The Forrest Mims Engineer’s Notebook

Forrest M. Mims, III

LLH
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FOREWORD

It's a real shame that the millions who have read Forrest's articles, columns, and books over the years have never had the chance to get to know him personally. I've been lucky enough to be able to call him my friend for several years. This book is special to me because the first edition of this book was the reason why I met and got to know Forrest.

I first met Forrest in 1979. I can't recall the exact date, but it was a fearsomely hot mid-summer day in Fort Worth, Texas. I was working at Radio Shack's national headquarters in their technical publications department. My boss, Dave Gunzel, had spearheaded an effort for Forrest to generate a book of IC applications circuits that were similar to Forrest's actual working laboratory notebooks. Forrest was carefully preparing each page by hand on transparent Mylar sheets using a fine-tip pen. I monitored his progress eagerly, and one day Dave told me that Forrest Mims would be arriving the following week with the last of his Mylar originals.

Wow! I was going to really meet Forrest Mims! I hadn't seen a photo of Forrest before, nor had Dave told me much about how he looked or acted. (In retrospect, I now realize that was deliberate on Dave's part—he wanted me to "discover" Forrest on my own.) I had my own mental picture of Forrest, though. Obviously, a serious fellow. Anyone who came up with all those electronic circuits couldn't have much time for laughter. Probably sharply focused and not interested in anything other than electronics. An older gentleman, certainly, with a white beard and a fondness for jackets with elbow patches. A pipe and slight Germanic accent were also likely. He would probably think I was really stupid and not have a lot of patience with me.

The Big Day quickly arrived. Forrest was due in that afternoon. I had carefully rehearsed my welcoming speech: "Hello, Mr. Mims. It is certainly good to see you. Would you like an ashtray for your pipe?"

I was alone in the technical publications office that afternoon when someone I didn't recognize stuck his head into the office doorway. He was wearing normal business attire, smiled easily, spoke with a slight Texas accent, and was looking for Dave Gunzel. Oh brother, I thought, another new employee who's lost in Tandy Center. Doesn't this guy know that Forrest Mims is going to show up this afternoon and I don't have any time to waste on him??? I mumbled something about Dave being gone for a few minutes and that we were expecting a visitor later that afternoon.

The stranger seemed apologetic. He didn't want to waste any of my time or Dave's if we were expecting someone important, he said; he just needed to tend to a couple of matters quickly and wouldn't bother us
any further. He approached my desk and extended his hand toward me.

"Hi," he said, "I'm Forrest Mims; you must be Harry."

I don't recall my reply, but I think it was the unmistakable sound of self-mortification.

Forrest had work to do and wondered if I could help. He needed to spray the Mylar sheets with a protective coating before turning them over to us for printing. We commandeered a vacant area of the then-new Tandy Center, spread out the Mylar sheets, and spent the next couple of hours emptying aerosol cans of clear lacquer while discussing the state of the universe.

That afternoon, I discovered what a remarkably unpretentious guy Forrest is. Here was one guy who had earned the right to a massive ego, yet he was straightforward, down to Earth, and almost skeptical of his achievements. Our conversation ranged from electronics to lasers to politics to Texas history to computers to religion. . . . well, you name it. It was incredible how many subjects Forrest was interested in, and how insatiable his curiosity was about everything in the natural world. By the end of that afternoon, I felt as if I had known Forrest for years.

A lot has happened since then. I eventually left Texas to become a book editor in New York and, a few years after that, moved to California where I became a founding partner in HighText Publications. Throughout, Forrest remained a valued friend and trusted confidant. The intelligence and insight that are apparent in his circuits extends to many other areas, and he has a wit and sense of irony that are delicious. While we don't get to spend much time physically in each other's company, it's a rare week when we don't have at least two or three lengthy telephone conversations. As technology has advanced, so have our modes of interaction; we often exchange a couple of faxes per day on various subjects.

We had no idea that the book we worked on back on that hot summer afternoon in 1979 would go on to sell over 750,000 copies in its various editions. Some of the pages we worked on back in 1979 appear in this book, a testimony to the enduring quality and relevance of Forrest's work. For readers such as yourself, this book will be a valuable reference to contemporary, real-world IC applications. For me, it brings back a lot of good memories. And, no, Forrest doesn't smoke a pipe, doesn't wear jackets with elbow patches, and doesn't have a beard.

Harry L. Helms
INTRODUCTION

Since my student days at Texas A&M University I have kept a series of laboratory notebooks. In these notebooks I record details about experiments, measurements, and new ideas. Also included are many electronic circuit diagrams. Dave Gunzel, formerly the director of technical publications at Radio Shack, took an interest in my notebooks in the mid-1970s and suggested that Radio Shack might someday want to publish a book of electronic circuits based on their hand-drawn format. Several years later, Radio Shack assigned me to produce Engineer's Notebook, a 128-page book of electronic circuits. The book soon became a Radio Shack bestseller. As new integrated circuits were added to Radio Shack's product line and others were dropped, I revised the book as necessary. Later, Radio Shack authorized me to do an edition of the book for McGraw-Hill.

This revised edition for HighText Publications represents the best and most interesting circuits from all previous editions.

The integrated circuits described in this book remain among the most popular ever introduced. Most of them are readily available from Radio Shack, electronics parts suppliers, and mail-order dealers. Magazines such as Radio-Electronics carry ads from mail-order IC dealers. A few of the chips are specialized and finding sources for them may be more difficult. Four of the devices—the CEX-4000, S50240, PCIM-161, and SAD-1024—may be available only from dealers in surplus and discontinued ICs. However, the overwhelming majority of chips described in this book are readily available from many different sources. In fact, prices for some of the more common devices have fallen substantially since the first edition of this book. Some are available today for pennies!

Most of the part numbers given for the integrated circuits in this book are generic, and various manufacturers may add additional letters or numbers or even use a completely different number. For example, the 4011 is a quad of CMOS NAND gates. An "A" suffix (4011A) means this chip can operate from a 3- to 12-volt supply. A "B" suffix (4011B) means the chip can operate from a 3- to 18-volt supply. The high-voltage version of the chip is by far the most common. National Semiconductor adds a CD prefix to its versions of the 4011B (CD4011B), while Motorola adds an MC1 prefix (MC14011B). Nevertheless, both chips are functionally identical.

For additional information about chip identification and specifications, see the data books published by the various integrated circuit manufacturers. These books are available directly from manufacturers of integrated circuits and from industrial supply companies that represent integrated circuit manufacturers. They are also available from some mail-order electronics parts dealers.

Forrest M. Mims II
ABOUT THE AUTHOR

Forrest Mims has been an electronics hobbyist since building a one-tube radio kit at the age of 11. Following graduation from Texas A&M University in 1966 and service as a photointelligence officer in Vietnam, he worked for three years with high-powered lasers, solid-state instrumentation, and trained monkeys with the Air Force Weapons Laboratory in New Mexico. Since becoming a full-time writer in 1970, he’s written several hundred magazine articles and scholarly papers. His articles and columns have appeared in virtually every significant electronics magazine, including Popular Electronics, Radio-Electronics, and Modern Electronics. His articles on other scientific topics have appeared in a wide range of other publications, including National Geographic World, Science Digest, Highlights for Children, and Scientific American. His editorial exploits have included an assignment from the National Enquirer to evaluate the feasibility of eavesdropping on Howard Hughes by laser (it was possible, but Forrest declined to take part) and getting dropped by Scientific American as their “The Amateur Scientist” columnist because he admitted to the magazine’s editors that he was a born-again Christian. His book sales total in the millions, and he is likely the most widely-read electronics writer in the world.

Forrest is currently busy as the founding editor of Science PROBE!, a new magazine aimed at amateur scientists. In this role, Forrest is creating the sort of magazine that he wishes had been available in his youth while acquiring a new understanding of the frustrations of being an editor. He still keeps up a hectic pace of electronics and science experimentation and writing.

Forrest and his wife Minnie have three children, and they currently live in the Texas countryside near San Antonio. They are active in church activities, and Forrest is a Baptist deacon. He has his office and electronics lab in an old restored farmhouse adjacent to his home.
PARTS SOURCES

The chips and related components (resistors, capacitors, etc.) used in this book are available from a variety of sources, including electronics stores (such as Dick Smith Electronics in Australia and David Reid stores in New Zealand), advertisers in electronics magazines, and industrial electronics suppliers. Some chips—such as the SN76477N, SN76488N, and SAD-1024A—are a bit "rarer" and you may have to look for them at companies specializing in surplus and discontinued devices.

Manufacturers of integrated circuits publish "data sheets" giving the bare-bones specifications for a chip and "applications notes" that give additional information, including circuit schematics using the chip. These can be obtained by contacting the national headquarters of the chip manufacturer or their nearest sales office.

The manufacturer of an integrated circuit is identified by a prefix in front of the actual part number. For example, "LM741" and "MC741" would both indicate the device was the common 741 operational amplifier found on pages 93 to 96 of this book. However, the "LM" would indicate the device was manufactured by National Semiconductor while the "MC" would denote a device manufactured by Motorola. Here are some common prefixes and manufacturers:

- AD Analog Devices
- Am Advanced Micro Devices
- Bx Sony
- CA RCA (now Harris)
- CD RCA (now Harris)
- Cx Sony
- DM National Semiconductor
- F Fairchild (now National Semiconductor)
- FSS Ferranti
- HA Harris
- HA Hitachi
- HD Hitachi
- HG Hitachi
- HI Harris
- IR Sharp
- KA Samsung
- LF National Semiconductor
- LM National Semiconductor
- LT Linear Technology
- M Mitsubishi
- MB Fujitsu
- MC Motorola
- MM Motorola
- NE Signetics
- PM Precision Monolithics
- T Toshiba
- TL Texas Instruments
- TMS Texas Instruments
- XR Exar
- μPB NEC
REVIEWING THE BASICS

INTRODUCTION

"Can I use a 0.22 µF capacitor instead of a 0.01 µF unit?"

"Is it okay 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:

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

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

Resistors are identified by a color code:

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1</th>
<th>2</th>
<th>3 (Multiplier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLACK</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>BROWN</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>RED</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>ORANGE</td>
<td>3</td>
<td>3</td>
<td>1,000</td>
</tr>
<tr>
<td>YELLOW</td>
<td>4</td>
<td>4</td>
<td>10,000</td>
</tr>
<tr>
<td>GREEN</td>
<td>5</td>
<td>5</td>
<td>100,000</td>
</tr>
<tr>
<td>BLUE</td>
<td>6</td>
<td>6</td>
<td>1,000,000</td>
</tr>
<tr>
<td>VIOLET</td>
<td>7</td>
<td>7</td>
<td>10,000,000</td>
</tr>
<tr>
<td>GRAY</td>
<td>8</td>
<td>8</td>
<td>100,000,000</td>
</tr>
<tr>
<td>WHITE</td>
<td>9</td>
<td>9</td>
<td>(none)</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 okay to substitute resistors. For example, it's almost always okay to use a 1.8K resistor in place of a 2K 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 okay 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:

The voltage at \( \gamma \) is \( I \times R_2 \). I means the current through \( R_1 \) and \( R_2 \). So \( I = 10/(R_1 + R_2) \) or 0.005 amperes.

Therefore, \( \gamma = (0.005) \times (1000) \) or 5 volts.

Note that the total resistance of \( R_1 \) and \( R_2 \) is simply \( R_1 + R_2 \). This rule provides a handy trick for making custom resistances.
Voltage dividers are used to bias transistors:

They're also a convenient source of variable voltage:

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. Capacitance is specified in farads. One farad represents a huge capacitance so most capacitors have values of small fractions of a farad:

1 microfarad (\(\mu F\)) = \(10^{-6}\) farad
1 picofarad (pF) = \(10^{-12}\) farad
or
1 \(\mu F\) = 1,000,000 pF

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

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 \(\mu F\) across power supply pins of digital ICs. Stops false triggering.)

2. Smooth rectified AC voltage into steady DC voltage. (Place 100-10,000 \(\mu F\) 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:

7. Or to differentiate a fluctuating signal:

8. Perform a timing function:

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.

**SEMICONDUCTORS**

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:

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 \( (I_{LED}) \) of 20 mA at \( V_{cc} = 5 \) volts, \( R = 165 \) ohms. Don’t exceed \( I_{LED} \)!!
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:

![Diagram showing pin 1 of an IC]

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

![Diagram of an IC with part numbers and date code]

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

![Another diagram showing date code]

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

Note that LLLLL (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

A → B → OUT
L L
L H
H L
H H

OR

A → B → OUT
L L
L H
H L
H H

NOR

A → B → OUT
L L
L H
H L
H H

EXCLUSIVE-OR

A → B → OUT
L L
L H
H L
H H

EXCLUSIVE-NOR

A → B → OUT
L L
L L
H L
H L

YES (BUFFER)

A → OUT
L L
H H

NOT (INVERTER)

A → OUT
L H
H L

3-STATE LOGIC

CONTROL
A → OUT
L L
L H
H L
H H

CONTROL
A → OUT
L L
L H
H L
H H

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

INTRODUCTION

MOS ICs 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:

\[ \text{[Diagram of CMOS circuit]} \]

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 Vdd! (Two exceptions: the 4049 and 4050.)

2. Avoid, if possible, slowly rising and falling input signals since they can cause excessive power consumption. Rise times faster than 15 microseconds are best.

3. All unused inputs must be connected to Vdd (+) or Vss (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:

\[ \text{[Diagram of NMOS transistor]} \]

A PMOS transistor is identical except the P and N regions are exchanged. The SiO2 (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 punctured by static electricity:

\[ \text{[Diagram of static electricity puncturing]} \]

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:

   Rpu:
   PULLUP RESISTOR.
   TTL OR LS

   +5 (Vdd)
   Rpu: 470 - 4.7K
   FOR TTL;
   1K - 10K
   FOR LS.

   CMOS

2. DIFFERENT SUPPLY VOLTAGES:

   +5
   +3-15
   10K
   1K
   TTL OR LS
   CMOS

3. CMOS LED DRIVERS:

   Vdd (+3-5V)
   GLOWS WHEN LOW.
   Vdd (+3-15V)
   GLOWS WHEN HIGH.
   R = \frac{Vdd - 1.7}{.01} (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:

   +3-15
   1N4001
   5-10K
   1N4001
   10K
   47K
   2200
   4
   R
   C
   5V
   TTL OR LS
   CMOS

   TYPICAL VALUES: R = 100K, C = 0.01 - 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 Vdd.
QUAD NAND GATE 4011

The basic CMOS building block chip, more applications than TTL 7400/74LS00 quad NAND gate.

CONTROL GATE

\[
\begin{array}{c|c|c|c}
A & B & OUT \\
\hline
L & L & H \\
L & H & H \\
H & L & H \\
H & H & L \\
\end{array}
\]

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

INVERTER

\[
\begin{array}{c|c|c|c}
A & OUT \\
\hline
L & H \\
H & L \\
\end{array}
\]

AND GATE

\[
\begin{array}{c|c|c}
A & B & OUT \\
\hline
L & L & L \\
L & H & L \\
H & L & L \\
H & H & H \\
\end{array}
\]

NOR GATE

\[
\begin{array}{c|c|c|c|c|c}
A & B & OUT \\
\hline
L & L & H \\
L & H & L \\
H & H & L \\
\end{array}
\]

4-INPUT NAND GATE

\[
\begin{array}{c|c|c|c|c|c}
A & B & C & D & OUT \\
\hline
L & X & X & X & H \\
L & L & X & X & H \\
L & L & L & X & H \\
L & L & L & L & L \\
\end{array}
\]

OR GATE

\[
\begin{array}{c|c|c|c}
A & B & OUT \\
\hline
L & L & L \\
L & H & L \\
H & L & H \\
H & H & H \\
\end{array}
\]

EXCLUSIVE-OR GATE

\[
\begin{array}{c|c|c|c|c|c}
A & B & C & D & OUT \\
\hline
L & L & H & H & L \\
L & L & H & H & H \\
L & L & L & H & L \\
L & L & L & H & H \\
\end{array}
\]

AND-OR GATE

\[
\begin{array}{c|c|c|c|c}
A & B & C & D & OUT \\
\hline
X & X & H & H & H \\
X & X & H & H & H \\
X & X & X & H & H \\
X & X & H & H & H \\
\end{array}
\]

EXCLUSIVE-NOR GATE

\[
\begin{array}{c|c|c|c|c|c}
A & B & C & D & OUT \\
\hline
L & L & H & H & H \\
L & L & H & H & H \\
L & L & L & H & H \\
L & L & L & H & H \\
\end{array}
\]
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.

CAUTION: Battery power only!

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 74011 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

![Diagram of Bounceless Switch]

IMPORTANT: CONNECT ALL UNUSED INPUTS TO PIN 7 OR 14.

INCREASED OUTPUT DRIVE

INVERTER

NOR GATE

USE THIS METHOD TO INCREASE CURRENT THE 4001 CAN SOURCE OR SINK. OK TO ADD MORE GATES.

GATED TONE SOURCE

TONE FREQUENCY IS ABOUT 1KHz.

![Diagram of Gated Tone Source]

LED FLASHER

LED FLASHES 1-2 TIMES/SECOND.

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>H</td>
</tr>
</tbody>
</table>

NOT ALLOWED

OR GATE

![Diagram of OR Gate]
**QUAD AND GATE 4081**

Building block chip, use for buffering and logic, not as versatile as 4011.

**AND GATE BUFFER**

![AND Gate Buffer Diagram]

**NAND GATE**

![NAND Gate Diagram]

**NOR GATE**

![NOR Gate Diagram]

**4-INPUT NAND GATE**

![4-Input NAND Gate Diagram]

**4-INPUT AND GATE**

![4-Input AND Gate Diagram]

**DIGITAL TRANSMISSION GATE**

![Digital Transmission Gate Diagram]

**AND-OR-INVERT GATE**

![And-Or-Invert Gate Diagram]
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.B-9) IF 4012 IS UNAVAILABLE.

4012 AS INVERTER TO REVERSE OPERATION.

CONTROLLED INVERTER

BINARY FULL ADDER

PHASE DETECTOR

LED STOPS GLOWING WHEN THE INPUT FREQUENCIES ARE EQUAL.
QUAD EXCLUSIVE-OR GATE (CONTINUED)

4070

EXCLUSIVE-NOR

3-INPUT EX-OR

IC1 = 1/4 4070
IC2 = 1/6 4049

A B OUT
L L H
L H L
H L L
H H H

10 MHz OSCILLATOR

IC1 = 4070

\[ V_{DD} = 3 \text{ to } 15 \text{ volts} \]
FREQUENCY VARIES WITH \( V_{DD} \):

\[
\begin{array}{|c|c|c|}
\hline
V_{DD} & \text{FREQUENCY} & \text{AMPLITUDE} \\
\hline
5 & 2.4 \text{ MHz} & 3.5 \text{ V} \\
10 & 9.4 \text{ MHz} & 8.0 \text{ V} \\
15 & 11.0 \text{ MHz} & 12.0 \text{ V} \\
\hline
\end{array}
\]

8-INPUT EX-OR

SQUARE WAVE GENERATOR

IC1, 2 = 4070

\[ V_{DD} = 3 \text{ to } 15 \text{ volts} \]
RISETIME = 50 NANOSECONDS
FREQUENCY = 2 MHz WHEN \( V_{DD} = 10 \text{ volts} \)
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

$V_{dd}$

$1, 2 = \frac{1}{3} \cdot 4049$  Pulse Rate $= \frac{1}{4RC}$

Bounceless Switch

$V_{dd}$

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

Triangle Wave Source

$V_{dd}$

Frequency $= \frac{1}{4RC}$

Square Wave Generator

$AV_{dd}$

Repetition Rate $= \frac{1}{4RC}$

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

Linear 10x Amplifier

$V_{dd}$

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

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 \( V_{CC} \)

Incorporation of increased output drive.

Note unusual location of power supply pins.

LOGIC PROBE

V \( \frac{1}{6} \) 4050

INPUT

1k

LED glows when input is low.
DUAL 4-INPUT NAND GATE 4012

VERY USEFUL IN MAKING DECODERS. ALSO CAN BE USED TO ADD ONE OR MORE ENABLE INPUTS TO VARIOUS CIRCUITS.

ENABLE INPUT

1-OF-4 DECODER

WHEN ENABLE IS L, THE OUTPUT CORRESPONDING TO THE BA BINARY INPUTS GOES LOW. ALL OTHER OUTPUTS GO HIGH WHEN ENABLE IS H.
TRIPLE 3-INPUT NAND GATE
4023

HANDY FOR MAKING CUSTOM DECODERS, CONVERTERS AND MULTIPLE INPUT GATES.

6-INPUT OR GATE

DECIMAL-TO-BCD CONVERTER

DECIMAL IN (SELECTED DIGIT H, ALL OTHERS L.)

9-INPUT NAND GATE

ALL UNUSED INPUTS MUST BE GROUNDED.

1-OF-4 DECODER
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.

18
PROGRAMMABLE GAIN AMPLIFIER

\[ V_{out} = \frac{R_F}{R_{in}} \]

0000 TO 1111 AT DCBA GIVES \( R_{in} \) OF FROM \( R \) TO \( R/15 \)

PROGRAMMABLE FUNCTION GENERATOR

IC 1, 2, 3 = 4066, \( V_{dd} = 3-15 \)V

RI - RIO = 10K TRIMMER POTS

PRODUCES REPETITIVE 10-STEP WAVEFORM.
PROGRAM HEIGHT OF EACH STEP VIA RI - RIO.
VARY RATE VIA RII AND C1.
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

NOTE UNUSUAL LOCATION
OF POWER SUPPLY PINS.
(A0-A9: ADDRESS INPUTS)

ADDRESS LINES TO
OTHER 2102L'S

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

74193

SA 74LS193

SI

SH

SG

SF

SE

SD

SC

SB

SA

LOAD

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.

CASCADING 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 x 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

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 ½ 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 PUSHBUTTON.
2. SWITCH S4 AND S5 TO L.
3. CLOSE S3.
4. INPUT DATA.
5. PRESS BOUNCELESS PUSHBUTTON.
6. REPEAT STEPS 1-5.

READ: 1. OPEN S3.
2. SWITCH S5 TO H.
3. CLOSE, THEN OPEN, S1.
4. SELECT Clocked OR MANUAL OUTPUT (S2).

NOTE: BEST TO OUTPUT DATA THROUGH 74LS367 HEX BUFFER.

S4 - CHIP ENABLE

S5 - WRITE ENABLE

DATA INPUT SWITCHES (SPOT WITH NEUTRAL CENTER)
DUAL D FLIP-FLOP
4013

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

1-OF-4 SEQUENCER

DIVIDE-BY-2

MODULO-8 COUNTER

SERIAL IN/OUT, PARALLEL OUT SHIFT REGISTER
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-5 COUNTER

DIVIDE-BY-3 COUNTER

DIVIDE-BY-4 COUNTER

4-BIT SERIAL SHIFT REGISTER
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

<table>
<thead>
<tr>
<th>CLOCK</th>
<th>POLARITY</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>0</td>
<td>D</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>LATCH</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>LATCH</td>
</tr>
</tbody>
</table>

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

STEPPEW 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.
14-STAGE BINARY COUNTER 4020

A RIPPLE COUNTER WITH CARRY OUTPUT. THE 14-STAGE BINARY COUNT IS COMPLETED IN 16,384 CLOCK PULSES. THIS MAKES POSSIBLE VERY LONG DURATION TIMERS, ASSUMING THE OUTPUTS ARE DECODED. THE OUTPUTS REQUIRE A BRIEF SETTLING TIME AFTER EACH CLOCK PULSE.

14-BIT BINARY COUNTER

THE SECOND AND THIRD OUTPUTS (A4 AND A8) OF THE 4020 ARE NOT AVAILABLE. THIS CIRCUIT INCLUDES A 3-BIT COUNTER TO SUPPLY THE MISSING OUTPUTS. A IS THE LOWEST ORDER OUTPUT.

STAIRCASE GENERATOR

OUTPUT IS A STEPPED VOLTAGE. APPLICATIONS INCLUDE ANALOG-TO-DIGITAL CONVERSION AND WAVEFORM SYNTHESIS.
DUAL BCD COUNTER
4518

TWO SYNCHRONOUS DECADE COUNTERS IN ONE PACKAGE. WHEN ENABLE IS HIGH AND
RESET IS LOW, EACH COUNTER ADVANCES ONE COUNT PER CLOCK PULSE.

CASCADED BCD COUNTERS

THE TWO GATES TRIGGER THE SECOND COUNTER AT HLLH (DECIMAL 9).

BCD KEYBOARD ENCODER

PRESS 50-59, THEN TOGGLE RESET SWITCH 510 TO VCC AND BACK TO GROUND.
BCD EQUIVALENT OF SELECTED KEY (50-59) APPEARS D C B A VDD
DECADE COUNTER/DIVIDER 4017

S E Q U E N T I A L L Y M A K E S 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

O-99 COUNTER

SI: A = RESET
B = RUN
OK, TO ADD MORE 4017's
DECADE COUNTER/DIVIDER (CONTINUED)

4017

BCD KEYBOARD ENCODER

TOGGLE S10, THEN PRESS S0-S9.

FREQUENCY DIVIDER

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 HIGH). DIS — INHIBITS INPUT WHEN HIGH. C LOCK — INPUT MR — MASTER RESET (WHEN HIGH). OF — OVERFLOW. A, B, C, D — BCD OUTPUTS.

3-DIGIT EVENT COUNTER

LATCH (LE) 10  
RESET (MR) 13  
EVENTS (CLOCK) 12  
DISABLE (DIS) (WHEN HIGH) 11

OK TO USE LIQUID CRYSTAL DISPLAY OR COMMON CATHODE LED DISPLAY.

SELECT RI-R7 SO LED CURRENT DOES NOT EXCEED 10mA.

6-DIGIT FREQUENCY COUNTER

LATCH: STORES TOTAL COUNT IN ONE COUNT CYCLE.
RESET: CLEAR COUNT TO 000000 PRIOR TO NEW COUNT CYCLE.
COUNT: COUNT INPUT

FREQUENCY INPUT SEE NEXT PAGE FOR MORE INFO...

6-DIGIT COUNTER (FACING PAGE)
3-DIGIT BCD COUNTER (CONTINUED)
MC14553

6-DIGIT COUNTER

This circuit shows how to cascade two 3-digit counters. Maximum count 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 audio signals.
**BCD-TO-DECIMAL DECODER 4028**

Decodes 4-bit BCD input into 1-of-10 outputs. Selected output goes high; all others stay low. Use for decimal readouts, sequencers, programmable counters, etc.

**0-9 SECOND TIMER**

1 Hz clock +9

1/2 4518

Ground unused inputs of second 1/2 4518

+9

Reset Run

OK to use outputs to control external logic or devices.

**1-OF-8 DECODER**

Address inputs

**COUNT TO N AND HALT**

Use the adjacent circuit with these changes:

1. omit 4049
2. make pin 2 high
3. use pin 7 as control input.

**COUNT TO N AND RECYCLE**

Vdd

1/2 4518

To n+1

(4028)
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 (pin 5 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 once per second when E is high.

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.

R1 - R7 = 220 Ω
VDD = +5 - 9 V

Import: All inputs must go somewhere!
**8-STAGE SHIFT REGISTER 4021**

Parallel input / serial output shift register. Also serial input. Data at parallel inputs is forced into the register irrespective of the clock status when pin 9 is made high. Keep pin 9 low for normal operation.

**PARALLEL-TO-SERIAL DATA CONVERTER**

Parallel data in

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>G</td>
<td>F</td>
<td>E</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

4021

CLOCK IN

SERIAL DATA OUT → SEND LOAD

All 1's (H's) are sent after the 8-bit word is transmitted.

**8-STAGE DELAY LINE**

The first parallel input (pin 7) is grounded. This loads a single L when SI is switched to initiate. The single L bit reaches the output after 8 clock pulses.

**PSEUDO-RANDOM SEQUENCER**

This circuit generates a pseudo-random bit sequence and recycles. To change bit pattern, connect different patterns of inputs of second 4021 to Vdd or ground.

1K (OR)

4.7K

10μF (Adjust R1; change sound with SI.)

TO AUDIO AMPLIFIER FOR SOUND EFFECTS.
ANALOG MULTIPLEXER
4051

INPUT ADDRESS AT CBA SELECTS
1-OF-8 ANALOG SWITCHES. SIGNAL
AT SELECTED SWITCH I/O (INPUT/
OUTPUT) IS THEN APPLIED TO COMMON
I/O (OUTPUT/INPUT). THE INPUT
SIGNAL MUST NOT EXCEED VDD.
THE INHIBIT (INH) INPUT SHOULD BE
GROUND FOR NORMAL OPERATION.
ALL SWITCHES ARE OPEN WHEN
INH IS HIGH.

1-OF-8 MULTIPLEXER
(DeMULTIPLEXER)

ADDRESS INPUTS

DATA IN

DATA OUT

Vee (SEE NOTE
AT LEFT)

VDD

NOTE:
CONNECT PIN 7
TO GROUND OF
INPUT CIRCUIT.
IF GROUND IS
COMMON, CONNECT

TONE SEQUENCER

CYCLES THROUGH
8 TONES AND
REPEATS. R1
CONTROLS TEMPO.
R2-R9 ARE
INDIVIDUAL TONE
RESISTORS. USE
1K-100K EACH.

VDD (+3-15v) I/O I/O I/O I/O
2 1 1 0 3 A B C

I/O I/O 0 I/O I/O I/O INH Vee
4 6 7 5

DO NOT REDUCE RIO.
USE AMPLIFIER FOR
MORE VOLUME.

C2 0.05

1,2,3,4,5,6 = 4049

37
60-Hz TIMEBASE

MM5369

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

VDD

5369

C1

C2

R1

R2

1K

20M

VDD

60Hz OUT

CRYSTAL FREQUENCY OUT
(3.579545 MHz)

RI - USE TWO 10M
IN SERIES.

* MOTOROLA SPECIFIES THAT C1 = 30 pF
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., 5-50 pF) 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

VDD

4017

10 Hz OUT

60Hz IN

THIS IS A
÷10 DIVIDER.

1-Hz TIMEBASE

VDD

4017

1 Hz OUT

10 Hz IN

THIS IS A
÷10 DIVIDER.

DIGITAL STOPWATCH

D C B A

BDC OUTPUTS

CONNECT TO LED OR LC
DECODER/DIVIDER (e.g.
4511 OR 4543).

1/2 451B
HIGH DIGIT

1/2 451B
LOW DIGIT

VDD

START

STOP

OPERATION:
1. TOGGLE SI FROM
CLEAR TO READY.
2. SWITCH S2 FROM
STOP TO START.
3. SWITCH S2 FROM
START TO STOP.

CLOCK IN

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 TOSSEr

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:

![Battery Supply Diagram]

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 86.)

OPERATING REQUIREMENTS

1. $V_{cc}$ must not exceed 5.25 volts.

2. Input signals must never exceed $V_{cc}$ 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 $V_{cc}$.

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 uF) 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 $V_{cc}$ 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 uF 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:

![LED Driver Diagram]

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 $V_{cc}$ 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
A

AND GATE
A

OR GATE
A

AND-OR GATE
A

NOR GATE

4-INPUT NAND GATE
A

EXCLUSIVE-OR GATE
A

EXCLUSIVE-NOR GATE
A

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

HALF ADDER

RS LATCH

D FLIP-FLOP

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 47 nF.

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.

IC 1, 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

NOR GATE

4-INPUT NAND GATE

4-INPUT AND 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

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.

NOR GATE

NAND GATE

2-INPUT DATA SELECTOR

SELECTS 1-OF-2 INPUTS AND TRANSMITS ITS LOGIC STATE TO THE OUTPUT.

ADDRESS | DATA IN | OUT
---------|---------|-------
A        | B       | A     |
L        | X       | L     |
L        | X       | H     |
H        | L       | X     |
H        | H       | X     |

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

ONE-SHOT

THIS CIRCUIT IS EQUIVALENT
TO A BINARY HALF-ADDER.

RS LATCH

AND GATE

OR GATE

4-INPUT NOR GATE

THIS CIRCUIT IS A MONOSTABLE
MULTIVIBRATOR OR PULSE STRETCHER.
AN INPUT PULSE TRIGGERS AN
OUTPUT PULSE WITH A DURATION
DETERMINED BY R AND C. OUTPUT
PULSE WIDTH IS APPROXIMATELY 0.8RC.
DUAL 4-INPUT NAND GATE 
74LS20

Many decoder and encoder applications can be used as dual 3-input NAND gate with enable (control) input for each gate.

BCD DECODERS

Outputs go high when appropriate BCD word appears at inputs DCBA. Outputs stay low for all other inputs. (Omit final inverter to provide active low output.) Use this method to decode any 4-bit nibble.

DECIMAL-TO-BINARY CODED DECIMAL (BCD) ENCODER

Selected input should be low and all other inputs should be high. BCD equivalent will appear at the outputs.
TRIPLE 3-INPUT NOR GATE
74LS27

USEFUL FOR DATA SELECTORS
AND NOR GATE FLIP-FLOPS
THAT REQUIRE CLEAR AND
PRESET INPUTS.

GATED RS LATCH

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

3-INPUT OR GATE

3-INPUT DATA SELECTOR

SELECTS 1-OF-3 INPUTS AND TRANSMITS
ITS LOGIC STATE TO THE OUTPUT.

ADDRESS (DATA SELECT)

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>DATA IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>B A</td>
<td>C B A</td>
<td></td>
</tr>
<tr>
<td>L L</td>
<td>X X L</td>
<td>L</td>
</tr>
<tr>
<td>L L</td>
<td>X X H</td>
<td>H</td>
</tr>
<tr>
<td>L H</td>
<td>X L X</td>
<td>L</td>
</tr>
<tr>
<td>L H</td>
<td>X H X</td>
<td>H</td>
</tr>
<tr>
<td>H L</td>
<td>L X X</td>
<td>L</td>
</tr>
<tr>
<td>H L</td>
<td>H X X</td>
<td>H</td>
</tr>
<tr>
<td>H H</td>
<td>X X X</td>
<td>L</td>
</tr>
</tbody>
</table>
8-INPUT NAND GATE
74LS30

Handy for byte-size (8-bit) decoding applications. Can decode up to 256 input combinations. Also useful as programmable NAND gate.

8-BIT DECODER

UNANIMOUS VOTE DETECTOR

1, 2, 3, 4, 5, 6 = 74HCU7404/74LS04
1', 2' = 74HCU7404/74LS04

LED GLOWS WHEN ALL INPUT SWITCHES ARE CLOSED.

OUTPUT GOES LOW ONLY WHEN INPUT IS LHLLHLLH (DEcimal 100). UP TO 256 INPUTS CAN BE DECODED BY REARRANGING UP TO 8 INPUT INVERTERS.

PROGRAMMABLE NAND GATES

5-INPUT

6-INPUT

7-INPUT
DUAL AND-OR-INVERT GATE
74LS51

VERY VERSATILE BUILDING BLOCK CHIP. IDEAL FOR CUSTOMIZED DATA SELECTORS, LATCHES AND EXPANSION OF A SINGLE INPUT TO AN AND-OR INPUT.

LATCH WITH ENABLE INPUT

Vcc (+5V)

Typical And-Or Input

Q OUTPUT FOLLOWS DATA INPUT WHEN ENABLE INPUT IS HIGH. NO CHANGE WHEN ENABLE IS LOW.

THIS CIRCUIT SELECTS 1-OF-2 4-BIT WORDS. NOTE THAT THE SELECTED WORD IS INVERTED AT THE OUTPUTS. THE CIRCUIT REQUIRES TWO 74LS51 CHIPS.

1-OF-2 DATA SELECTOR
DUAL NAND SCHMITT TRIGGER
74LS13

Two 4-input NAND gates with a switching threshold. Outputs go low when inputs exceed 1.7 volts. Outputs go high when inputs fall to 0.9 volt. If any input is low, the respective output will stay high and the gate will not trigger.

GATED THRESHOLD DETECTOR

--- indicates threshold level.

(When control input is high)

GATED OSCILLATOR

Oscillates when control is high. Change R1 and C1 to change frequency. OK to use this circuit as gated clock for logic circuits.

TWO-STATE LED FLASHER

LED flashes twice each second when control input is high. LED stays on and does not flash when control is low.

PHOTOTRANSISTOR RECEIVER

Use to clean up incoming light pulses.
HEX INVERTER
7404/74LS04

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

BOUNCETFREE SWITCH

OUTPUT FOLLOWS SWITCH POSITION.
1,2 = 1/3 7404/74LS04

UNIVERSAL EXPANDER

ALLOWS ONE SIGNAL TO 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>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>
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>Hi-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

Adding 3-State Output to TTL

Bidirectional Data Bus

1-OF-2 DATA SELECTOR

Input words

Selects 1-OF-2 2-bit words.

Selects:

H = B' A'
L = B A
HEX 3-STATE BUS DRIVER
74LS368

Each gate functions as an inverter 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>Hi-Z</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

BIDIRECTIONAL DATA BUS

Only one input gate can be enabled at one time. Any number of output gates can be enabled.

GATED TONE SOURCE

Tone frequency = 3.8kHz

Bouncedless switch (with enable)
4-BIT MAGNITUDE COMPARATOR
74LS85

Compares two 4-bit words. Indicates which is larger or if they are equal.

8-BIT COMPARATOR

HIGH EQUAL LOW

B IN B' IN

74LS85

INPUTS

OUTPUTS

B3 A<B A=B A>B A=B A>B A<B

74LS85

A IN A' IN

BINARY HI-LO GAME

Enter guesses in 52-55. An open switch is high and a closed switch is low.

Press S1 for a few seconds to load random number in 74193/74LS193. Use DIP switch array or toggles for 52-55.
BCD-TO-DECIMAL DECODER
7441

Decodes 4-bit BCD input into 1-of-10 outputs. Selected output goes low; all others stay high. Originally designed to drive gaseous glow discharge tubes. All outputs go high for binary inputs exceeding HLLH (1001).

1-OF-10 DECODED COUNTER

LEDs flash on sequentially in response to decoded count. Only one LED series resistor is required.

10-NOTE TONE SEQUENCER

Increase C1 to decrease tempo. Increase C2 to increase tone frequencies. Tones are determined by R3-R12.

57
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 RB1 (ripple blanking input) is low, all outputs are high (off). This permits unwanted leading 0's in a row of digits to be blanked.

MANUALLY SWITCHED DISPLAY

0-9 SECOND/MINUTE TIMER

Close S1 to start timing cycle. Calibrate 555 for 1 pulse (count) per second or 1 count per minute by adjusting R1.
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

TO PIN 4
7448

4.7K

0-99 TWO DIGIT COUNTER

LOWEST ORDER DISPLAY

HIGHEST ORDER DISPLAY

R1-R14:
330Ω

COMMON CATHODE LED DISPLAY

7490 / 74LS90

7490 / 74LS90
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 E1 is low, all outputs are high. To enable chip, make E1 high and E2 low. (Note: E2 = E2A + E2B.)

1-TO-8 DEMULTIPLEXER

DATA OUT

74LS138

DATA IN

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

2-TO-8 STEP SEQUENCER

OUTPUTS

74LS138

TO DESIRED SEQUENCE (E.G. CONNECT TO OUTPUT 4 AND CIRCUIT WILL CYCLE FROM 0 TO 3).

RI CONTROLS CYCLE RATE.

USE TO FLASH LEDS, CONTROL RELAYS, ETC.
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. Address in (selects 1-of-16 outputs)

SELECTED OUTPUT IS LOW WHEN DATA IN IS LOW. ADDRESS IN (SELECTS 1-OF-16 OUTPUTS)

BACK AND FORTH FLASHER

These LEDs flash back and forth, visually appealing.

INCREASE R1 TO SLOW FLASH RATE.
QUAD 1-OF-2 DATA SELECTOR
74LS157

FOUR 2-LINE TO 1-LINE MULTIPLEXERS. MANY USES IN ROUTING DATA. ALL 4 DATA SELECTORS ARE ENABLED WHEN PIN 15 IS LOW.

DOUBLE DUTY DISPLAY

BUS A
74LS157
11
14
3
6

BUS B
10
13
8
15

Vcc
16

7-SEGMENT DECODER (7447/7448) AND 7-SEGMENT DISPLAY.

BUS SELECTOR

BUS A
74LS157
11
14

BUS B
5
13
6
15

SELECT

OUTPUT

LOW = BUS A
HIGH = BUS B

WORD SORTER

74LS85
74LS157

A>B
A=B
A<B

Vcc
16

15
13
12
10
1
14
11
9

16

270

LARGEST WORD

74LS85
74LS157

Vcc
15
13
12
10
1
14
11
9

16

15
13
10

THIS CIRCUIT CONTINUALLY MONITORS TWO DATA BUSINES. BUS WITH HIGHEST MAGNITUDE DATA WORD IS ROUTED AUTOMATICALLY TO OUTPUT.
1-OF-8 DATA SELECTOR
74LS151

EQUIVALENT TO 8-LINE TO 1-LINE MULTIPLEXER.

PROGRAMMABLE GATE

3-BIT ADDRESS SELECTS ONE SWITCH AND APPLIES ITS STATUS (OPEN = HIGH AND CLOSED = LOW) TO THE OUTPUT. ANY 3-INPUT LOGIC FUNCTION CAN BE PROGRAMMED IN SECONDS.

PATTERN GENERATOR

PROGRAM ANY DESIRED LOW-HIGH BIT PATTERN. THEN PLAY IT BACK.

OCTAL KEYBOARD ENCODER

PRESS NUMBERED SWITCH AND ITS BINARY EQUIVALENT APPEARS ON THE READOUT LEDs. THE LEDS ARE OPTIONAL.
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.

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:

TONES 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 RI 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>Q</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>

φ is clock input.
? is rising edge of clock pulse.

2-BIT STORAGE REGISTER

Wave Shaper

Divide-by-two counter

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

\( \Phi \) 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:

DIVIDE-BY: TWO

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

DIVIDE-BY: THREE

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

DIVIDE-BY: FOUR

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

66
DUAL J-K FLIP-FLOP

7476

Two J-K flip-flops in a single package. Similar to 7473/74HC73 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>H</td>
<td>X</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>X</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>X</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>X</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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

Parallel Out (A B C D)

4-BIT BINARY UP COUNTER

DCEA binary out → A (2^0) B (2^1) C (2^2) D (2^3)
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.

68
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 Q OUTPUTS HIGH.

DATA BUS

Vcc (+5V)
CLR 1Q 1Q 1D 2D 2Q 2Q

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 DECENTRAL 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
BCD (DECADE) COUNTER
74LS196

More sophisticated version of the popular 7490/74LS90 BCD counter. Includes 4-Preset inputs which permit any BCD number to be loaded when pin 1 is made low. The counter is cleared to LLLL when pin 13 is made low. φ indicates clock input.

DECADE COUNTER

DECIMAL 16

4-BIT LATCH

WHEN LOAD INPUT IS LOW, OUTPUTS FOLLOW INPUTS. NO CHANGE WHEN LOAD INPUT IS HIGH. NOTE THAT A PAIR OF 74LS196'S CAN BE USED IN A DECIMAL COUNTING UNIT (COUNTER PLUS REGISTER).

DIVIDE-BY-5 COUNTER

DIVIDE-BY-10 COUNTER

0-4 COUNT IS AVAILABLE AT DCBA OUTPUTS.
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-12 COUNTER

DIVIDE-BY-9 COUNTER

10-HZ PULSE SOURCE

DIVIDE-BY-120 COUNTER

This method of cascading counters can be used to create any divide-by-n counter.
4-BIT (BINARY) COUNTER
7493 / 74LS93

EASY TO USE 4-BIT BINARY COUNTER. LESS EXPENSIVE THAN MORE SOPHISTICATED COUNTERS. RST INDICATES RESET PINS. NOTE UNUSUAL LOCATION OF POWER SUPPLY PINS.

DIVIDE-BY-10 COUNTER

DIVIDE-BY-11 COUNTER

DIVIDE-BY-12 COUNTER

DIVIDE-BY-16 COUNTER

4-BIT BINARY COUNTER

COUNTS FROM 0-15 IN BINARY AND RECycles. GLOWING LED = L (0); OFF LED = H (1). 555 TIMER IC MAKES GOOD INPUT CLOCK.

<table>
<thead>
<tr>
<th>DCBA</th>
<th>DCBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLLL</td>
<td>HLLL</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLH</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLH</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLH</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLL</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLL</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLL</td>
</tr>
<tr>
<td>LLLL</td>
<td>HLLL</td>
</tr>
</tbody>
</table>

R1-R4 = 270Ω
BCD UP-DOWN COUNTER
74192

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

CASCADED COUNTERS

SINGLE UP-DOWN INPUT

UP (0-99)
DOWN (99-0)

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.

74
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 LLLL 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 1/4 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
SI-S4 (CLOSED SWITCH = LOW
AND OPEN SWITCH = HIGH).
WHEN COUNT REACHES
LLLL AND THEN UNDERFLOWS,
THE BORROW PULSE LOADS N
AND THE COUNTER RECYCLES.

COUNT UP TO N AND HALT

PRESS SI (NORMALLY
CLOSED) TO RESET.

COUNT UP TO N
AND RECYCLE

76
**4-BIT SHIFT REGISTER 74LS194**

Bidirectional universal shift register. Shifts right when SO is high and SI is low. Shifts left when SO is low and SI is high. Shifts one position per clock pulse. Loads data at inputs when SO and SI are high. Important: Bypass power supply pins with 0.1\(\mu\)F capacitor.

**SEQUENCE GENERATOR**

Load any desired bit pattern into SI-SB (open = high and closed = low). Press S9 (normally closed) to load. Data will move right one output per clock pulse. LEDs are optional.

**BARGRAPH GENERATOR**

When power is first applied, make enable input low to start circuit. Outputs go low and stay low one at a time from left to right (A-D) in sequence with clock. When final output goes low, all outputs but the first go high and recycle.

---

78
**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.

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.

1, 2, 3, 4 = 7400/74LS00
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>IN</td>
</tr>
<tr>
<td>H</td>
<td>HI-Z</td>
</tr>
</tbody>
</table>

4-BIT BUS TRANSFER

TO BUS

FROM BUS

VCC (+5V)

19 18 17 16 15 14 13 12 11

20

1

WRITE

19

READ

* WHEN L

BUS

8-BIT BUS BUFFER

BUS A

BUS B

VCC

19

18 16 14 12 9 7 5 3

2 4 6 8 11 13 15 17

ENABLE

L = A → B

H = ISOLATED

Ā = INVERTED

BUS A
OCTAL BUFFER
74LS244

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

CONTROL (E1, E2) OUT
L IN
H HI-Z

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>OUTPUT</th>
<th>ENABLE</th>
<th>D</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>L</td>
<td>X</td>
<td>Q</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>X</td>
<td>HI-Z</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

REG. 2 (74LS373)

REG. 1 (74LS373)

H: disconnects REG. 1 from bus.
L: connects REG. 1 to bus.
H: outputs follow inputs.
L: input data (on bus) loaded.

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>D</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<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>Q</td>
</tr>
<tr>
<td>X</td>
<td>HI-Z</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
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:

EASILY CONTROLLED WITH A SINGLE FEEDBACK RESISTOR. FET INPUT OP-AMPS (BIFETS) HAVE A VERY HIGH FREQUENCY RESPONSE. IT'S USUALLY OK TO SUBSTITUTE OP-AMPS IF BOTH ARE NORMALLY POWERED BY A DUAL POLARITY SUPPLY (1/2 LF353 FOR 741C, ETC.)...BUT PERFORMANCE WILL IMPROVE OR DECREASE ACCORDING TO THE NEW OP-AMP'S 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 ARE A FLASHER CHIP AND A DOT-BARGRAPH 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 IDEAL FOR DO-IT-YOURSELF STEREO, PUBLIC ADDRESS SYSTEMS, INTERCOMS AND OTHER AUDIO APPLICATIONS.
VOLTAGE REGULATORS
7805 (5-VOLTS)
7812 (12-VOLTS)
7815 (15-VOLTS)

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

T1 - 117-12.6 V, 1.2A or 3A TRANSFORMER
B1 - 1A-4A FULL WAVE BRIDGE RECTIFIER

VOLTAGE REGULATOR

VOLTAGE IN

+5, 12 OR 15 VOLTS

GROUND

Cin - optional; use 0.33 µF or so if
regulator far from power supply.
Cout - optional; use 0.1 µF or more to
trap spikes that bother logic ICs.

CURRENT REGULATOR

USES INCLUDE STABLE
BIASING FOR
LEDs, LAMPS,
etc.

OUTPUT CURRENT = REGULATOR VOLTS
R1

OUTPUT
-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**

-5.5 to -35 volts in

-5 volts out

2.2 μF

*Working voltage must exceed Vin.*

**Adjustable Negative Power Supply**

-5.5 to -35 volts in

-5 to -30 volts out

2.2 μF

22 μF

Radj

1 k

<table>
<thead>
<tr>
<th>Radj</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>680</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 > 25μF.

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

Vin (≥ 28V) 2

Limit maximum Vout to 27V when input is 28V.

<table>
<thead>
<tr>
<th>R (Ω)</th>
<th>Vout (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.8</td>
</tr>
<tr>
<td>330</td>
<td>3.0</td>
</tr>
<tr>
<td>470</td>
<td>4.0</td>
</tr>
<tr>
<td>1K</td>
<td>7.3</td>
</tr>
<tr>
<td>2.2k</td>
<td>13.5</td>
</tr>
<tr>
<td>3.3k</td>
<td>18.0</td>
</tr>
</tbody>
</table>
-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.

ADJUSTABLE NEGATIVE REGULATOR

\[ V_{IN} > V_{OUT} \]
\[ -1.5 \text{ TO } -37 \text{ VOLTS IN} \]
\[ -V_{OUT} = -1.25V \left( 1 + \frac{R_2}{R_1} \right) \]

* WORKING VOLTAGE MUST EXCEED \( V_{IN} \).

PRECISION LED REGULATOR

SUPPLIES CONSTANT CURRENT (I) TO LED.

\[ V_{IN} = -5 \text{ TO } -37 \text{ V} \]

\[ \text{LED } I = 1.5V/R_1. \]
\[ R_2 \text{ GIVES } \pm 15\% \text{ ADJUSTMENT.} \]
\[ \text{LED } I = 15 \text{ mA WHEN } R = 100 \Omega. \]
2-37 VOLT REGULATOR

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

```
V_{\text{IN}} (\pm 10 V) \quad \text{V}_{\text{OUT}}
```

```
R_1 \quad R_2 \quad R_3 \quad \text{TYPICAL VALUES}

V_{\text{OUT}} \quad R_1 \quad R_2 \quad R_3
3.0 \quad 4.12 \text{K} \quad 3.01 \text{K} \quad 1.74 \text{K}
3.6 \quad 3.57 \text{K} \quad 3.65 \text{K} \quad 1.80 \text{K}
5.0 \quad 2.15 \text{K} \quad 4.99 \text{K} \quad 1.50 \text{K}
6.0 \quad 1.15 \text{K} \quad 6.04 \text{K} \quad 9.66
```

FOR ANY VOLTAGE BETWEEN 2-7 VOLTS:

\[ V_{\text{OUT}} = (V_{\text{REF}}) \times \left( \frac{R_2}{R + R_2} \right) \]

\[ V_{\text{REF}} = 6.8 - 7.5 \text{ V (MEASURE AT PIN 6)} \]

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

7-37 VOLT REGULATOR

```
V_{\text{IN}} (V_{\text{IN}} = V_{\text{OUT}} + 5) \quad \text{V}_{\text{OUT}}
```

```
R_2 \quad R_3 \quad \text{TYPICAL VALUES}

V_{\text{OUT}} \quad R_1 \quad R_2 \quad R_3
9 \quad 1.87 \text{K} \quad 7.15 \text{K} \quad .48 \text{K}
12 \quad 4.87 \text{K} \quad 7.15 \text{K} \quad 2.90 \text{K}
15 \quad 7.87 \text{K} \quad 7.15 \text{K} \quad 3.75 \text{K}
28 \quad 21.0 \text{K} \quad 7.15 \text{K} \quad 5.33 \text{K}
```

FOR ANY VOLTAGE BETWEEN 7-37 VOLTS:

\[ V_{\text{OUT}} = (V_{\text{REF}}) \times \left( \frac{R_1 + R_2}{R_2} \right) \]

\[ R_3 \text{ (R3, WHICH IS OPTIONAL, GIVES TEMPERATURE STABILITY)} \]

90
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

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

VOLTAGE DETECTOR

USE TO DETECT TTL LOGIC LEVELS.

SIMPLE TIMER

\[ \text{DELAY} = (R_1 C_1) \left( \ln \left( \frac{9}{9-V_{\text{ref}}} \right) \right) \]

1.5 TO 5V POWER SUPPLY
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.

ATTACH HEAT
SINK IF REQUIRED

1 - ADJUST
2 - INPUT
3 - OUTPUT

1.2 TO 20 VOLT REGULATOR

R1 CONTROLS
OUTPUT

1.2K
50K

2 TO 35 VOLTS
IN

1.2 TO 33 VOLTS
OUT

POWER PULSE GENERATOR

Vcc = 5 TO 15 VDC

RS SETS AMPLITUDE.
R1 CONTROLS RATE.

USE TO FLASH
INCAPDSECENT
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

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

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

NON-INVERTING AMPLIFIER

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

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

UNITY GAIN FOLLOWER

USE TO COUPLE HIGH IMPEDANCE TO LOW IMPEDANCE.

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

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

COMPARATOR

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

LEVEL DETECTOR

\[ R_1 \text{ SETS THE VOLTAGE DETECTION THRESHOLD (UP TO } +9) \text{. WHEN } V_{\text{in}} \text{ EXCEEDS THE THRESHOLD (ALSO CALLED THE REFERENCE), THE LED GLOWS.} \]

TYPICAL USES:
AMPLIFICATION OF DC VOLTAGE AND PULSES.
OPERATIONAL AMPLIFIER  (CONTINUED)

741C

BASIC INTEGRATOR

\[ V = \pm 5-18 \text{V} \]

\[ C_1 = 0.001 \]
\[ R_1 = 10k \]
\[ R_2 = 100k \]
\[ R_3 = 10k \]

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

When \( V = \pm 9 \text{V} \)
And \( \text{IN} = \pm 0.25 \text{V} \),
\( \text{OUT} = \pm 1 \text{V} \).

BASIC DIFFERENTIATOR

\[ V = \pm 5-18 \text{V} \]

\[ C_1 = 0.000022 \mu F \]
\[ R_1 = 100k \]
\[ R_2, R_3 = 10k \]

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

When \( V = \pm 9 \text{V} \)
And \( \text{IN} = \pm 0.25 \text{V} \),
\( \text{OUT} = \pm 0.25 \text{V} \).

CLIPPING AMPLIFIER

\[ V = \pm 5-18 \text{V} \]

\[ \text{DI AND D2 = ZENER DIODES. IF } V_2 = 6 \text{V}, \]
Then output cannot exceed \( \pm 6.7 \text{V} \).

\[ \text{V}_{\text{OUT}} = -V_{\text{IN}} \left( \frac{R_2}{R_1} \right) \ldots \]
Up to \( V_2 + 0.7 \text{V} \).

BRIDGE AMPLIFIER

\[ R_3 = 100k \]
\[ R_5 = 100k \]
\[ R_6 = 5k \]

\[ +0.1 \text{mA} \]

\[ \text{R4: BALANCE, R6: ZERO} \]

\* \( R_1 \) is unknown resistor. Use CdS cell for \( R_1 \) to make a very sensitive light meter.

SUMMING AMPLIFIER

\[ V = \pm 5-18 \text{V} \]

\[ \text{V}_{\text{OUT}} = - (V_{\text{IN1}} + V_{\text{IN2}}) \]

NOTE: \( \text{VOUT cannot exceed } \pm 5 \text{V} \).

DIFFERENCE AMPLIFIER

\[ V_{\text{OUT}} = V_{\text{IN2}} - V_{\text{IN1}} \]
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.

4-BIT D/A CONVERTER

HIGH PASS ACTIVE FILTER

LOW PASS ACTIVE FILTER

VALUES SHOWN:
-0 dB = 750 Hz
-3 dB = 350 Hz
-35 dB = 60 Hz

VALUES SHOWN:
-0 dB = 50 Hz
-3 dB = 250 Hz
-50 dB = 10 kHz

95
OPERATIONAL AMPLIFIER 741C

(CONTINUED)

OPTICAL POWER METER

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

BARGRAPH LIGHT METER

Q1 IS A PHOTOTRANSISTOR CONNECTED AS A PHOTODIODE. A SILICON SOLAR CELL CAN ALSO 470 BE USED. USE GREEN LEDS FOR READOUT.

ELECTRONIC BELL

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

AUDIBLE LIGHT SENSOR

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

PULSE GENERATOR

C1 STORES THE PEAK VOLTAGE AT VIN.

APPLICATIONS INCLUDE USE AS ANALOG "MEMORY" THAT STORES PEAK AMPLITUDE OF A FLUCTUATING VOLTAGE.

PULSES ARE DC. AMPLITUDE WHEN C1 = 0.1 uF IS 5 VOLTS.

FUNCTION GENERATOR

R1 100K
R2 27K
R3 100K
R4 10K
R5 1K
R6 10K
R7 10K
R8 100K
R9 10K
R10 10K

C1 100uF
C2 1uF
C5 .0022

SQUARE: ± 7.5V
TRIANGLE: ± 2V
SINE: ± 2V

FREQUENCY = 1 KHz
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 TLO84C. NOTE THAT PIN CONNECTIONS ARE THE SAME AS 1458. THIS OP-AMP, HOWEVER, OFFERS MUCH BETTER PERFORMANCE.

SAMPLE AND HOLD

PEAK DETECTOR

TRACKS V_{IN} AND STORES PEAK V_{IN} IN C1.

REDUCE C1 FOR FASTER RESPONSE TO CHANGING V_{IN}

PROGRAMMABLE GAIN OP-AMP

AUDI MIXER

CONNECT OUTPUTS OF PREAMPLIFIERS TO INPUTS 1-3. OK TO ADD MORE CHANNELS. WORKS WELL WITH TLO84 MICROPHONE PREAMPLIFIERS.
QUAD OPERATIONAL AMPLIFIER
TL084C (JFET INPUT)

HIGH IMPEDANCE (10¹² 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

LOW-Z PREAMPLIFIER

USE LOW TO MEDIUM IMPEDANCE Dynamic Mike

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

RED
WHITE
BLUE

INFRARED VOICE COMMUNICATOR

R2 (GAIN 1M CONTROL) R2 (GAIN 100K)

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

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

MAXIMUM RANGE: HUNDREDS OF FEET AT NIGHT WITH LENSES AT Q1 AND LED. POWER AMP: SEE LM386.
**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: shorting the outputs directly to V+ or GND or reversing the power supply may damage this chip.

---

**BANDPASS FILTER**

![Bandpass Filter Diagram]

**INFRARED TRANSMITTER**

![Infrared Transmitter Diagram]

Carefully adjust R3 for best voice quality. For more input, receive power reduce R5 to 50 ohm... but do not allow more than plus op-amp 50 mA through LED!

---

**PULSE GENERATOR**

![Pulse Generator Diagram]

DI-D2: ok to eliminate. If so, connect R2 to pin 1 and eliminate R3.

**INTERFACE CIRCUITS**

![Interface Circuits Diagram]

Observe Q1's power rating!

TTL Driver

All +1/4 LM 324 N

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

FUNCTION GENERATOR

X10 AMPLIFIER

FREQUENCY = 1.2 KHz

NOTE: DO NOT SUBSTITUTE LM3900 FOR OTHER OP-AMPS.
QUAD COMPARATOR
LM339

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

+INPUT VOLTAGE +2-32V

R1-R2 DETERMINE REFERENCE VOLTAGE (+4.5 V as shown).

INVERTING COMPARATOR WITH HYSTERESIS

INVERTING COMPARATOR

NOTES: HYSTERESIS PROVIDED
BY FEEDBACK RESISTOR STOPS OSCILLATION.

NON-INVERTING COMPARATOR WITH HYSTERESIS

TTL DRIVER  CMOS DRIVER

3-STATE OUTPUT

+REFERENCE VOLTAGE

+INPUT VOLTAGE

+REFERENCE VOLTAGE

+INPUT VOLTAGE

TO TTL

TO CMOS

CONTROL L=ENABLE A=H1-2

\[ \frac{1}{2} 74L5367 \]
LED BARGRAPH READOUT

Adjust R1 to achieve sensitivity up to a few millivolts per LED. See Popular Electronics (Sept. 1978, pp. 92-97).

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=5000Ω, 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.

SQUAREWAVE OSCILLATOR
LED FLASHER / OSCILLATOR
3909

EASIEST TO USE IC IN THIS NOTEBOOK. FLAES 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

POWER FLASHER

INFRARED TRANSMITTERS

LIGHT CONTROLLED TONE

LAMP FLASHER

104
DOT/BAR DISPLAY DRIVER
LM3914N

One of the most important chips in this notebook is the LM3914N. It 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:

R₁ and R₁₀ 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.

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, and adjust R₁. Replace the 1K pot with a fixed resistor of the proper value.
DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

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.

S1 is the mode switch. Use a DPDT toggle. Position 1 selects bar and position 2 selects dot. Omit S1 if only one mode is required. Simply wire in the correct connections.

FLASHING BAR READOUT

When all 10 LEDs are on the display flashes. Otherwise the LEDs do not flash. Increase C1 to slow flash rate.

The circuits on this page are adapted from National Semiconductor's LM3914 literature. Both work well.
DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

SOLID-STATE OSCILLOSCOPE

R1: VERTICAL GAIN
R3: HORIZONTAL SWEEP/TIMEBASE
USE R3 TO SYNCHRONIZE SCOPE WITH INCOMING WAVE.

SCREEN:
100 RED LEDS CONNECTED TO INTERSECTING LINES LIKE THIS

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

SI: 1 = TRIGGERED SWEEP
2 = FREE RUNNING

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

ANY LED OUTPUT LM3914

C1 = 47 UF (PREVENTS CHATTER)
DI = IN914

OPTICAL COUPLING

RY1

POINT Q1 AT 1-OF-10 LEDS TO DETECT SPECIFIC OUTPUT LEVEL.

RELAY: NORMALLY OPEN NORMALLY CLOSED
**DOT/BAR DISPLAY DRIVER**

**LM3915N**

LOGARITHMIC VERSION OF THE LM3914 N. THE LM3914N USES A STRING OF 1K RESISTORS AS A VOLTAGE DIVIDER WITH LINEARLY SCALED DIVISIONS. THE VOLTAGE DIVIDER RESISTORS OF THE LM3915N ARE SCALED TO GIVE A -3 dB INTERVAL FOR EACH OUTPUT. THIS CHIP IS IDEAL FOR VISUALLY MONITORING THE AMPLITUDE OF AUDIO SIGNALS.

**0 TO -27 dB DOT/BAR DISPLAY**

![Diagram](image)

**LED DISPLAY**

<table>
<thead>
<tr>
<th>dB</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(FULLSCALE OR FS)</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>

*OK TO USE DOT MODE.*

THE INPUT SIGNAL CAN BE CONNECTED DIRECTLY TO PINS WITHOUT RECTIFICATION, LIMITING OR AC COUPLING. SEE THE LM3914N 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 = \frac{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_DD MUST NOT
EXCEED 1.6 VOLTS!

ALARM CLOCK

NOTE: ALL UNUSED PINS MUST GO TO
V_DD OR V_SS (YOUR CHOICE).
(BACK)

ALARM CLOCK RADIO

KEEP RADIO
SWITCH ON.

TO AL1

TO V_SS

CLOCK CONTROLLED RELAY

*CAUTION: USE
CARE WHEN
SWITCHING
LINE VOLTAGE!

TO AL1

TO V_SS

CURRENT DRAIN:
RELAY ON = 14.8 mA
RELAY OFF = 1.8 mA

SI: NORMALLY CLOSED
PUSHBUTTON.
OPEN (PRESS) TO
RESET. MUST
WAIT FOR 15
SECOND ALARM
CYCLE BEFORE
RESETTING.
**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**

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

**One-Shot Timer**

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.
**Timer (Continued)**

**555**

**Toy Organ**

![Circuit Diagram for Toy Organ]

- R1 100k (Controls Frequency Range)
- R2 1k
- S1
- S2
- S3
- S4
- S5
- C1 0.10 μF
- C2 0.05 μF
- C3 0.01 μF
- C4 0.005 μF
- C5 0.001 μF

Typical Values:

 TOO LOUD? ADD 100K RESISTOR.

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

**LED Transmitter**

![Circuit Diagram for LED Transmitter]

- C1 0.05 μF
- C6 4.7 μF
- R1 10k
- R2 1k
- BJR
- 555
- 8
- 4
- 3
- +5-15

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.

Circuit pulses LED with 45 μsec long, 120 mA pulses at a rate of 4.8 kHz.

**Pulse Generator**

![Circuit Diagram for Pulse Generator]

- C1 0.01 μF
- R1 1M
- R2 1k

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

**Missing Pulse Detector**

![Circuit Diagram for Missing Pulse Detector]

- R1 100k
- 555
- C1 0.1 μF

This circuit is a one-shot that is continually retriggered by incoming pulses. A missing or delayed pulse that 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.
TIMER (CONTINUED)

555

ULTRA-LONG TIME DELAY

R1 controls pulse rate from 555. This rate is divided by the 4017's to give x10, x100 and x1000 delays.

555

100k

R1

.1µF

C2

4.7µF

C1

.05µF

C3

1K

R2

LED

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

TOUCH WIRE (TOUCH AND LED WILL GLOW 1 SECOND)

ADDITIONAL STAGES

1 = RESET

TYPICAL OUTPUT: 555 (PIN 3) 4017 (X10 OUTPUT)

2 = RUN

LIGHT DETECTOR

produces warning tone when light strikes photocell. Makes a good open door alarm for refrigerator or freezer.

DARK DETECTOR

silent when light strikes photocell. Remove light and tone sounds. Faster response than adjacent circuit.
NEON LAMP POWER SOURCE

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

FREQUENCY DIVIDER

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

TRIANGLE WAVE GENERATOR

Adjust RI to provide up to 10 kHz. Output frequency this high produces closely spaced triangle waves. The waves are separated at slower frequencies ( ).

ONE-SHOT TONE BURST

Press SI and steady output frequency appears at pin 3. Release SI 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

Interval Timer

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

+5-15

R1 500K
R2 1K
C1 .0uF

556

556

R4 500K
R3 5K (VOLUME)

B.J. SPKR

C2 .01uF

R5 1M

THIS CIRCUIT IS AN OSCILLATOR FOLLOWED BY A FREQUENCY DIVIDER. ADJUST R1 AND R4 FOR VERY UNUSUAL SOUND EFFECTS.

R1 1M
R2 24K
C1 1-100uF

R1 1M
C3 .05uF
C5 .05uF 1-100uF

R4 1M

R3 24K

556

OUTPUTS

R5 1M
C2 .05uF

C4 .01uF

R6 270Ω
B.J. SPKR

TWO-STAGE TIMER

+5-15

R1 1M
R2 24K
C1 1-100uF

R3 24K

R4 1M

R1 1M

R3 24K

R2 24K

R5 1M

R6 270Ω
B.J. SPKR

C3 .05uF
C5 .05uF 1-100uF

C4 .01uF

TRIGGER

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.

PROGRAMMABLE 4-STATE TONE GENERATOR

+5-15

R1 2.2K
R2 100K
C1 33uF

556

556

R4 5K

4051

A MODE SELECT

B A OUTPUT

L L TWO-TONE
L H STEADY
H L BURST
H H METRONOME

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

CHANGE C1 AND C4 TO ALTER THE OUTPUT TONES.

117
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

RI 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

See above circuit. Add this voltage divider to keep duty cycle constant when rate is changed.

FIXED DUTY CYCLE PULSER

THIS WILL DRIVE LED

LONG DURATION TIMER

RS = R6 = R7 = 4.7K

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

```
IN .01
.01 4.7K
.01 4.7K
.01 4.7K
7555
.01 4.7K
.22

+ -

Vcc

*CALIBRATE INPUT MUST BE SQUARE WAVE.
```

**LIGHT PROBE FOR BLIND**

```
CdS PHOTO-CELL
10K (ZERO)
0-1mA
22K

7555

1K (VOLUME)
8 OHM SPKR

4.7uF
```

**EVENT FAILURE ALARM**

```
7555

IC1 = 4011

ALARM TONE SOUNDS IF SI IS NOT CLOSED WITHIN 5-30 SECONDS.

2N2907
2.2-10uF

TO AUDIO AMP
```

120
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.

PULSE-FREQUENCY-MODULATED INFRARED COMMUNICATOR

TRANSMITTER

R3 100K
R1 5.6K
R2 5.6K
MIC
+9

741
555
C1 .1
C2 470pF
C3 10µF
LED
+9

R6 100K
R4 100K
R5 10K

OPERATION: Point LED at Q1. Apply power and adjust R4 in XMTR until good quality sound heard from RCVR (~35-45 kHz). Lenses will give range of hundreds of feet at night.

RECEIVER

R1 10K
C1 .1
R2 1K
C3 1µF
Q1 PHOTO-E TRANSISTOR

741
565
R3 1M
R4 3.9K
C4 .001
C5 .047
C6 10µF
C7 100µF

580
8Ω SPKR

TRANSMITTER: R3 controls gain. R4 controls carrier frequency. For initial tests, remove MIC and connect TRANSMITTER RADIO PHONE output to R3 via 4.7 µF and GND. Use low volume setting. R3 must be 10K.

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!

KEEP PWR LEADS ON BOTH UNITS SHORT. USE 0.1µF ACROSS PWR CONNECTIONS (AT CHIPS) IF OSCILLATION OCCURS. HAVE FUN.
PHASE-LOCKED LOOP (PLL) 4046

Exceptionally versatile chip. Contains two phase comparators and voltage controlled oscillator (VCO). Use VCO and one phase comparator to make PLL circuits. On this page use VCO only.

SPEAKER AMPLIFIER*

*Use with circuits on this page.

CHIRP BURST SEQUENCER

R2: Adjust for 1-4 chirps per cycle. Chirps will have different frequencies.

R3: Controls pitch of chirps. For tones instead of chirps, connect to pin 12 instead of pin 11.

ADJUST R1 TO VARY FREQUENCY (0.5 Hz → 18.5 kHz)

SIREN

CHANGE R1 OR C1 TO ALTER CYCLE TIME.

CHANGE R4 OR C2 TO ALTER FREQUENCY.

CHANGE R3 OR C3 TO ALTER WAIL.
PHASE LOCKED LOOP (CONTINUED)

4046

SOUND EFFECTS GENERATOR

PRODUCES FASCINATING VARIETY OF UNDULATING AND CHOPPED TONES. R1 CONTROLS CYCLE TIME. R2 CONTROLS DELAY TIME. R4 CONTROLS FREQUENCY RANGE. R5 CONTROLS CHOPPING RATE. CHANGING R5'S SETTING GIVES MOST DRAMATIC RESULTS.

LOCK INDICATOR *

* USE TO VERIFY LOCK OF 4046 IN PLL MODE.

LED GLOWS OR FLICKERS WHEN 4046 IN PLL MODE IS OUT OF LOCK.

FREQUENCY SYNTHESIZER

SELECT TIMEBASE FREQUENCY MULTIPLICATION FACTOR. SET TIMEBASE TO ~100Hz.

TONE BURST GENERATOR

R1 SETS TONE FREQUENCY.

R3 SETS BURST RATE.

123
TONE DECODER

567

Contains a phase-locked loop. Pin 8 goes low when the input frequency matches the chip's center frequency \( f_0 \). The latter frequency is set by the timing resistor and capacitor \((R \text{ and } C)\) and is \( (1.1) \div (RC) \). \( R \) should be between 2k-20k. The 567 can be adjusted to detect any input between 0.01Hz to 50kHz. 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 VALUE IN MICROPARDs OF THE LOW PASS CAPACITOR SHOULD BE \( \frac{m}{f_0} \) WHERE \( m \) RANGES BETWEEN 1300 (FOR UP TO 14% \( f_0 \) DETECTION BANDWIDTH) TO 62,000 (UP TO 2% \( f_0 \) DETECTION BANDWIDTH). THE OUTPUT CAPACITOR SHOULD HAVE ABOUT TWICE THE CAPACITANCE OF THE LOW PASS FILTER CAPACITOR.

BASIC TONE DETECTOR CIRCUIT

ADJUSTABLE TONE SOURCE (OPTIONAL)

R3 1K
C3 2.2uF
C4 1uF

+9

SW7

3

R2 10K
+9

R1 100K
C1 .1uF

1

This circuit is handy for learning tone decoder basics. The 567 portion can be used in many different applications (see below). The predicted \( f_0 \) is 1.1 kHz. The test circuit \( f_0 \) was 1.3 kHz.

INFRARED REMOTE CONTROL SYSTEM

TRANSMITTER

R3 10
C1 .33uF

1

ADJUST R1 UNTIL RECEIVER LED GLOWS.

R1 10K
R2 1.2K

+9

555

INFRARED LED

RECEIVER

R3 100K
C1 .1uF
1K

PHOTO-TRANSMITTER

RANGE: SEVERAL INCHES.

C3 2.2uF
C4 .1uF

OK TO USE UV RELAY.

USE LENSES TO INCREASE.
2-FREQUENCY OSCILLATOR

2-PHASE OSCILLATOR

LATCHING THE 567 OUTPUT *

Both circuits show only the latch components. RL is the load (LED, relay, etc).

*Output stays on even after input tone is removed.

NARROW BAND FREQUENCY DETECTOR

Adjust R1 and R2 to respond to closely spaced frequencies. LED1 and 3 will glow if frequency is high or low. LED 2 will glow when the input frequency is centered.
TOUCH-TONE® DECODER

IC 1, 2, 3 = 7402
ACTIVE OUTPUT = 4

697 Hz  C2 = 4.7 μF
567

770 Hz  C2 = 4.7 μF

852 Hz  C2 = 4.7 μF

941 Hz  C2 = 2.2 μF

1209 Hz  C2 = 2.2 μF

1336 Hz  C2 = 2.2 μF

1477 Hz  C2 = 2.2 μF

IN: 50–200 mV

REPEAT THIS CIRCUIT BELOW.
TUNE EACH 567 VIA R1.

IN: 50–200 mV

IC 1, 2, 3 = 7402
ACTIVE OUTPUT = 4
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

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.

Basic V/F Converter

FSK* Data Transmitter

CAUTION: This chip incorporates both bipolar and CMOS circuitry. Therefore CMOS handling precautions must be followed to avoid permanent damage.
VOLTAGE-TO-FREQUENCY (CONTINUED)
FREQUENCY-TO-VOLTAGE CONVERTER
9400

AUDIO FREQUENCY METER

INPUT FREQUENCY MUST CROSS 0 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

*ADAPTED FROM A DESIGN BY MICHAEL PAIVA OF TELEDYNE.

THE SPKR IS OPTIONAL BUT MAY PROVE HELPFUL DURING INITIAL TESTING. USE AN INFRARED LED, THE LED, Q1 CAN BE THE PHOTOTRANSISTOR SUPPLIED WITH R7 IN THE RECEIVER IS ZERO ADJUST.
VOLTAGE CONTROLLED
OSCILLATOR (VCO)

566

Very stable, easy to use triangle and square wave outputs. R1 and C1 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

R2 controls frequency.

TWO-TONE WARBLER

R1 controls warble rate.

R3 controls tone frequency.

\[ \text{Center Frequency} = \frac{2(V_{cc} - \text{input volts})}{R1 \cdot C1 \cdot V_{cc}} \]

*FSK MEANS FREQUENCY SHIFT KEYING.*

L 1.5 kHz lines or store binary data over telephone lines.
H 3.0 kHz data on magnetic tape.

\[ V_{cc} = 9 \text{ volts.} \]
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 Vcc1 or Vcc2.

Vcc1 = 3.5 to 6 volts
Vcc2 = 8 to 18 volts

PULSE WIDTH MODULATOR

8-BIT ANALOG-TO-DIGITAL CONVERTER

8-bit data bus

Bus enable (when low)

This project for advanced experimenters.

IC1 = 74LS500
IC2 = 74LS502

131
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

TI: 120 VAC / 25.2 VAC CT

Caution!
You must insulate connections!

* Use TO-220 heat sink.

132
256-STEP STAIRCASE GENERATOR

DAC 801 TONE GENERATOR

+5

RI 100K

10K

CI .01

8.2Ω

RI AND CI CONTROL TONE RANGE.

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

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

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 = maximum current into pin 2.

R_set = \frac{0.077}{I_{set}} at 25°C.

10% OUTPUT VOLTAGE VARIES ~10 MILLIVOLTS/° KELVIN.

10 K

0.001 μF

1.5 K

0.3 K

0.001 μF

LED CURRENT

10 Ω

6.4 mA

15 Ω

4.3 mA

CONSTANT LED OUTPUT FOR ANY INPUT BETWEEN 3-20 VOLS.
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  X200 AMPLIFIER

BASS BOOSTER  AUDIBLE ALARM

HIGH GAIN POWER AMPLIFIER

CIRCUIT SHOWN IS VERY SENSITIVE LIGHT WAVE RECEIVER. OK TO USE OTHER OP-AMPS FOR THE TLO84.

Q1 - PHOTOTRANSISTOR
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. Spread some heat sink compound on the LM383 tab before attaching the heat sink.

8-WATT AMPLIFIER

```
+5-20V

+1 2 3 4 5
C1 10μF
C2 1μF
C3 470μF
C4 22μF
C5 1000-2000μF

R1 220
R2 2.2
R3 220
R4 220
R5 2.2
R6 1M
R7 100k
C6 470μF
C7 10μF
C8 2μF
```

* C4 - Place close as possible to the IC.
R2 - OK to use 4-10Ω resistors in parallel.

**OPERATION:**
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.

16-WATT BRIDGE AMPLIFIER
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

NOTE: GND pins should be heat sunk for maximum power.

4-WATT AMPLIFIER

This circuit works well. Note fewer parts in LM1877/LM377 stage... thanks to split power supply.
COMPLEX SOUND GENERATOR
SN76477N

INTEGRATES 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.

NOTE: THE SN76488 INCLUDES BUILT-IN SPEAKER AMPLIFIER. THE SN76477 DOES NOT.

ENVELOPE SELECT 1
GROUND 2
EXTERNAL NOISE CLOCK 3
NOISE CLOCK 4
NOISE FILTER 5
NOISE FILTER 6
DECAY 7
MIXER SELECT C 27
MIXER SELECT A 26
MIXER SELECT B 25
ONE-SHOT 24
ONE-SHOT 23
VCO SELECT 22
S.L.F. 21
S.L.F. 20
PITCH CONTROL 19
VCO 18
VCO 17
EXTERNAL VCO 16
AUDIO OUTPUT 13
AMPLITUDE 11
FEEDBACK 12
ATTACK/DECAY 8
SYSTEM ENABLE 9

14

+4.5 - 12V (9V BEST)
VREG

THIS CHIP IS EASY TO USE IF YOU FOLLOW DATA SHEET INSTRUCTIONS.

PERCUSSION SYNTHESIZER

SI—PRESS TO ACTIVATE SOUND.

SN76477N

CONTROLS DECAY
ADDS EXPONENTIAL DECAY
USE 270K TO SLOW
FREQUENCY CONTROL
CONTROL SOUN D DURATION
1-10M
1M
100K
10K
K
.1
.47
100K
470
47K
8-OHM SPKR

10M
100-500 (VOLUME)
NOISE GENERATOR

PRODUCES STEADY HISS. MAKE SNARE DRUM BY CONNECTING PUSHBUTTON IN SERIES WITH SPEAKER. ADD S.L.F. OSCILLATOR TO MODULATE THE HISS. (SELECT S.L.F. + NOISE BY CONNECTING 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 1 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 Vcc GOES FROM +6 TO +9V.

---

ONE-SHOT OUTPUT 1
VCO OUTPUT 2
NOISE CLOCK OUTPUT 3
S.L.F. OUTPUT 4
NOISE 5
NOISE 6
DECAY 7
DECAY 8
INHIBIT 9
AUDIO INPUT 10
S-VOLTS OUT 11
Vcc (+9V) 12
AUDIO OUT 13
GROUND 14
ENVELOPE SELECT 1 26
ENVELOPE SELECT 2 27
S.L.F. SELECT 24
MIXER B INPUT 25
MIXER A INPUT 24
MIXER C INPUT 23
ONE-SHOT 22
ONE-SHOT 21
ONE-SHOT
VCO SELECT 20
S.L.F. 19
S.L.F. 18
S.L.F.
VCO 17
VCO 16
VCO
EXTERNAL VCO CONTROL 15

---

BOMB DROP PLUS EXPLOSION

+6 TO 9

PRESS TO START

C6 100μF

SN76488N

R1 680K
R2 500K
R3 470K
C1 470pF
C2 4.7μF
C3 .005
C4 22μF
C5 33μF
RS 100K
R2 CONTROLS DURATION OF EXPLOSION.
RS CONTROLS ALTITUDE.

8Ω SPKR
COMPLEX SOUND GENERATOR (CONTINUED)
SN76488N

IMPROVED STEAM ENGINE AND WHISTLE

R2 CONTROLS ENGINE SPEED.
R4 CONTROLS WHISTLE FREQUENCY.

PRESS FOR WHISTLE
* USE .0047 FOR RASPY WHISTLE OR .01 FOR PURE TONE.

C5
C4 100µF

8 Ω SPKR

THE ULTIMATE SIREN

R3 (OPTIONAL VOLUME CONTROL)

R1 CONTROLS CYCLE RATE.
R2 CONTROLS FREQUENCY.

ADJUST R1 FOR HIGH RESISTANCE TO GIVE ULTRA SLOW SIREN.
RHYTHM PATTERN GENERATOR
MM5871

PRODUCES SIX DIFFERENT RHYTHM PATTERNS AND TRIGGERS FIVE DIFFERENT INSTRUMENTS.
ADJUSTABLE TEMPO. COMPlicated TO USE, BUT WELL WORTH THE EFFORT.

RHYTHM BOX

POWER CORD
T1 120V-24V TRANSFORMER

B1 BRIDGE RECTIFIER
C1 1000 µF 35V

7815

2

LM317 CASE

R1 240
R2 SK

+27V

GND (0V)

+15V

C2 .1µF
R3 200k
C3 .1µF
R4 2M

S2688/MM5837N

Q1 2N2222

D1 1N914 100k

Q2 2N2222

D2 1N914 100k

R8 100k

R9 100k

12 13 11 10 9

TRIGGER OUTPUTS
(SEE FACING PAGE)

BASS DRUM

BLOCK

BONGO

SNARE

BRUSH

1/4 TIME
TRIGGER OUTPUTS

16 15 14 13 12 11 10 9

VGG TEMPO VDD VSS

1/4 TIME

PULSE WIDTH
RHYTHM PATTERN GENERATOR (CONTINUED)

MM5871 PIN EXPLANATIONS:
1 - VGG (-27V ± 2V)
2 - TEMPO CONTROL (RC NETWORK)
3 - TRIGGER OUTPUT PULSE WIDTH CONTROL (RC NETWORK)
4 - VDD (-14V ± 2V)
5 - VSS (0V)

PATTERN SELECT INPUTS:
6 - ROCK 8 - MARCH 15 - C/W
7 - LATIN 14 - WALTZ 16 - SWING

TRIGGER OUTPUTS:
9 - BASS 11 - BONGO 13 - SNARE
10 - BLOCK 12 - BRUSH

RHYTHM BOX OPERATION:
POTS R10-R14 CONTROL VOLUME OF EACH INSTRUMENT. EXPERIMENT WITH SETTINGS FOR BEST RESULTS. OK TO SELECT TWO OR MORE PATTERNS SIMULTANEOUSLY!

*OK TO USE LM324; TLO84 WORKS BETTER.
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 $\phi_1$ AND $\phi_2$. 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.

SERIAL OPERATION

RI CONTROLS BIAS TO SECTION B. NOTE THAT ONLY ONE OUTPUT OF A IS CONNECTED TO INPUT OF B.

ADJUST RI (INPUT BIAS) FOR OPTIMUM AUDIO OUTPUT. OUTPUTS APPEAR LIKE THIS ON A SCOPE:

A \quad A' \quad \text{CLOCK GLITCHES}

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.
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.
TOP OCTAVE SYNTHESIZER
S50240

This PMOS chip accepts an input frequency ($\Phi$) and then divides it into a full octave plus one note on the equally tempered scale. This chip is ideal for music synthesizers, organs, etc. For top octave operation, $\Phi$ should be 2.00024 MHz; lower frequencies give lower octaves.

ADJUSTABLE OCTAVE SYNTHESIZER

For top octave, adjust R1 for clock frequency of 2.00024 MHz. For next lower octave, use 1.00012 MHz clock frequency.

IMPORTANT:
Press only ONE switch at any time to obtain simultaneous tones (chords). Use an op-amp mixer or summing amplifier like this:

SPECIAL EFFECTS

This produces bagpipe and other unusual sounds. Adjust R1 to vary interruption rate.
OPTOCOUPLERS

TIL III - 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.

USE TIL 119 WHEN INPUT
SIGNAL IS SMALL.

TIL III / TIL 119 TEST CIRCUIT

This circuit shows TTL interfacing.

TIL III gives 1.5kV isolation.

CALCULATOR/COMPUTER INTERFACING

KEYBOARD INPUT

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 □ ⅛ +
3. Press SI for timing period.
4. Read time to tenth second from
   display.

Note: This shows CMOS
interface.
OPTOCOUPLERS
MOC3010 - SCR
SCS11C3 - TRIAC

INFRARED LED SWITCHES
TRIAC (MOC3010) OR SCR
(SCS11C3). MOC3010 WILL
SWITCH 120 VOLTS AC AT
100 mA. SCS11C3 WILL
SWITCH 200 VOLTS DC AT
300 mA.

CALCULATOR OUTPUT PORTS

SCR (DC) PORT

TYPICAL OPERATION: KEY IN
NUMBER WHICH PLACES DECIMAL
ANYWHERE BUT FINAL DIGIT. THEN
PRESS 1 1 0 0. NUMBER
IN DISPLAY WILL BE DECREMENTED
EACH TIME 0 IS Pressed. WHEN
COUNT REACHES 0, DECIMAL
MOVES TO LAST DIGIT AND
ACTUATES OUTPUT PORT. 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.

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

Vcc
470 Ω
1 2
BUS
3

Vcc
470 Ω
1 2
BUS
3

Vcc
470 Ω
1 2
BUS
3
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

\[ R_s = \frac{\text{Signal Voltage}}{0.025} \]
## INTEGRATED CIRCUIT INDEX

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### Note:
The Linear index includes some CMOS/MOS chips.

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