going low.

Count down from N and recycle

Set desired N into S1-S4 (closed switch = low and open switch = high). When count reaches LLLL and then underflows, the borrow pulse loads N and the count recycles.

Count up to N and halt

Press S1 (normally closed) to reset.
8-BIT SHIFT REGISTER
74LS164

Data at one of the two serial inputs is advanced one bit for each clock pulse. Data can be extracted from the 8 parallel outputs or in serial form at any single output. Enter data at either input. The unused input must be held high or clocking will be inhibited. Making pin 9 low clears the register to LLLL.

8-BIT SERIAL-TO-PARALLEL DATA CONVERTER

Use for receiving binary data sent over one channel.

Clock

The 7490 divides the clock pulses by 8 and loads data in 74LS164 into the 74LS374 at 8-bit intervals.

PSEUDO-RANDOM VOLTAGE GENERATOR

Output is pseudo-random stepped voltage. Change pattern by moving pin 2 of 7400 to pins 3, 4, 5, 6, 7, 8, 9, 10 or 11 of 74LS164.
OCTAL BUFFER
74LS240

IDEAL FOR INTERFACING EXTERNAL CIRCUITS TO HOME COMPUTERS. INVERTS DATA.

<table>
<thead>
<tr>
<th>CONTROL (E1, E2)</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>IN</td>
<td>HI-Z</td>
</tr>
</tbody>
</table>

4-BIT BUS TRANSFER

TO BUS

FROM BUS

WRITE *

READ *

* WHEN L

BUS

8-BIT BUS BUFFER

BUS B

ENABLE

L = \overline{A} \rightarrow B

H = ISOLATED

\overline{A} = INVERTED

BUS A
OCTAL BUFFER
74LS244

NON-INVERTING VERSION
OF 74LS240. IDEAL FOR
COMPUTER INTERFACING.

<table>
<thead>
<tr>
<th>CONTROL (E1, E2)</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>IN</td>
</tr>
<tr>
<td>H</td>
<td>HI-Z</td>
</tr>
</tbody>
</table>

4-BIT BUS TRANSFER

TO BUS

FROM BUS

WRITE *

READ *

* WHEN L BUS

8-BIT BUS BUFFER

BUS B

ENABLE

L = A → B
H = ISOLATED

BUS A
OCTAL D-TYPE LATCH
74LS373

Eight "transparent" D-type latches. Output follows input when enable is high. The data at the inputs is loaded when the enable input is low. This chip has 3-state outputs which are controlled by pin 1. See truth table below.

3-STATE REGISTER

This is a general purpose 8-bit storage register. Here's the truth table:

<table>
<thead>
<tr>
<th>D</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

DATA BUS REGISTERS

H: Places outputs in Hi-Z mode
L: Makes data available
H: Outputs follow data on bus
L: Load data from bus

At any instant only one 74LS373 can write data on the bus. Any number can read data from bus.
OCTAL D FLIP-FLOP
74LS374

Eight D-type edge triggered flip-flops. Unlike 74LS373, outputs do not follow inputs. Instead, a rising clock pulse at pin 11 loads data appearing at inputs. This chip has 3-state outputs which are controlled by pin 1.

CLOCKED
3-STATE REGISTER

General purpose clocked register. Here's the truth table:

<table>
<thead>
<tr>
<th>Control</th>
<th>Clock</th>
<th>D</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>Q</td>
<td>X</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>HI-Z</td>
<td>X</td>
</tr>
</tbody>
</table>

COMMON INPUT/OUTPUT BUS REGISTER

This circuit gives 74LS374 common input and output lines. When output control is high, data on bus is loaded into the 74LS374 on the rising edge (\(^{+}\)) of the clock pulse. When output control is low, data in the 74LS374 is written onto the bus.
OCTAL BUS TRANSCEIVER
74LS245

ALLows DATA TO BE TRANSFERRED IN EITHER DIRECTION BETWEEN TWO BUSES. INCLUDES HIGH IMPEDANCE (HI-Z) OUTPUTS.

BUS TRANSCEIVER

A → B WHEN H
B → A WHEN L

VCC (+5 V)

ENABLE WHEN L
HI-Z WHEN H

BUS A

BUS B
LINEAR INTEGRATED CIRCUITS

INTRODUCTION

The output of a linear IC is proportional to the signal at its input. The classic linear IC is the operational amplifier. This graph shows the linear input-output relationship of a typical OP-AMP circuit:

![Graph showing linear input-output relationship]

Many non-digital ICs—including OP-AMPS—can be used in both linear and non-linear modes. They are sometimes described as analog ICs.

Linear ICs generally require more external components than digital ICs. This increases their susceptibility to external noise and makes them a little trickier to use. On the other hand, some linear ICs can do essentially the same thing as a network of digital chips.

Here's a brief description of the linear chips in this section:

VOLTAGE REGULATORS

Provide a steady voltage, either fixed or adjustable, that is unaffected by changes in the supply voltage as long as the supply voltage is above the desired output voltage.

OPERATIONAL AMPLIFIERS

The ideal amplifier: almost perfect, high input impedance and gain, low output impedance. Gain is easily controlled with a single feedback resistor. FET input OP-AMPS (BIFFETS) have a very high frequency response. It's usually OK to substitute OP-AMPS if both are normally powered by a dual polarity supply (±12V for 741C, etc.)... but performance will improve or decrease according to the new OP-AMPS specifications.

COMPARATOR

Same as an OP-AMP, without a feedback resistor. Ultra-high gain gives a snap-like response to an input voltage at one input that exceeds a reference voltage at the second input.

TIMERS

Use alone or with other ICs for numerous timing and pulse generation applications.

LED CHIPS

Most important: a flasher chip, and a dot-bar graph analog-to-digital display. Very easy to use.

OSCILLATORS

A voltage controlled oscillator and a combined voltage-to-frequency and frequency-to-voltage converter. Also included is a tone decoder that can be set to indicate a specific frequency.

AUDIO AMPLIFIERS

This section includes several easy to use power amplifiers that are ideally for do-it-yourself stereo, public address systems, intercoms and other audio applications.
VOLTAGE REGULATORS
7805 (5-VOLTS)
7812 (12-VOLTS)
7815 (15-VOLTS)

ATTACH HEAT SINK IF REQUIRED.

1 - INPUT
2 - OUTPUT
3 - GROUND

FIXED VOLTAGE REGULATORS.
IDEAL FOR STAND-ALONE
POWER SUPPLIES, ON-CARD
REGULATORS, AUTOMOBILE
BATTERY POWERED PROJECTS,
Etc. UP TO 1.5 AMPERES
OUTPUT IF PROPERLY HEAT
SUNK AND SUFFICIENT INPUT
CURRENT AVAILABLE. THERMAL
SHUTDOWN CIRCUIT TURNS OFF
REGULATOR IF HEATSINK TOO SMALL.

5-VOLT LINE POWERED TTL/LS POWER SUPPLY

CAUTION: YOU MUST INSULATE THESE CONNECTIONS!

TI - 117-12.6 V, 1.2A OR 3A TRANSFORMER (273-1505 OR 273-1511).
B1 - 1A - 4A FULL WAVE BRIDGE RECTIFIER (276-1161, 276-1151 OR 276-1171).
(RADIO SHACK CATALOG NUMBERS IN PARENTHESES.)

VOLTAGE REGULATOR

CURRENT REGULATOR

CIN - OPTIONAL; USE 0.33μF OR SO IF
REGULATOR FAR FROM POWER SUPPLY.
COUT - OPTIONAL; USE 0.1μF OR MORE TO
TRAP SPIKES THAT BOTHER LOGIC ICs.

USES INCLUDE STABLE
BIASING FOR
LEDs, LAMPS,
Etc.

OUTPUT CURRENT = REGULATOR VOLTS

R1
-5 VOLT REGULATOR
7905

Fixed -5 volt regulator can be used to give adjustable voltage output up to 1.5 amperes output if properly heat sunk and sufficient input current available. Thermal shutdown circuit turns regulator off if heatsink too small.

**Fixed -5 Volt Regulator**

*Working voltage must exceed Vin.*

**Adjustable Negative Power Supply**

<table>
<thead>
<tr>
<th>R Adj</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>-5.74</td>
</tr>
<tr>
<td>100</td>
<td>-6.99</td>
</tr>
<tr>
<td>330</td>
<td>-11.03</td>
</tr>
<tr>
<td>480</td>
<td>-18.20</td>
</tr>
</tbody>
</table>

Example: In = -20V
1.2-37 VOLT REGULATOR
LM317

CAN SUPPLY UP TO 1.5 AMPERES OVER A 1.2-37 VOLT OUTPUT RANGE. NOTE MINIMUM NUMBER OF EXTERNAL COMPONENTS IN BASIC REGULATOR CIRCUIT BELOW. USE HEAT SINK FOR APPLICATIONS REQUIRING FULL POWER OUTPUT. SEE APPROPRIATE DATA BOOK FOR ADDITIONAL INFORMATION:

1.25-25 VOLT REGULATOR 6-VOLT NICAD CHARGER

Vin should be filtered. OK to omit C1 if Vin very close to LM317. R1 controls output voltage. *Add if output >25 V and C2 >25 µF.

Bi IS BATTERY OF 4 NICKEL CADMIUM STORAGE CELLS IN SERIES. THIS CIRCUIT CHARGES Bi AT A CURRENT OF 51.2 mA. INCREASE R1 TO REDUCE CURRENT. FOR EXAMPLE, CURRENT IS 43 mA WHEN R1 IS 24 OHMS.

PROGRAMMABLE POWER SUPPLY

LIMITS MAXIMUM Vout TO ~27 V WHEN INPUT IS 28 V.
-1.2 TO -37 VOLT REGULATOR
337T

CAN SUPPLY UP TO -1.5 AMPERES OVER A -1.2 TO -37 VOLT OUTPUT RANGE. FEW EXTERNAL COMPONENTS REQUIRED. COMPLEMENTS LM317 ADJUSTABLE POSITIVE REGULATOR.

ATTACH HEAT SINK IF REQUIRED

1 - ADJUST
2 - OUTPUT
3 - INPUT

ADJUSTABLE NEGATIVE REGULATOR

* WORKING VOLTAGE MUST EXCEED $V_{IN}$.

PRECISION LED REGULATOR

LED $I = 1.5V/R_1$.
$R_2$ GIVES ± 15% ADJUSTMENT.
LED $I = 15$ mA WHEN $R = 100 \Omega$. 

SUPPLIES CONSTANT CURRENT ($I$) TO LED.
2-37 VOLT REGULATOR

723

VERY VERSATILE SERIES REGULATOR. UP TO 40 VOLTS INPUT AND 2-37 VOLT OUTPUT. MAXIMUM OUTPUT CURRENT OF 150 mA CAN BE EXTENDED TO 10 A BY ADDING EXTERNAL POWER TRANSISTORS. SHOWN BELOW ARE TWO BASIC CIRCUITS. TRY THESE, THEN SEE APPROPRIATE DATA BOOK FOR ADDITIONAL CIRCUITS.

2-7 VOLT REGULATOR

7-37 VOLT REGULATOR

TYPICAL VALUES

<table>
<thead>
<tr>
<th>Vout</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>4.12 k</td>
<td>3.01 k</td>
<td>1.74 k</td>
</tr>
<tr>
<td>3.6</td>
<td>3.57 k</td>
<td>3.05 k</td>
<td>1.80 k</td>
</tr>
<tr>
<td>5.0</td>
<td>2.15 k</td>
<td>4.99 k</td>
<td>1.50 k</td>
</tr>
<tr>
<td>6.0</td>
<td>1.15 k</td>
<td>6.04 k</td>
<td>966</td>
</tr>
</tbody>
</table>

FOR ANY VOLTAGE BETWEEN 2-7 VOLTS:

\[ V_{out} = (V_{ref}^*) \times \left( \frac{R_2}{R + R_2} \right) \]

*\( V_{ref} = 6.8-7.5 \text{ V (MEASURE AT PIN G)} \)

\[ R_3 = \frac{R_1 \times R_2}{R_1 + R_2} \]

TYPICAL VALUES

<table>
<thead>
<tr>
<th>Vout</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1.87 k</td>
<td>7.15 k</td>
<td>.48k</td>
</tr>
<tr>
<td>12</td>
<td>4.87 k</td>
<td>7.15 k</td>
<td>2.90 k</td>
</tr>
<tr>
<td>15</td>
<td>7.87 k</td>
<td>7.15 k</td>
<td>3.75 k</td>
</tr>
<tr>
<td>28</td>
<td>21.0 k</td>
<td>7.15 k</td>
<td>5.33 k</td>
</tr>
</tbody>
</table>

FOR ANY VOLTAGE BETWEEN 7-37 VOLTS:

\[ V_{out} = (V_{ref}^*) \times \left( \frac{R_1 + R_2}{R_2} \right) \]

\( R_3 \) (R3, WHICH IS OPTIONAL, GIVES TEMPERATURE STABILITY)

74
ADJUSTABLE SHUNT (ZENER) REGULATOR
TL431

EASY TO USE THREE TERMINAL ADJUSTABLE PRECISION SHUNT REGULATOR. OUTPUT CAN BE SET TO FROM 2.5 TO 36 VOLTS.

ADJUSTABLE REGULATOR

VOLTAGE DETECTOR

\[ V_{\text{out}} = \left(1 + \frac{R_1}{R_2}\right) V_{\text{ref}} = 3 \pm 30 \text{V} \]

USE TO DETECT TTL LOGIC LEVELS.

SIMPLE TIMER

1.5 TO 5 V POWER SUPPLY

LED GLOWS AFTER DELAY PERIOD

TYPICAL VALUES:

\[ R_1 = 1 \text{ M} \Omega \]
\[ C_1 = 10 \mu \text{F} \]

Delay = \( R_1 C_1 \left(\ln \frac{q}{q - V_{\text{ref}}}\right) \)}
1.2 TO 33 VOLT REGULATOR

350T

Can supply up to 3 amperes over 1.2 to 33 volt output range. Few external components required. Heat sink required for full power output.

1 - Adjust
2 - Input
3 - Output

1.2 TO 20 VOLT REGULATOR

POWER PULSE GENERATOR

$V_{cc} = 5 \text{ TO } 15 \text{ VDC}$

RS sets amplitude. RI controls rate.

Use to flash in incandescent lamp, vary d.c. motor speed, etc.
OPERATIONAL AMPLIFIER

741C

THE MOST POPULAR OP-AMP. USE FOR ALL GENERAL PURPOSE APPLICATIONS. (FOR SINGLE SUPPLY OPERATION AND VERY HIGH INPUT IMPEDANCE, USE OTHER OP-AMPS IN THIS NOTEBOOK.)

INVERTING AMPLIFIER

\[ V = \pm 5-18V \]

\[ V_{out} = -V_{in} \left( \frac{R_2}{R_1} \right) \]

NON-INVERTING AMPLIFIER

\[ V = \pm 5-18V \]

\[ V_{out} = V_{in} \left( 1 + \frac{R_2}{R_1} \right) \]

UNITY GAIN FOLLOWER

USE TO COUPLE HIGH IMPEDANCE TO LOW IMPEDANCE.

\[ V = \pm 5-18V \]

\[ V_{out} = V_{in} \]

COMPARATOR

\[ V = \pm 5-18V \]

TYPICAL APPLICATION SHOWN BELOW

LEVEL DETECTOR

\[ V_{in} \] MUST BE NEGATIVE.

\[ V_{in} \] MUST BE NEGATIVE.

TYPICAL USES: AMPLIFICATION OF DC VOLTAGE AND PULSES.

RI SETS THE VOLTAGE DETECTION THRESHOLD (UP TO +9). WHEN VIN EXCEEDS THE THRESHOLD (ALSO CALLED THE REFERENCE), THE LED GLOWS.
OPERATIONAL AMPLIFIER (CONTINUED)

741C

BASIC INTEGRATOR

\[ V = \pm 5-18V \]

IN

\[ \text{Cl} \]

\[ \text{R2} \]

\[ +V \]

\[ \text{741} \]

\[ 2 \rightarrow 7 \]

\[ \text{OUT} \]

\[ \text{R} \]

\[ \text{R} \]

\[ \text{IN} \]

\[ \text{R3} \]

\[ \text{OUT} \]

\[ 10 \text{ KHz IN:} \]

\[ \text{Cl} = 0.001 \]

\[ \text{R1} = 10k \]

\[ \text{R2} = 100k \]

\[ \text{R3} = 10k \]

\[ \text{WHEN } V = \pm 9V \]

\[ \text{AND } IN = \pm 2.5V, \]

\[ \text{OUT} = \pm 1V. \]

BASIC DIFFERENTIATOR

\[ V = \pm 5-18V \]

\[ \text{IN} \]

\[ \text{R2} \]

\[ +V \]

\[ \text{741} \]

\[ 2 \rightarrow 7 \]

\[ \text{OUT} \]

\[ \text{R1} \]

\[ \text{C1} = 0.00022 \mu F \]

\[ \text{R2, R3} = 10k \]

\[ \text{WHEN } V = \pm 9V \]

\[ \text{AND } IN = \pm 2.25V, \]

\[ \text{OUT} = \pm 0.25V. \]

CLIPPING AMPLIFIER

\[ V = \pm 5-18V \]

\[ \text{IN} \]

\[ \text{D1, D2} \]

\[ \text{ZENER DIODES.} \]

\[ \text{IF } V_2 = 6V, \]

\[ \text{THEN OUTPUT} \]

\[ \text{CANNOT EXCEED} \]

\[ \pm 6.7V. \]

\[ V_{\text{OUT}} = -V_{\text{IN}} \left( \frac{R_2}{R_1} \right) \ldots \]

\[ \text{UP TO } V_2 + 0.7V. \]

*RI IS UNKNOWN RESISTOR. USE CdS CELL FOR R1 TO MAKE A VERY SENSITIVE LIGHT METER. *

SUMMING AMPLIFIER

\[ V = \pm 5-18V \]

\[ \text{IN} \]

\[ \text{R1} = 100k \]

\[ \text{R2} = 100k \]

\[ \text{R3} = 33k \]

\[ \text{OUT} \]

\[ \text{Vout} = -(V_{\text{IN1}} + V_{\text{IN2}}) \]

NOTE: Vout CANNOT EXCEED ±V.

DIFFERENCE AMPLIFIER

\[ V = \pm 5-18V \]

\[ \text{IN} \]

\[ \text{R1} = 100k \]

\[ \text{R2} = 100k \]

\[ \text{R3} = 100k \]

\[ \text{OUT} \]

\[ \text{Vout} = V_{\text{IN2}} - V_{\text{IN1}} \]
OPERATIONAL AMPLIFIER (CONTINUED)

741C

LIGHT WAVE RECEIVER

60-Hz NOTCH FILTER

USE TO RECEIVE VOICE MODULATED LIGHT WAVES. OK TO USE SINGLE POLARITY POWER SUPPLY FOR NON-VOICE RECEPTION.

HIGH PASS ACTIVE FILTER

LOW PASS ACTIVE FILTER

4-BIT D/A CONVERTER

VALUES SHOWN:

CUTOFF ≈ \frac{1}{2\pi RC}

VALUES SHOWN:

CUTOFF ≈ \frac{1}{2\pi RC}
OPERATIONAL AMPLIFIER
741C

OPTICAL POWER METER

BARGRAPH LIGHT METER

SI

1: 0 - 10.0 mA
2: 0 - 1.0 mA
3: 0 - 0.1 mA

FULL SCALE METER READINGS

CAUTION: THIS IS A VERY SENSITIVE CIRCUIT! TOO MUCH LIGHT WILL SLAM THE METER NEEDLE.

Q1 IS A PHOTOTRANSISTOR (RADIO SHACK 276-130) CONNECTED AS A PHOTODIODE. A SILICON SOLAR CELL CAN ALSO BE USED. USE GREEN LEDs FOR READOUT.

ELECTRONIC BELL

AUDIBLE LIGHT SENSOR

ADJUST R3 TO JUST BELOW OSCILLATION POINT. ADJUST R2 AND R3 FOR SOUNDS SUCH AS BELL, DRUM, TINKLING, ETC.

LIGHT ON PCI DECREASES TONE FREQUENCY. LIGHT ON PC2 INCREASES TONE FREQUENCY.
DUAL OPERATIONAL AMPLIFIER
1458

Two 741C op-amps in a single 8-pin mini-dip. Try to use this chip for circuits that require two or more 741's. You'll save time, space and money.

PEAK DETECTOR

R2
10k

\[ +5 \text{V} \]

R4
10k

\[ \frac{1}{2} \text{R3} \]

\[ 1458 \]

\[ \text{Vin} \]

\[ \text{IN914} \]

\[ R1 \]

10k

C1
100\mu F

R3
10k

\[ \text{Vout} \]

Applications include use as analog "memory" that stores peak amplitude of a fluctuating voltage.

PULSE GENERATOR

C1

\[ \text{Vin} \]

\[ \text{R2} \]

10k

C1

\[ .001 \mu F \]

.01 \mu F

10 \mu F

1.00 \mu F

\[ .01 \mu F \]

\[ 5872 \text{Hz} \]

4.60 \text{Hz}

5.1 \text{Hz}

8 \text{Hz}

\[ \text{FREQUENCY} \]

R3
10k

\[ \frac{1}{2} \text{R4} \]

\[ 1458 \]

\[ \text{R5} \]

1k

\[ \text{R6} \]

10k

\[ \text{R7} \]

10k

\[ \frac{1}{2} \text{R8} \]

\[ 1458 \]

\[ \text{C3} \]

.0022

\[ \text{R9} \]

9

\[ \text{10K} \]

\[ \text{R10} \]

27k

\[ \text{R1} \]

10k

\[ \text{R5} \]

100k

\[ \text{C2} \]

.1 \mu F

\[ \text{Square: } \pm 7.5 \text{V} \]

\[ \text{Triangle: } \pm 2 \text{V} \]

\[ \text{FREQUENCY = 1 kHz} \]

\[ \text{SINE: } \pm 2 \text{V} \]

Pulses are DC. amplitude when C1 = 0.1 \mu F is 5 volts.
DUAL OPERATIONAL AMPLIFIER
LF353N (JFET INPUT)

HIGH IMPEDANCE (10^12 OHM) JUNCTION FET INPUTS. OUTPUT SHORT CIRCUIT PROTECTION. HIGH SLEW RATE (13V/μSEC), LOW NOISE OPERATION. AMPLIFIERS ARE SIMILAR TO THOSE IN THE TL084C. NOTE THAT PIN CONNECTIONS ARE THE SAME AS 1458B. THIS OP-AMP, HOWEVER, OFFERS MUCH BETTER PERFORMANCE.

SAMPLE AND HOLD

PEAK DETECTOR

TRACKS \( V_{IN} \) AND STORES PEAK \( V_{IN} \) IN \( C_1 \).

REDUCE \( C_1 \) FOR FASTER RESPONSE TO CHANGING \( V_{IN} \)

PROGRAMMABLE GAIN OP-AMP

CONNECT OUTPUTS OF PREAMPLIFIERS TO INPUTS 1-3. OK TO ADD MORE CHANNELS. WORKS WELL WITH TL084 MICROPHONE PREAMPLIFIERS.
QUAD OPERATIONAL AMPLIFIER
TL084C (JFET INPUT)

HIGH IMPEDANCE (10^12 OHMS) JUNCTION FET INPUTS. OUTPUT SHORT CIRCUIT PROTECTION. HIGH SLEW RATE (12 V/μSEC) PLUS LOW NOISE OPERATION. PERFORMANCE SIMILAR TO LF353N.
NOTE THAT PIN CONNECTIONS ARE SAME AS LM324.

MICROPHONE PREAMPLIFIER

USE LOW TO MEDIUM IMPEDANCE DYNAMIC MICROPHONE.

GAIN = \( \frac{R_2}{R_1} \)

NOTE SINGLE POLARITY POWER SUPPLY (THANKS TO R3 AND R4) AND AC COUPLING.

LOW-Z PREAMPLIFIER

USE LOW IMPEDANCE (LOW-Z) MICROPHONE.
OK TO USE 8Ω SPKR AS MICROPHONE. CONNECT DIRECTLY TO INPUTS (POOR TO FAIR) OR USE TRANSFORMER (GOOD):

INFRARED VOICE Communicator

POINT THE LED AT Q1 AND ADJUST R4 UNTIL BEST VOICE QUALITY IS OBTAINED. (R4 APPLIES PEEBIAS TO LED.) R6 LIMITS MAXIMUM LED CURRENT TO A SAFE 40 mA.
QUAD OPERATIONAL AMPLIFIER
LM324N

OPERATES FROM SINGLE POLARITY POWER SUPPLY. MORE GAIN (100 dB) BUT LESS BANDWIDTH (1 MHz WHEN GAIN IS 1) THAN THE LM3900 QUAD OP-AMP. NOTE UNUSUAL LOCATION OF POWER SUPPLY PINS. CAUTION: SHORING THE OUTPUTS DIRECTLY TO V+ OR GND OR REVERSING THE POWER SUPPLY MAY DAMAGE THIS CHIP.

BANDPASS FILTER

INFRARED TRANSMITTER

PULSE GENERATOR

CAREFULLY ADJUST R3 FOR BEST VOICE QUALITY. FOR MORE POWER REDUCE R5 TO 50 Ω... BUT DO NOT ALLOW MORE THAN PLUS OP-AMP. 30 mA THROUGH LED!

INTERFACE CIRCUITS

OBSERVE Q1'S POWER RATING!

TTL DRIVER

ALL 1/4 LM324N

LAMP DRIVER

BUFFER (OUT = IN)

LED DRIVER
QUAD OPERATIONAL AMPLIFIER
LM3900N

OPERATES FROM SINGLE POLARITY POWER SUPPLY. LESS GAIN (70 dB) BUT WIDER BANDWIDTH (25 MHz AT GAIN OF 1) THAN THE LM324 QUAD OP-AMP. NOTE STANDARD POWER SUPPLY PIN LOCATIONS. CAUTION: SHORTING THE OUTPUTS DIRECTLY TO V+ OR GROUND OR REVERSED POWER CONNECTIONS MAY DAMAGE THIS CHIP.

ASTABLE MULTIVIBRATOR

TOGGLE FLIP-FLOP

USE AS CLOCK, PULSE GENERATOR OR DUAL FLASHER (SHOWN).

FUNCTION GENERATOR

X10 AMPLIFIER

FREQUENCY = 1.2 KHz

Vout = Vin \left( \frac{R_2}{R_1} \right)
QUAD COMPARATOR
LM339 (276-1712)

Four independent voltage comparators in a single package. Note that a single polarity power supply is required. (Most comparators are designed primarily for dual supply operation.) Note unusual location of the supply pins. Comparators may oscillate if output lead is too close to input leads. Ground all pins of unused comparators.

NON-INVERTING COMPARATOR INVERTING COMPARATOR

OPTIONAL INPUT VOLTAGE
+9
R1 5K
R2 5K
R3 4.7K
R4 100K

RI-R2 DETERMINE REFERENCE VOLTAGE (+4.5 V as shown).

+ INPUT VOLTAGE
+2-32

OUT

INVERTING COMPARATOR WITH HYSTERESIS

LED GLOWS WHEN INPUT VOLTAGE (PIN 5) FALLS BELOW REFERENCE VOLTAGE (PIN 4).

NON-INVERTING COMPARATOR WITH HYSTERESIS

+ REFERENCE VOLTAGE

+ INPUT VOLTAGE
+2-32

OUT

3.3K
1M
1M

NOTE: HYSTERESIS PROVIDED BY FEEDBACK RESISTOR STOPS OSCILLATION.

TTL DRIVER CMOS DRIVER 3-STATE OUTPUT

+5
+3-15
10K
100K

CONTROL
L = ENABLE
H = HI = I2

OUT

1/6 74LS367
QUAD COMPARATOR (CONTINUED)

LM339

LED BARGRAPH READOUT

Window Comparator

The LED glows when the input voltage is within the window determined by R1-R3. The window is 4-8 millivolts wide when R1 = 500Ω, R2 = 1200Ω, and R3 = 1M. It extends from 1.5-4.2 volts when R1 and R3 = 15,000Ω and R2 = 25,000Ω. Use pots for R1-R3 for a fully adjustable window.

Programmable Light Meter

Adjust R1 and R3 so LED glows when light at PCI is above or below any desired level.
LED FLASHER / OSCILLATOR 3909

EASIEST TO USE IC IN THIS NOTEBOOK. FLASHES LEDs OR CAN BE USED AS TONE SOURCE. WILL DRIVE SPEAKER DIRECTLY. WILL FLASH A RED LED WHEN V+ IS ONLY 1.3 VOLTS.

LED FLASHER

![Diagram of LED Flasher]

POWER FLASHER

![Diagram of Power Flasher]

INFRARED TRANSMITTERS

TRANSMITS STEADY 1 KHZ TONE.
IR LED (276-142) IN914 +1.5V

![Diagram of Infrared Transmitter 1]

TRANSMITS DISTINCTIVE WARPED TONE
IR LED (276-142) IN914 +1.5V

![Diagram of Infrared Transmitter 2]

LIGHT CONTROLLED TONE

TONE FREQUENCY INCREASES WITH LIGHT.

![Diagram of Light Controlled Tone]

LAMP FLASHER

# 112 OR OTHER 1.5-3 V BULB.

![Diagram of Lamp Flasher]
LED FLASHER/OSCILLATOR (CONTINUED)

3909

WHOOPER

CHIRPER

SUN POWERED OSCILLATOR

TOY ORGAN

TTL CONTROLLED 3909
DOT/BAR DISPLAY DRIVER
LM3914N

One of the most important chips in this notebook. Lights up to 10 LEDs (Bar mode) or 1-OF-10 LEDs (Dot mode) in response to an input voltage. Chip contains a voltage divider and 10 comparators that turn on in sequence as the input voltage rises. Here's a simplified version of the circuit:

\[ \text{LED} + V \]

\[ R_{Hi} \]

\[ \text{IK} \]

\[ \text{IK} \]

\[ +3-18 \]

\[ \text{BUFFER} \]

\[ \text{REFERENCE VOLTAGE SOURCE (1.2V)} \]

\[ \text{IN} \]

\[ \text{REF OUT} \]

\[ \text{REF ADJUST} \]

\[ R_{Lo} \]

\[ 20K \]

\[ 3 \]

\[ \text{GND} \]

\[ \text{MODE} \]

\[ S1 \]

\[ \text{LM3914} \]

\[ \text{LEDS} \]

\[ 10 \]

\[ 9 \]

\[ 8 \]

\[ 7 \]

\[ 6 \]

\[ 5 \]

\[ 4 \]

\[ 3 \]

\[ 2 \]

\[ 1 \]

\[ \text{TO OUTPUT LEDs} \]

\[ \text{IF THE LEDS FICKER, CONNECT A CAPACITOR (0.05 \mu F TO 2.2 \mu F) FROM LED ANODE LINE TO PIN 2.} \]

\[ \text{R2 100K} \]

\[ +3-18 \]

\[ \text{R1 1K} \]

\[ \text{R Lo IN R Hi REF REF MODE OUT ADJ} \]

\[ \text{DOT/BAR DISPLAY} \]

When \( +V = +3-18\) volts, the readout range is 0.13 - 1.30 volts. To change range to 0.1 - 1.0 volt (0.1 volt per LED), insert a 5K potentiometer between pins 6 and 7. Connect voltmeter across pins 5 and 8 and adjust R2 for 1 volt at pin 5. Then adjust 1K pot until LED 10 glows. Repeat this procedure for 0.1 volt at pin 5 and led 1. OK to replace the 1K pot with a fixed resistor of the proper value.

R_{Hi} and R_{Lo} are the ends of the divider chain. The reference voltage output (Ref out) is 1.2-1.3 volts. Connect pin 9 to pin 11 for Dot mode or +V for Bar mode.
20-ELEMENT READOUT

This circuit shows how to cascade 2 or more LM3914's. When +V = 5 Volts, the readout range is 0.14 V to 2.7 V. Highest order LED stays on during overrange. Avoid substitutions for R1, R2 and R3.

SI is the mode switch. Use a DPDT toggle. Position 1 selects bar and position 2 selects dot. Omit SI if only one mode is required. Simply wire in the correct connections.

FLASHING BAR READOUT

The circuits on this page are adapted from National Semiconductor's LM3914 literature. Both work well.

When all 10 LEDs are on, the display flashes. Otherwise, the LEDs do not flash. Increase C1 to slow flash rate.
DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

SOLID-STATE OSCILLOSCOPE

SCREEN:
100 RED LEDS CONNECTED TO INTERSECTING LINES LIKE THIS

R1: VERTICAL GAIN
R3: HORIZONTAL SWEEP (TIMEBASE)

USE R3 TO SYNCHRONIZE SCOPE WITH INCOMING WAVE.

ADD OP-AMP TO INPUT FOR MORE SENSITIVITY. USE R1 TO CALIBRATE.

THIS IS AN EXPERIMENTAL SOLID-STATE SCOPE THAT WILL FIT IN A POCKET SIZE HOUSING.

THE RESOLUTION IS POOR, BUT VARIOUS WAVEFORMS CAN BE VISUALIZED.

EXPAND BOTH THE VERTICAL AND HORIZONTAL CIRCUITS FOR MORE RESOLUTION.

FOR MORE INFORMATION SEE POPULAR ELECTRONICS, AUGUST 1979 (PP.78-79).

USING THE LM3914 AS A CONTROLLER:

RELAY

OPTICAL COUPLING

C1 - 47 µF (PREVENTS CHATTER)
D1 - 1N914
RY1 - RADIO SHACK 275-004
DOT/BAR DISPLAY DRIVER
LM3915N

LOGARITHMIC VERSION OF THE LM3914 N. THE LM3914 N USES A STRING OF 1K RESISTORS AS A VOLTAGE DIVIDER WITH LINEARLY SCALED DIVISIONS. THE VOLTAGE DIVIDER RESISTORS OF THE LM3915 N AREcaled TO GIVE A -3dB INTERVAL FOR EACH OUTPUT. THIS CHIIP IS IDEAL FOR VISUALLY MONITORING THE AMPLITUDE OF AUDIO SIGNALS.

0 TO -27 dB DOT/BAR DISPLAY

LED DISPLAY

<table>
<thead>
<tr>
<th>dB</th>
<th>(FULLSCALE OR FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>●●●●●●●●●●●</td>
</tr>
<tr>
<td>-3</td>
<td>(.707 FS)</td>
</tr>
<tr>
<td>-6</td>
<td>(.500 FS)</td>
</tr>
<tr>
<td>-9</td>
<td>(.354 FS)</td>
</tr>
<tr>
<td>-12</td>
<td>(.250 FS)</td>
</tr>
<tr>
<td>-15</td>
<td>(.177 FS)</td>
</tr>
<tr>
<td>-18</td>
<td>(.125 FS)</td>
</tr>
<tr>
<td>-21</td>
<td>(.088 FS)</td>
</tr>
<tr>
<td>-24</td>
<td>(.062 FS)</td>
</tr>
<tr>
<td>-27</td>
<td>(.044 FS)</td>
</tr>
</tbody>
</table>

BAR MODE*

- OK TO USE DOT MODE.

THE INPUT SIGNAL CAN BE CONNECTED DIRECTLY TO PIN 5 WITHOUT RECTIFICATION, LIMITING OR AC COUPLING. SEE THE LM3914 N FOR MORE IDEAS AND TIPS.
LED VU METER MODULE
NSM3916

Includes LED bargraph driver and LEDs on same substrate.
Make mode pin high for bargraph mode. Leave open for dot mode. See data supplied with module for more information. Also, see LM3914 and LM3915.

VU BAR GRAPH DISPLAY

BACK AND FORTH FLASHER

R1 controls cycle rate. R4 controls range.

1 = 1/3 4049 (ground unused inputs - pins 7, 9, 11, 14)
**LCD CLOCK MODULE**  
**PCIM-161**

**Complete Clock Module.** Requires only 1.5 Volt cell and switches. For complete information see data supplied with module. V<sub>dd</sub> must not exceed 1.6 volts!

**Alarm Clock**

To set alarm:
1. Press AL2 twice; press set until hour appears.
2. Press AL1; press set until minutes appear.

**Alarm Clock Radio**

Keep radio switch on.

**Clock Controlled Relay**

*Caution: Use care when switching line voltage!*

Current drain:
- Relay on = 14.8 mA
- Relay off = 1.8 mA

**Timer 555**

The first and still the most popular IC timer chip operates as a one-shot timer or an astable multivibrator. The 555 is two 555 circuits on one chip.

**555 Equivalent Circuit**

![555 Equivalent Circuit Diagram]

1 and 2 are comparators. Circuit can be made from individual parts as shown... but 555 is much simpler.

**One-Shot Timer**

![One-Shot Timer Diagram]

Values of R1 and C1 shown will pull relay in for up to about 11 seconds. Use pointer knob and paper scale to help calibrate circuit. Uses include darkroom timing. Circuit can be triggered by a negative pulse or with a pushbutton switch across pins 1 and 2.

**Bounceless Switch**

Pressing SI gives clean 0.1 second output pulse.

**Timer Plus Relay**

Relay: 6V, 500Ω 12 mA

Values shown give 1 second output pulse.
LED TRANSMITTER
Circuit pulses LED with 45 μsec long, 120 mA pulses at a rate of 4.8 kHz.

PULSE GENERATOR
Use to supply clock pulses to TTL and LS logic circuits. R1 controls pulse repetition rate.

MISSING PULSE DETECTOR
This circuit is a one-shot that is continually retriggered by incoming pulses. A missing or delayed pulse prevents retriggering before a timing cycle is complete. Causes pin 3 to go low until a new input pulse arrives. R1 and C1 control response time. Use in security alarms, continuity testers, etc.

TOY ORGAN
Typical Values:
- C1 = 0.10 μF
- C2 = 0.05 μF
- C3 = 0.01 μF
- C4 = 0.005 μF
- C5 = 0.001 μF

Use any available values if these are not available.

Add additional stages if desired. Switches are normally open pushbuttons.

Radio Shack 276-2023
TIMER (CONTINUED)

555

ULTRA-LONG TIME DELAY TOUCH SWITCH

RI CONTROLS PULSE RATE FROM 555. THIS RATE IS DIVIDED BY THE 4017's TO GIVE X10, X100 AND X1000 DELAYS.

RI = 10K
RI = 1K
C1 = 10µF

R1 = 100K
C2 = 1µF
C3 = 5.05µF
C1 = 4.7µF

TOUCH WIRE (TOUCH AND LED WILL GLOW 1 SECOND)

WORKS BEST INDOORS DUE TO STRAY AC FIELD. ELSEWHERE TRY TOUCHING PINS 1 AND 2.

TOUCH SWITCH

ADDITIONAL STAGES

1 = RESET TYPICAL OUTPUT: 555 (PIN 3) 4017 (X10 OUTPUT)
2 = RUN

LIGHT DETECTOR

DARK DETECTOR

PRODUCES WARNING TONE WHEN LIGHT STRIKES PHOTOCELL. MAKES A GOOD OPEN DOOR ALARM FOR REFRIGERATOR OR FREEZER.

SILENT WHEN LIGHT STRIKES PHOTOCELL. REMOVE LIGHT AND TONE SOUNDS. FASTER RESPONSE THAN ADJACENT CIRCUIT.

CdS PHOTOCELL (RADIO SHACK 276-11G)

8Ω SPKR

8Ω SPKR

555

555

R1 = 47K
R2 = 1K
C1 = 0.05µF

R1 = 47K
R2 = 1K
C1 = 0.05µF

C2 = 4.7µF

C2 = 4.7µF
TIMER (CONTINUED)

555

NEON LAMP POWER SOURCE

**NEON LAMP POWER SOURCE**

- **R1**: 8.2 - 1K
- **R2**: 1K
- **C1**: 0.1 µF, 250V
- **L1**: NEON LAMP

Works best with better quality neon lamps. Reduce R1 slightly for more output voltage.

FREQUENCY DIVIDER

- **R1**: 100K
- **R2**: 1K
- **C1**: 10 µF
- **R3**: 10K

The 555 functions as a one-shot that is retrigged by the input wave. Waves arriving during the timing cycle are ignored.

TRIANGLE WAVE GENERATOR

- **R1**: 100K
- **R2**: 1K
- **C1**: 0.1 µF

Adjust R1 to provide up to 10 kHz. Output frequency increases as this high produces closely spaced triangle waves. The waves are separated at slower frequencies (\( V \rightarrow V \rightarrow V \)).

ONE-SHOT TONE BURST

- **R1**: 100K
- **R2**: 24K
- **C1**: 0.1 µF
- **R3**: 10K

Press S1 and steady output frequency appears at pin 3. Release S1 and output frequency continues until C2 is discharged by R4. Increase C2 (or R4) to increase length of the burst. Change frequency of tone burst via R2 or C1.
DUAL TIMER

556

Contains two independent timers on a single chip. Both timers are identical to the 555. All the application circuits can also be built with two 555's. This pin cross reference will simplify substituting two 555's for a 556 or half a 556 for a 555:

<table>
<thead>
<tr>
<th>Function</th>
<th>555</th>
<th>556(1)</th>
<th>556(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>1</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Trigger</td>
<td>2</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Output</td>
<td>3</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Reset</td>
<td>4</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Control V</td>
<td>5</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Threshold</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Discharge</td>
<td>7</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Vcc</td>
<td>8</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

3-STATE TONE SOURCE

555/556 SCR OUTPUT

Timer 1 is connected as astable oscillator. Timer 2 is a one-shot relay driver. 1 fires 2 once each cycle. 2 pulls relay in for 3.5 seconds.
DUAL TIMER (CONTINUED)

556

SOUND SYNTHESIZER

This circuit is an oscillator followed by a frequency divider. Adjust R1 and R4 for very unusual sound effects.

PROBLEMABLE 4-STATE TONE GENERATOR

Both timers are in one-shot mode. Grounding the trigger input initiates the first timer's cycle time. The second timer's cycle begins after the first is complete.

MODE SELECT

<table>
<thead>
<tr>
<th>B</th>
<th>A</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>TWO-TONE</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>STEADY</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>BURST</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>METRONOME</td>
</tr>
</tbody>
</table>

L = GND
H = +5-15 (Vdd)

Change C1 and C4 to alter the output tones.
QUAD TIMER
558

Contains four independent monostable timers. Each timer is similar to part of a 555 timer. Astable operation possible with one timer. Vcc = +4.5 to 18 volts. Control and reset pins are common.

BASIC TIMER

ONE-SHOT

PROGRAMMABLE SEQUENCER

Outputs A, B, C, D go high, then low, sequentially. R1-R4 and C1-C4 control delay per step. RS controls rate.
QUAD TIMER (CONTINUED)

558

FULLY ADJUSTABLE PULSE GENERATOR

R1 controls pulse rate,
R2 controls pulse width.
R3 = R4 = 1.5 to 4.7K.

VERY USEFUL CIRCUIT! PULSE
RATE AND WIDTH TOTALLY
INDEPENDENT. SEE BELOW FOR
MORE INFORMATION.

SIMPLE OSCILLATOR

FIXED DUTY CYCLE PULSER

SEE ABOVE CIRCUIT. ADD THIS
VOLTAGE DIVIDER TO KEEP DUTY
CYCLE CONSTANT WHEN RATE IS
CHANGED.

LONG DURATION TIMER

RS = R6 = R7 = 4.7K

SELECT R1C1, R2C2, R3C3 AND R4C4 TO GIVE DESIRED DELAY PER
STAGE. DELAY = R x C. TOTAL DELAY = SUM OF ALL STAGES. LED TURNS
OFF AFTER TIME DELAY AND TURNS ON AGAIN.

103
**TIMER 7555**

CMOS VERSION OF THE 555. VERY LOW POWER CONSUMPTION. WIDER SUPPLY VOLTAGE RANGE. LONGER TIMING CYCLES. CAUTION: APPLY POWER TO 7555 BEFORE CONNECTING EXTERNAL CIRCUIT.

**FREQUENCY METER**  
**LIGHT PROBE FOR BLIND**

**EVENT FAILURE ALARM**

ALARM TONE SOUNDS IF SI IS NOT CLOSED WITHIN 5-30 SECONDS.
PHASE-LOCKED LOOP
565

Sophisticated analog system that automatically tracks a fluctuating input signal. Voltage-controlled oscillator (VCO) frequency is controlled by output voltage from phase comparator. This causes VCO frequency to move toward input signal. The comparator voltage output is amplified and available for communications applications... as shown below. See Radio Shack data book for more information.

PULSE-FREQUENCY-MODULATED INFRARED COMMUNICATOR

TRANSMITTER

OPERATION: Point LED at * ELECTRET (270-092) BEST. R3: Try IM for more gain.

RECEIVER

KEEP PWR LEADS ON BOTH UNITS SHORT. USE 0.1uF ACROSS PWR CONNECTIONS (AT CHIPS) IF OSCILLATION OCCURS. HAVE FUN.

TRANSMITTER: R3 CONTROLS GAIN. R4 CONTROLS CARRIER FREQUENCY. FOR INITIAL TESTS, REMOVE MIC AND CONNECT TRANSISTOR RADIO PHONE OUTPUT TO R3 VIA 4.7uF AND GND. USE LOW VOLUME SETTING. R3 MUST BE 100K.

RECEIVER: R5 CONTROLS GAIN. C2 AND C3 GIVE VCO CENTER FREQUENCY OF ~40.4 KHz. SHIELD Q1 WITH TUBE TO BLOCK EXTERNAL LIGHT. USE LOW GAIN (R5) WHEN ADJUSTING TRANSMITTER!
TONE DECODER

567

CONTAINS A PHASE-LOCKED LOOP.
PIN B GOES LOW WHEN THE INPUT
FREQUENCY MATCHES THE CHIP'S
CENTER FREQUENCY (f0). THE LATTER
FREQUENCY IS SET BY THE TIMING
RESISTOR AND CAPACITOR (R AND C)
AND IS (1.1) / (RC). R SHOULD BE
BETWEEN 2K-20K. THE 567 CAN
BE ADJUSTED TO DETECT ANY INPUT
BETWEEN 0.01 HZ TO 500KHZ. NOTE:
1 SECOND OR MORE MAY BE REQUIRED
FOR THE 567 TO LOCK ON TO LOW
FREQUENCY INPUTS! SEE THIS CHIP'S
SPECIFICATIONS FOR MORE INFORMATION. THE LOW PASS FILTER CAPACITOR.

BASIC TONE DETECTOR CIRCUIT

INFRARED REMOTE CONTROL SYSTEM

TRANSMITTER

RECEIVER

ADJUSTABLE TONE SOURCE
(OPTIONAL)

THIS CIRCUIT IS
HANDY FOR LEARNING
TONE DECODER
BASICS. THE 567
PORTION CAN BE
USED IN MANY
DIFFERENT APPLICATIONS
(SEE BELOW). THE
PREDICTED FO IS
1.1 KHZ. THE TEST
CIRCUIT FO WAS 1.5 KHZ.
TONE DECODER (CONTINUED)

567

2-FREQUENCY OSCILLATOR  2-PHASE OSCILLATOR

LATCHING THE 567 OUTPUT

NARROW BAND FREQUENCY DETECTOR

ADJUST R1 AND R2 TO RESPOND TO CLOSELY SPACED FREQUENCIES. LED 1 AND 3 WILL GLOW IF FREQUENCY IS HIGH OR LOW. LED 2 WILL GLOW WHEN THE INPUT FREQUENCY IS CENTERED.
TOUCH-TONE® DECODER

IC1, 2, 3 = 7402
ACTIVE OUTPUT = H

REPEAT THIS CIRCUIT
BELOW.

TUNE EACH 567 VIA R1.

IN: 50-200 mV
12-KEY PUSHBUTTON TONE MODULE

CEX-4000

Generates the 12 standard telephone tone dialing frequency pairs. V+ should not exceed 6 volts. Requires 3.58 MHz crystal. OK to use from 1 to 12 keys for remote control.

Touch-Tone® is a registered trademark of AT&T.

PORTABLE TOUCH-TONE® GENERATOR

Remote Control
VOLTAGE-TO-FREQUENCY
FREQUENCY-TO-VOLTAGE
CONVERTER
9400 (276-1790)

In voltage-to-frequency (V-F) mode, an input voltage which has been converted into a current by a resistor at pin 3 is transformed into a proportional frequency. In frequency-to-voltage mode a frequency at pin 11 is converted into a proportional voltage. This chip can be operated from a single or dual polarity power supply.

CAUTION: THIS CHIP INCORPORATES BOTH BIPOLAR AND CMOS CIRCUITRY. THEREFORE CMOS HANDLING PRECAUTIONS MUST BE FOLLOWED TO AVOID PERMANENT DAMAGE.

BASIC V/F CONVERTER  FSK* DATA TRANSMITTER

1. BIAS
2. ZERO
3. ADJUST
4. VSS
5. VREF OUT
6. GND
7. VREF
8. OUTPUT
9. COMMON
10. FREQ/2 OUT
11. COMPARATOR IN
12. AMPLIFIER OUT
13. NC
14. VDD

NOTE: UNUSUAL LOCATION OF POWER SUPPLY PINS.

R2 100K
R3 100K
R1 10K
C1 0.01µF
C2 47pF
R6 100K
R5 33K
R4 33K

9400

V/F

FREQ OUT (KHz)
0 2 4 6 8

R1 - OPTIONAL (USE TO SUPPLY INPUT VOLTAGE DURING TESTS).
R2 CONTROLS OUTPUT OVER WIRE OR RADIO.

C2
L IN
H IN
47pF
39k
10k
1µF
1000
1k

* FREQUENCY SHIFT KEYING. USE TO SEND BINARY.
VOLTAGE-TO-FREQUENCY (CONTINUED)

FREQUENCY-TO-VOLTAGE CONVERTER

9400

AUDIO FREQUENCY METER

Input frequency must cross zero volt. Works up to 25 kHz. R2 is zero adjust for meter. Adjust R7 to give maximum reading at 25 kHz in. For more stability, change R6 to 6-V zener diode.

ANALOG DATA TRANSMISSION SYSTEM

TRANSMITTER

Receiver

The SPKR is optional but may prove helpful during initial testing. Use an infrared LED (Radio Shack 276-142). Q1 can be the phototransistor supplied with the LED or Radio Shack 276-130. R7 in the receiver is zero adjust.
VOLTAGE CONTROLLED OSCILLATOR (VCO) 566

VERY STABLE, EASY TO USE TRIANGLE AND SQUARE WAVE OUTPUTS. RI AND CI CONTROL CENTER FREQUENCY. VOLTAGE AT PIN 5 VARIES FREQUENCY. IMPORTANT: OUTPUT WAVE DOES NOT FALL TO 0 VOLT! AT 12 VOLTS (PIN 8), FOR EXAMPLE, TRIANGLE OUTPUT CYCLES BETWEEN +4 AND +6 VOLTS. SQUARE OUTPUT CYCLES BETWEEN +6 AND +11.5 VOLTS.

FUNCTION GENERATOR

FSK GENERATOR *

FSK MEANS FREQUENCY SHIFT KEYING.

USE TO TRANSMIT BINARY DATA OVER TELEPHONE LINES OR STORE BINARY DATA ON MAGNETIC TAPE.

Vcc = 9 VOLTS.

TWO-TONE WARBLER

RI CONTROLS WARBLE RATE.

R3 CONTROLS TONE FREQUENCY.

1/2 = 1/3 4049
ANALOG-TO-DIGITAL CONVERTER TL507

Provides analog-to-digital conversion for microprocessors. Can provide 4-bit or 8-bit output with external counter plus steering logic. Makes good pulse width modulator.

Note: Use Vcc 1 or Vcc 2.

Vcc 1 = 3.5 to 6 volts
Vcc 2 = 8 to 18 volts

PULSE WIDTH MODULATOR

8-BIT ANALOG-TO-DIGITAL CONVERTER

8-BIT DATA BUS → MSB

BUS ENABLE (WHEN LOW)

THIS PROJECT FOR ADVANCED EXPERIMENTERS.
8-BIT DIGITAL-TO-ANALOG CONVERTER  DAC 801

Provides very fast 8-bit digital-to-analog conversion. Will accept TTL levels at inputs B1 to B8. Can provide ± output. Use to interface microcomputer to analog devices.

B1 = Most Significant Bit.
B8 = Least Significant Bit.
V± = ±4.5 to 18 V.

8-BIT DAC

DAC 801 POWER SUPPLY

TL: 120 VAC / 25.2 VAC CT (273-1512)
(OK to use 273-1505 for non-precision applications.)

Caution!
You must insulate connections!

*Use TO-220 heat sink.
8-BIT DIGITAL-TO-ANALOG CONVERTER DAC 801 (CONTINUED)

256-STEP STAIRCASE GENERATOR

DAC 801 TONE GENERATOR

RI: CLOCK RATE
CI: INCREASE TO SLOW RATE
S1: CLOSE FOR UNIPOLAR OUTPUT

R2: FULL SCALE ADJUSTMENT

RI AND CI CONTROL TONE RANGE.

CHANGE OR OMIT ONE OR MORE INPUTS TO DAC 801 TO MAKE UNIQUE WAVEFORMS.

NOTE: +10V REFERENCE CAN BE +5 TO +10V IN NON-PRECISION ROLES (E.G. TONE GENERATION).
TEMPERATURE SENSOR AND ADJUSTABLE CURRENT SOURCE
LM334 (276-1734)

VERSATILE 3-LEAD COMPONENT THAT LOOKS MORE LIKE A TRANSISTOR THAN AN IC. CAN BE USED AS A TEMPERATURE SENSOR, CURRENT SOURCE FOR LEDS AND OTHER COMPONENTS OR CIRCUITS, VOLTAGE REFERENCE, ETC.

BASIC THERMOMETERS

BASIC CURRENT SOURCE

VOLTAGE REFERENCE

CALIBRATED LED

RAMP GENERATOR

LIGHT METER

1 = R
2 = + V
3 = - V (GND)

Iset = CURRENT INTO PIN 2.

Rset = .0677 / Iset AT 25°C.

MAXIMUM CURRENT OUT = 10 mA.

DEVICE BEING POWERED

OUTPUT.

LED CURRENT

CONSTANT LED OUTPUT FOR ANY INPUT BETWEEN 3-20 VOLTS.

IN 914

10K

1K

3.3K

3

0.8 - 5.0 V

OUTPUT:

68K

3

LM334

+2.5 - 20V

MUST BE IV OR MORE ABOVE OUTPUT.

+3 - 20V

10K

1K

3

LM334

0.8 - 5.0 V

ADJUST VOLTAGE OUTPUT

LM334

+3 - 20V

LM334

+3 - 20V

LED

LM334

+1.5 - 20V

PCI - CDS PHOTOCELL (RADIO SHACK 276-116)

PCI

0 - 1 mA

222 BULB CLOSE TO PCI GIVES 2.5 mA OUTPUT.

RSZ009

1K

1K

15 Ω

4.3 mA

10 Ω

6.4 mA

1KHz

IN

TOP FLATTENS IF INPUT PULSE RATE TOO SLOW.

PCI - CDS PHOTOCELL (RADIO SHACK 276-116)

&
POWER AMPLIFIER
LM386

Designed mainly for low voltage amplification, will drive directly an 8-ohm speaker. Gain fixed at 20 but can be increased to any value up to 200.

X20 AMPLIFIER

![X20 Amplifier Diagram]

* R1 controls input signal level.

BASS BOOSTER

![Bass Booster Diagram]

Gain: 100 Hz = 25 dB
2 kHz = 19 dB

AUDIBLE ALARM

![Audible Alarm Diagram]

Circuit shown is very sensitive light wave receiver. OK to use other op-amps for the TLO84.

Q1 = Phototransistor (Radio Shack 276-130)

HIGH GAIN POWER AMPLIFIER

Use care; speaker can be loud!

Gain = 20 (to change see above).
8-WATT POWER AMPLIFIER
LM383 / TDA2002

Power amplifier designed specifically for automotive applications—but ideal for any audio amplification system. Designed to drive a 4-ohm load (equivalent to a single 4-ohm speaker or two 8-ohm speakers in parallel). This chip contains thermal shutdown circuitry to protect itself from excessive loading. This will cause severe distortion during overload conditions. You must use an appropriate heat sink (e.g., Radio Shack 276-1363), spread some heat sink compound (276-1372) on the LM383 tab before attaching the heat sink.

8-WATT AMPLIFIER

* C4—PLACE CLOSE AS POSSIBLE TO THE IC.
R2—OK TO USE 4-10Ω RESISTORS IN PARALLEL.

16-WATT BRIDGE AMPLIFIER

1. USE HEAT SINK.
2. REDUCE POWER SUPPLY VOLTAGE TO 6-9 VOLTS (AS IN CIRCUIT BELOW). IF SEVERE DISTORTION OCCURS.
3. DON'T APPLY EXCESSIVE INPUT SIGNAL.
DUAL 2-WATT AMPLIFIER
LM1877/LM377

High quality, easy to use power amplifier. Ideal for do-it-yourself stereo, p.a. systems, intercoms, etc. Automatic thermal shutdown protects against overheating. 70 dB channel separation means virtually no crosstalk, only 3 microvolts noise input. Heatsinking: unnecessary in many applications since average power is usually well below brief peaks. In any case, pins 3, 4, 5, 10, 11 and 12 should be connected together. If load exceeds device rating, thermal shutdown will occur... and will cause severe distortion. Use heatsink (up to 10 square inches of copper foil on pc board or metal fin) if this occurs.

STEREO AMPLIFIER

PUBLIC ADDRESS SYSTEM

119
**COMPLEX SOUND GENERATOR**  
**SN76477N**

Incorporates S.L.F. (Super Low Frequency Oscillator), VCO (Voltage Controlled Oscillator), Noise Generator and a mixer that allows the outputs from one or more of the above to be combined. Can be operated together with appropriate resistors and capacitors to produce many kinds of sounds. Can be controlled by external logic. See data supplied with chip for more info.

This chip is easy to use if you follow data sheet instructions.

**PERCUSSION SYNTHESIZER**

Si - Press to activate sound.

**NOTE:** The SN76488 includes built-in speaker amplifier. The SN76477 does not.
COMPLEX SOUND GENERATOR (CONTINUED)
SN76477N /

NOISE GENERATOR

PRODUCES STEADY HISS. MAKE SNARE DRUM
BY CONNECTING PUSH BUTTON IN SERIES WITH
SPEAKER. ADD S.L.F. OSCILLATOR TO MODULATE
THE HISS. (SELECT S.L.F. + NOISE BY CONNECT-
TING PINS 25 AND 26 TO GND AND PIN 27 TO
+9V. ADD 1M POT FROM PIN 20 TO GND AND
1µF CAPACITOR FROM PIN 21 TO GND.) SOUNDS
LIKE STEAM TRAIN OR PROPELLER AIRCRAFT
DEPENDING ON ADJUSTMENT OF 1M POT.

UNIVERSAL UP-DOWN TONE GENERATOR

PRESS SI AND RELEASE TO HEAR UNDULATING TONE
THAT GRADUALLY DECAYS AND STOPS. CHANGE VCO
AND S.L.F. COMPONENTS FOR MANY DIFFERENT SOUND EFFECTS
RANGING FROM SIREN TO SCIENCE FICTION MOVIE SOUNDS. FOR CONTINUOUS
SOUND, OMIT COMPONENTS AT PINS 7, 8, 23, 24 AND GROUND PIN 9.
COMPLEX SOUND GENERATOR
SN76488N

Modified version of SN76477N.
Includes built-in amplifier for direct speaker drive. Note that SN76488N and SN76477N have different pinouts.

Many different sounds can be created. For best results, study carefully the technical data supplied with chip. Very easy to devise your own unique sounds!

Note: Sound output may change as $V_{cc}$ goes from +6 to +9V.

BOMB DROP PLUS EXPLOSION

R2 controls duration of explosion.
R5 controls altitude.
IMPROVED STEAM ENGINE AND WHISTLE

R2 CONTROLS ENGINE SPEED.
R4 CONTROLS WHISTLE FREQUENCY.

THE ULTIMATE SIREN

R1 CONTROLS CYCLE RATE.
R2 CONTROLS FREQUENCY.

ADJUST R1 FOR HIGH RESISTANCE TO GIVE ULTRA SLOW SIREN.
DUAL ANALOG DELAY LINE
SAD-1024A

Contains two independent 512 stage serial analog delay (SAD) lines (also called analog shift registers). OK to use each 512 stage SAD separately or in series. Analog delays of up to 1/2 second can be achieved. A 2-phase clock is required to drive inputs φ1 and φ2. Input data rides through the SAD on alternating clock pulses and appear at the two outputs after passing through all 512 stages. Connect V_{bb} to V_{dd} (pin 7) or, for optimum results, to 1 volt below V_{dd}. This chip can be tricky to use since several external adjustments are required. Circuits on this page explain operating requirements while a complete circuit is shown on facing page.

SAD IN/OUT CONTROLS

Adjust R1 (input bias) for optimum audio output. Outputs appear like this on a scope:

- A
- A'

Summed outputs (A+A'): 

Set scope to visualize input signal (compressing clock rate):

Any op-amp can be used, but low noise FET input types are best.
DUAL ANALOG DELAY LINE (CONTINUED)

SAD-1024A

ADJUSTABLE FLANGER OR PHASER

ADJUST CIRCUIT FOR DESIRED EFFECT
BY CONNECTING TRANSISTOR RADIO TO
AUDIO INPUT. TUNE RADIO TO A TALK
SHOW FOR BEST RESULTS. R13 AND R7
CONTROL BIAS TO SECTIONS A AND B OF
THE SAD. R9 BALANCES THE SAD OUTPUTS. R2 CONTROLS THE CLOCK RATE.
R7 IS THE MAIN BALANCE CONTROL.
IT CONTROLS THE RELATIVE AMPLITUDES
OF THE ORIGINAL AND DELAYED SIGNAL
APPLIED TO THE MIXER. CONNECT THE
OUTPUT TO A POWER AMPLIFIER. YOU MUST
ADJUST BIAS CONTROLS PROPERLY FOR BEST
RESULTS. SET R2 FOR LOW FREQUENCIES
(3-8KHz) FOR SINGLE ECHO. USE HIGHER
CLOCK FREQUENCIES (20-100KHz) FOR HOLLOW,
SWISHY SOUNDS. NOTE: THIS CIRCUIT IS NOT
FOR BEGINNERS.

REVERBERATOR

ADD THIS FEEDBACK CIRCUIT FOR
UNUSUAL REVERBERATION EFFECTS.
SLOW CLOCK FREQUENCIES GIVE
MOST STRIKING REVERBERATIONS.
TRY 5-20 KHz. FASTER CLOCK (20-
100 KHz) AND CAREFUL ADJUSTMENT
GIVES ROBOT-LIKE SOUND USED IN
SOME SCIENCE FICTION MOVIES.
OPTOCOUPLERS
TIL 111 - PHOTOTRANSISTOR
TIL 119 - PHOTODARLINGTON

Infrared LED turns on phototransistor when LED is forward biased. Use to reduce electrical noise and shock hazard. Ideal for isolating and interfacing microcomputer bus lines.

TIL 111 / TIL 119 TEST CIRCUIT

This circuit shows TTL interfacing.

TIL 119 is slower but more sensitive. TIL 111 gives 1.5 kV isolation.

CALCULATOR / COMPUTER INTERFACING

KEYBOARD INPUT

H = close
L = open

H = enable
L = disable

To key contacts (reverse if necessary)

IMPORTANT: These circuits may void your calculator's warranty. I have used both with a low cost calculator with LED readout. See Popular Electronics, Dec 1979 (pp. 85-87) for details. Always follow MOS handling procedures when working with calculators! If not, you may damage the unit's processing chip.

CALCULATOR TIMER

To operate:

1. Set RI to give 10 Hz frequency.
2. Enter ↓ 1 ↑
3. Press SI for timing period.
4. Read time to tenth second from display.

Note: This shows CMOS interface.
**Optocouplers**

MOC3010 - SCR
MOS11C3 - TRIAC

Infrared LED switches
TRIAC (MOC3010) or SCR (MOS11C3). MOC3010 will switch 120 volts AC at 100 mA; SC11C3 will switch 200 volts DC at 300 mA.

**Calculator Output Ports**

**SCR (DC) Port**

- Connect pins 1 and 2 to decimal point of lowest order readout digit.
- Be sure to observe polarity.
- Use only with calculator having LED readout.
- Typical operation: Key in number which places decimal anywhere but final digit. Then press [1] [1] [0]. Number in display will be decremented each time [1] is pressed. When count reaches 0, decimal moves to last digit and actuates output port.

**TRIAC (AC) Port**

- The load for all these circuits may be lamp, motor or other device which does not exceed rating of optocoupler.

**Computer Output Ports**

- For more information see **Popular Electronics**. Dec. 1979. (pp. 86-87).
- Some calculators will require different keystroke sequence.
- Important: These circuits may void the warranty of your calculator or computer. Follow MOS handling procedures to avoid damaging calculator or computer. Computer ports designed to interface with TTL or LS bus lines.
OPTOCOUPLER
MOC5010 LINEAR AMPLIFIER

CONVERTS CURRENT FLOW THROUGH LED INTO OUTPUT VOLTAGE.
IDEAL FOR TELEPHONE LINE COUPLING AND VARIOUS AUDIO APPLICATIONS.

ISOLATED ANALOG DATA LINK

SCR DRIVER

TTL INTERFACING

AC SIGNAL ISOLATOR

Rs = SIGNAL VOLTAGE
\[ \frac{0.025}{Rs} \]