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Please note that we now have a well-staffed mail-order dept. and we assure you of prompt delivery on items which we advertise. Orders received before Dec. 10, 1981 should reach you before Dec. 24, 1981.
Features

Band Pass and Beyond ....... 18
Tim Orr looks at switched capacitors and some new ICs, until after a few hours, his eyes start going funny. He has written this very informative article on filter networks, but, sadly, he now sees components before him at all times.

Into Linear ICs, Part 1 ...... 45
A brand new feature by Ian Sinclair, the author of our popular Into Electronics series. If you're just learning about this fascinating area, this article will help you stop blowing chips indiscriminately ... and learn to blow them with style.

Tubes ............... 26
Tubes are that all but forgotten technology of the very dim past, which creating things like combination table radio/space heaters and stereos that would keep your house down in a hurricane. Steve Rimmer dusts off a few for one last look.

IEEE Report .......... 34
The IEEE show was three days of everything you could imagine in electronics, plus free samples. John Van Lierde was there, (stuffing his pockets), and filed this report.

Early Radio in Canada .... 36
Radio in Canada predates even Pierre Berton, if such a span of time is imaginable. Of course, back then, having a radio in your car required a trailer. Jim Essex recalls the good ol' days.
Radio in Canada's come a long way since the days when our cover picture was taken. It's gone from type 01A tubes and huge horn speakers to microprocessor controlled tuners, creating radio dramas to simulcasts of everything from Stones' concerts to the discovery of intelligent life on TV. Delve into the illustrious past of broadcasting in Canada, on page 36.

**Projects**

**Universal Counter**

Count frequency, period, intervals or sheep with this truly universal counter. A sheep to voltage converter may be required for the latter application. by Jan vincent.

**Musical Doorbell**

This doorbell circuit can be programmed to play whole symphonies at the touch of a button, providing they only contain nine notes. No longer need you just trudge to the door, now you can waalz!

**4 Input Mixer**

This is really neat if you want to mix four doorbells together to create chaos. Other uses may present themselves to the imaginative.

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49
You can master complex electronics and mimic the strange bird’s erratic sound with this complete Mode kit!

You can duplicate the cry of the Road Runner and create many other unusual audio effects with the Mode Road Runner kit.

All the necessary control parts for the Road Runner sound effects generator are in the Mode kit, including some that are not commonly available. Clear, step-by-step instructions help you become an expert electronics technician.

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13. Single Channel Color Organ
14. Electronic Siren
15. Shimmer Strobe Light
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17. 5 Transistor 1 Watt Amplifier
18. Xenon Strobe
19. 3 Channel Color Organ
20. Loudmouth Siren
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25. FM Mini Broadcaster
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Circle No. 16 on Reader Service Card.
Digital Display Module
To serve the needs of microprocessor-based instrumentation OEM's, Hewlett-Packard has introduced the first member in a new family of high-performance digital display modules, the HP 1345A — a compact, self-contained unit for high-resolution vector graphics.

The HP 1345A produces vector graphics and/or alphanumerics on its 6-inch (diagonally measured) CRT in response to digital commands from an external processor. A built-in binary interface provides easy connection to a user's external 16-bit TTL level data bus.

Typical applications for the HP 1345A Digital Display Module include spectrum and network analyzers, waveform analyzers, curve tracers, digital storage oscilloscopes, and fourier analyzers — any microprocessor-based equipment requiring complex, rapidly-changing graphics information.

The 2048 by 2048 addressable resolution provides for high-resolution graphics with very high positional discrimination on the CRT. Picture quality is further enhanced by the HP 1345A's constant writing speed which ensures a uniformly bright display. An optional 4K word vector memory (RAM) saves user memory and eliminates refresh requirements by the user processor.

Additional display flexibility is assured by three programmable intensities plus blank or off, four programmable line types and four programmable writing speeds. A programmable automatic delta-X increment enables users to conserve memory and to draw complex graphs easily with less data transfer. ASCII characters are generated internally in four programmable sizes and four orientations for labeling graphs, soft keys, etc. Average character writing time is 15 microseconds enabling hundreds of alphanumerics to be displayed without flicker.

ATOMic Computer
The Acorn Atom is a very powerful small computer, and may be the lowest priced system of its type to date. Very little larger than the size of its keyboard, it fully exploits its 6502 processor with a complete range of features. Among its on board capabilities are superfast resident BASIC, high resolution graphics, integral printer connection, I/O capacity, internal speaker and cassette interface. Optional extras provide for disks, full colour, up to 32 K of RAM and network systems.

The Atom is actually going to be available in Canada in advance of its announcement in the United States, and at a very low price. The basic Atom, with 2K of user RAM (fully expandable) will be just $349.00 Canadian. It's available directly through Gladstone Electronics, 1736 Avenue Road, Toronto, Ontario, with other dealers in Canada now being established. It is also available via mail order directly from its Canadian distributors, Torch International Computers, Ltd., Suite 212, 7420 Woodbine Avenue, Markham, Ontario.

For more information about the Atom, check the ad on our back cover, or the Atom review (we plan to have) in next month's ETI.
The ZX80 Personal Computer

The Sinclair ZX80 is an extra ordinary personal computer. Con pact and hand case sized, it weighs just 12 ounces. Yet in performance it matches and surpasses systems times its size and price.

The ZX80 is an advanced ex ample of microelectronics design. Inside, it has ten times the number of parts of existing comparable ma chines. This unique design - packing the system onto fewer, more advanc ed LSI chips - gives the ZX80 a remarkably low price.

Along with a complete 128 page course in BASIC programming, the ZX80 comes with all the necessary cards for connecting to standard color or BW televisions and cassette recorders.

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Direct to disc

In 1968 Sheffield Lab made the first modern direct-to-disc recording and since that time have produced 2 to 3 new releases each year, many of which have been honoured with Grammy nominations for engineering excellence. Each of these superb recordings has been widely acclaimed throughout the audio industry for their overall musicality and faultless quality.

Because of the limited number of discs which can be pressed when the direct-to-disc method is employed, a number of Sheffield releases are out of print and considered as collectors' items. Highly prized are the very first Sheffield release "Lincoln Mayorga and Distinguished Col leagues, volume 1" and the 1975 recording "I've Got the Music in Me" by Thelma Houston and Pressure Cooker (Lab 2). Recent and very popular releases include:

Lab 10 - "Michael Newman, Classical Guitarist"
Lab 11 - "Still Harry after all These Years", the 3rd release of Harry James and his Big Band
Lab 12 - "New Baby", Don Randi and Quest
Lab 13 - "Growing up in Hollywood Town", Lincoln Mayorga and Amanda McBroom
Lab 14 - "The Drum Test Record"

New releases, include:
Lab 15 - "West of Oz, Lincoln Mayorga and Amanda McBroom
Lab 17 - "Tower of Power"

Sheffield Lab direct-to-disc records will be reduced in price to a suggested list of $24.95 and distribution consolidated with such other well known audiophile labels as Crystal Clear direct-to-disc, and American Gramaphone Fresh Aire (which also carry a suggested list of $24.95) and the incredible DBX encoded discs, all of which are distributed in Canada by Audio Market Sales.

For more information, contact Tom Baldock at Audio Market Sales, Climax Industries, 850 Syer Drive, Milton, Ontario L9T 4E3 telephone (416) 878-1189.

CCTV Camera

A new line-locked Vidiplex CCTV surveillance camera, TC2031, which receives both power and line lock information via its video cable has been added to the RCA Closed Circuit Video Equipment line.

TC2031 cameras can be mounted up to 1500 feet from the separate power unit supplied with the camera, using only a single economical RG-59U cable for both video and power line lock. The separation between camera and power unit can be doubled using RG-11U cable. Costly utility wiring is eliminated and camera size is minimized, making the TC2031 ideal for hard-to-reach places. Modular design of the separate power unit allows neat racking in multiple installations and line lock gives solid vertical interval switching as well as optimum VTR operation.

Designed using large scale integration (LSI) technology, RCA TC2000 Series cameras include the more useful features of premium cameras in an economical, compact and attractive design for general purpose use. Vidicon equipped models such as the TC2031 provide a 100,000 to 1 total automatic light range with automatic target control plus a 10:1 variable gain/bandwidth amplifier to increase sensitivity and improve signal-to-noise at the lowest camera light levels. Auto Track Electronic Focus provides high picture quality with no need for readjustment during the life of the tube, EIA RS-170 sync locked to the power line zero crossing, 2:1 interlace, automatic beam control, auto-black plus keyed clamp and the many other features of the TC2000 Series add up to dependable, maintenance free performance in a wide range of CCTV applications.

Optional User Price is $455

For additional information, contact RCA Closed Circuit Video Equipment, New Holland Avenue, Lancaster, PA 17604, telephone (717) 397-7561.

Fast Logic

Claimed to be the world's fastest systems of their type, a range of emitter coupled logic (ECL) gate arrays introduced by a British manufacturer offers local gate delays of 500 picoseconds and flip-flop clock rates higher than 300MHz, with low power dissipation.

Up to 100 gate functions can be realised using the SCD 1000, an array based on the use of a single-level ECL gate circuit which has been developed to allow relatively simple customisation for specific applications. It is customised on two layers of metalisation, and the manufacturer has developed special software to aid circuit layout. Inputs and outputs are through 28-pin connections, each of which has associated with it a buffer transistor capable of driving a 50-ohm line at ECL 10K logic levels. Power dissipation is less than one watt.

The SCD 2000 and 3000 versions show the choice which can be made between different combinations of speed and power dissipation. Customised in the same way as the SCD 1000, both offer up to 300 gate functions along with 64-pin connections. The SCD 2000 however has the same speed performance as the smaller system and some variants have a power dissipation of more than 3 watts, while the SCD 3000 offers gate delays of about 2 nanoseconds but has a maximum power dissipation of 750 milliwatts.

According to the manufacturer, the new circuits can be used to replace ECL 10K and ECL 100K standard SSI and MSI parts, giving savings in printed circuit board design effort, system volume, and power supply requirements which make their use economical in low production volume applications, even where their performance advantages are not particularly relevant.

For more information, contact Plessey Canada Limited, 300 Superstore Road, Downsview, Ontario M3J 2M2 telephone (416) 661-3711.
A QUIT REVOLUTION has been taking place for the past few years. Until now the lowly digital counter has required row upon row of TTL packages and plenty of power to keep the lights flashing. Then Intersil stepped into the arena with a new high density IC, the ICM7226. All those decade registers, crystal oscillators, timing logic and display drivers have been integrated into one small package that can drive eight LED displays, count at a rate of 10MHz, provide period and time measurements, and test itself. That means lower cost and easier construction for a high-quality counter. And, since the chip is CMOS, power drain is minimized, the chip runs cooler, and there is less heat to effect accuracy.

Now if that was not enough, we wanted more. So we added more. This construction project gives you a complete universal counter with all the features found on a professional frequency counter plus a few added bonuses, like extended range (to 120MHz in all modes), input attenuators, trigger level adjustments on the panel, slope selectors, easy to use controls and a priming circuit to allow you to measure time of just about any one-shot event you could dream up.

The counter is unique in that it is small enough to fit into a standard instrument enclosure, complete with power supply and all the front-end circuits, right next to your signal generator or radio transmitter. And its construction, with separate display and electronics board, makes the whole unit go together smoothly. You can probably find many other uses for this counter, and there are plenty of applications which would benefit from a simple-to-use counter.

Besides the IC construction and the small size, our counter has these other features. You can measure down to DC with two separate DC-coupled inputs with industry standard 1-megohm input impedance. There’s an external adjustable trigger circuit allows you to apply an inverted or non-inverted signal to the ICM7226, giving you the capability of triggering on the positive or negative going edge of the waveform. This selection enables the measurement of time for periodic pulses and one shot events. The final output of the low frequency front end is a TTL compatible signal in the range from DC to approximately 10MHz, and is applied directly to the input of the 7226 counter chip. Note, there are two low frequency front-end circuits used in this project, one for each input to the counter chip. The two channels are used in combination to measure time intervals of repetitive pulses or events, and in measuring the frequency ratio of two incoming frequencies. A complete discussion of the operation of these types of measurements is found in the description of the operating functions.

ICM7226 counter chip
As stated previously, the basic block of the counter is the Intersil ICM7226B decade counter chip. This counter can function as a frequency counter, period counter, frequency ratio (f2/f1) counter, time interval counter or as an event totalizer. The counter uses a 10MHz crystal timebase, and has an on-chip oscillator circuit. For period and time interval measurements, the 10MHz timebase is used to provide 0.1uSec resolution. In the frequency mode, gating times are user selectable from 0.01 sec, 0.1 sec, 1 sec or 10 sec ranges. A complete discussion of the various functions can be found in the list of operating functions and on the Intersil datasheet.

Power supplies
The final section is comprised four low current power supplies. The basic requirement is to supply well regulated power to the logic chips and the front end circuits. The four supplies required are +10.5 Volts, +5.1 Volts, -10.0 Volts and -5.0 Volts. The printed circuit boards have been designed with the on-board supplies, including the power transformer.
trigger-level control for each channel to adjust input sensitivity on either positive or negative-going signals. Plus, there's an input attenuator to help protect the input from over-voltage conditions and to prevent damage in the event of overload. At about the 10MHz level, there is a second input circuit that takes over to extend the range of the 7226 to more than 120MHz. With this input you can measure signals from 150kHz to over 120MHz, with a sensitivity of about 50mV. This counter could work with a short whip antenna set up near your radio transmitter.

The display has some pretty special features as well. There is a LED eight-digit, half-inch display for easy reading, and leading-zero blanking of unused digits. A very important bonus is a switch selectable time-base. Most counters supply only a 1-second time-base, too short for many applications and too long for high frequency use. Our counter has a complete time-base with a 10-second gate time for audio work as well as selectable settings of 1 second, 0.1 second and 0.01 second for the best speed in measurement at full accuracy.

Construction of the counter is easy and straightforward, but, as with any project proper care must be taken in the work. Handling the IC's requires care to prevent static discharge from tools or fingers; check and double check the polarity of all the IC's, diodes and transistors before applying the power. Aside from these basic precautions, there are no special skills required. There are seven IC's that make up the bulk of the circuitry, plus a few other components. The careful board layout keeps the high frequency signals away from the digital display and minimizes the number of jumpers.

The circuit

As mentioned earlier, the counter is based on a single IC that contains the essential electronics for a complete universal counter. The schematic diagram shows the complete counter with three inputs — one for extended operation to 120MHz, and two inputs for basic operation from DC to about 10MHz. The reason for the separate frequency ranges is that it is difficult and expensive to design a wide-band input circuit to handle this extreme range of input conditions. With two types of inputs, we can tailor each for maximum performance, and keep the cost low. If you wish to measure RF signals above 10MHz, you connect your signal to the input at the back of the enclosure. The signal is first applied to a combination preamplifier and ECL/TTL prescaler chip, where it is amplified and divided in frequency by a factor of 100. The result is then routed to SW7, which selects the 120MHz range or the 10MHz range. In our version, we mounted S1 on the rear apron of the enclosure beside the high frequency input.

On the other hand, if you want to apply a signal that falls in the range of DC to 10MHz, you would use the front panel connections. Notice that the input marked Channel A is the primary input used for all frequency, unit counting and period measurements. Channel B is used only in conjunction with Channel A for measurements of time intervals. More on how to use it later. From the input, the signal is amplified and converted to TTL levels, adjusted for trigger level sensitivity and slope, and applied to the counter chip. This chip contains the complete universal counter circuit including a crystal oscillator, time-base divider, control logic, eight decade counters, eight latches and display multiplexing circuits.

Construction

For best results, you should use PC boards to speed construction. The first matter of business in constructing the unit is to build up the power supply. The printed circuit board has been designed to accommodate the power transformer and all the power supply components. Use a fine tip soldering iron and the smallest gauge solder you have. All the components for the power supply except R25 can be installed. Be sure to polarize all the diodes, capacitors and the regulators correctly. Now, temporarily connect a 1k pot and a 220 ohm resistor in series, and place this combination into the circuit instead of R25. Apply power and check the voltages. Using the temporary 1k pot, adjust for 10.5 volt (point “h” on the PCB). Replace the pot-resistor combination with the nearest value fixed resistor for R25.

Thanks to that one big IC, the rest of the counter is easy to assemble. Mount all other components on the board, being careful to avoid solder bridges and to double check polarities. Use IC sockets for the large IC’s. Once the main board is assembled, clean the bottom of the board with flux remover.

Prepare the front and back panel. In our version, all the controls except the high frequency input and control switch, are mounted on the front panel.

Assemble the display board using collared (insulated*feedthrough) wirewrap pins soldered to both the

---

Fig. 1 The PSU

Fig. 2 The priming Circuit

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Fig. 1. The circuit diagram
applying power; this is a very expensive IC to destroy by applying reverse power.

Using coloured ribbon cable, connect the rotary switches to the PCB (see rotary switch detail drawing). Finally, secure the crystal to the bottom of the PCB. This reduces sensitivity and will get rid of any oscillations.

**Calibration**

Calibrating the counter is a snap if you have a frequency standard available. Ideally, that standard should be better than ±0.0005% accurate at room temperature to get the maximum accuracy. Using a 10MHz source, connect the frequency standard and turn on the counter. For best results you should calibrate at room temperature and allow at least five minutes for the counter to stabilize before starting. You should get a reading very close to 10MHz, then adjust trimmer capacitor C11 until the reading is exactly 10MHz. Disconnect the standard and you are ready to go.

If a standard is not available, use a source of known frequency, and adjust C11 for the closest reading possible. Always allow the equipment to warm up before taking any measurements to get the best accuracy. See the schematic for details on adjusting trim pots RV1, RV101.

Now that the counter is completed you will want to begin using your new test instrument. Be sure to connect your signal to the correct inputs, adjust the input attenuator for maximum sensitivity and will get rid of any oscillations.

Using the counter is straightforward and needs little explanation. Remember, that the decimal point denotes kilohertz for the low frequency inputs and megahertz for the VHF input. All times are in microseconds. If the prescaler oscillates, connect a 100k resistor from pin 6 to 0V on the bottom of the PCB. This reduces sensitivity and will get rid of any oscillations.

### PARTS LIST

<table>
<thead>
<tr>
<th>Resistors 1/4 W, 5%</th>
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<tbody>
<tr>
<td>R1,101 910K</td>
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<td>1,5K</td>
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<td>SW9 SPST N/O mom.</td>
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<tr>
<td>D2,D202</td>
<td>Case Approx 7x9x3 inch</td>
</tr>
<tr>
<td>D3,D4,D5 1N4148 or similar</td>
<td>printed circuit board, knobs, ribbon</td>
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<tr>
<td>D6,D7</td>
<td>cable, coax mini cable RG174/ll fuse holder, power cord.</td>
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<tr>
<td>D8,D9 1N4001</td>
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<td>Q1,Q101 J308 FET</td>
<td>For a partial kit of flag heatsink all</td>
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<tr>
<td>Q2,Q102 2N3646</td>
<td>semiconductor devices, PCB's, power</td>
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<tr>
<td>Q3 2N4401</td>
<td>transformer, displays and 10MHz crystal contact.</td>
</tr>
<tr>
<td>Q4 2N6027</td>
<td>Renwell Services</td>
</tr>
<tr>
<td>IC1,IC101 TLL10CN</td>
<td>P.O. Box 575</td>
</tr>
<tr>
<td>IC3 MC1458</td>
<td>Sutton West, Ontario</td>
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<tr>
<td>IC4 ICL7226BIPL</td>
<td>IC8,IC9 78L05</td>
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<tr>
<td>IC5 DS6629N</td>
<td>IC2 74LS86</td>
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<tr>
<td>IC6 LM340T-5 (do not use 7805)</td>
<td>IC10 7404</td>
</tr>
<tr>
<td>LED mini red LED</td>
<td>display 2 x NSB5581</td>
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<tr>
<td>Crystal 10MHz 22pF 35R</td>
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</table>

For a partial kit of flag heatsink all semiconductor devices, PCB's, power transformer, displays and 10MHz crystal contact.

Renwell Services
P.O. Box 575
Sutton West, Ontario

LOE 1R0

They will supply this kit for $159.95 and ship it prepaid by delivery service. Set of etched, drilled and plated PCB's only $21.95. Certified cheque of postal money order only.
The counter has a wide range of functions to match the wide operating frequency range. The six basic functions that can be selected are:

**Frequency measurement** — Using the prescaler circuit, frequencies to more than 120MHz can be accurately measured, with little or no loading of the external circuit. By selecting the gating time, the accuracy of the reading is dependant only on the calibration of timebase oscillator of the 7226 counter. Signals of less than 10MHz are applied to the channel A input, which has an impedance of 1M.

**Period measurements** — The counter can handle input signals to approximately 2MHz in the period measurement mode. The 7226 provides an accurate timebase which is counted and gated by the incoming signal, the result being displayed and scaled in microseconds. The operation of the period measurements is such that the displayed value is an average reading, averaged over several measurement cycles. For period and time interval measurements, the 10MHz timebase gives a 0.1 microsecond resolution, that can be read down to the nanosecond range.

**Time Interval** — The time interval function allows you to measure the time between two events, such as the time between two pulses. This function requires either a repetitive signal applied to input A and B, or for the two inputs to be prepared before the signals are applied. This is the function of the priming circuit; it prepares the counter inputs for a single event on the two inputs. As input A goes negative the internal counter begins counting in 0.1 microsecond units. When input B drops, the counter stops and displays the time interval between the two transitions.

To initiate the counter into the primed one-shot mode, take the following steps. Set trigger level controls to 11:00 o'clock and scope switches to the open or non-inverting position. The function switch must be in the (time) mode and the range switch in the .01 - 1 range. Depress the prime switch and hold in momentarily. If the gate light does not go out then press reset and try the prime switch again. The gate light turning off indicates the unit is primed and the next transition at input A will start the count and a pause at input B will finish it, displaying the result in uSec. This function will display one-shot events from fractions of a uSec, to 10 Sec.

**Unit counter** — The counter can be used as a high speed unit or event counter. It can actually count at a rate of 120 million events per second, and display more than 90 million on the display. The operation is very straight-forward. By applying a signal to input A, which drops from a positive voltage level to a ground or negative voltage level, the counter will increment once for each positive to negative transition. The counter is returned to zero by depressing the reset button, or the display may be held at any value by using the hold switch. The hold switch does not reset the counter; it simply prevents further input pulses from incrementing the count. Normal operation is continued upon returning the hold switch to the normal position.

**Frequency Ratio** — The Frequency ratio function allows you to display the relative ratio between two frequencies. In connecting two signals to input A and B, the higher frequency signal should be connected to input A. The resulting display is an average measurement of the ratio between the two inputs. For obvious reasons this ratio must always be equal to or greater than 1. The maximum frequency for this mode of operation is approximately 10MHz at input A and 2MHz at input B.

**Oscillator** — The counter can be used to monitor the internal timebase by selecting the OSCILLATOR function.
Loudspeaker Design Principles
Next month, David Tilbrook will be completing his discussion of loudspeaker design, and we'll be presenting a construction project to show you how to build a first rate four way system. This is a speaker system that will grace any stereo, unless you play a lot of Anne Murray, in which case you really don't deserve it.

1981 Index
If you've been planning on having your issues of ETI bound in wombat hide and turned into valuable reference works to treasure and pass onto your children (and who wouldn't), you'll definitely want the '81 index.

Stores Survey
Getting parts for projects can be a problem, especially if you live in someplace that really wasn't designed for human habitation... like Ottawa. Next month, we'll be presenting a list of all the Canadian electronics stores we could find, several of which will still accept payment in beaver pelts.

SLR Electronics
The electronics inside cameras have been getting extremely sophisticated over the years. Next year's new models are expected to include sixteen bit micro-processor image evaluation systems that de-activate the shutter when the lens is focused on someone particularly ugly, and a voice synthesizer to go 'say cheese'. A look inside, next month.

Temperature Controlled Soldering Iron
If your soldering iron is too hot, it can damage delicate PCB tracks, incinerate parts, and, in extreme cases, give you a sunburn. This little project gives you full control over the amount of heat it emits.

Big Bang
Yes, we were planning a short bit on electronics in guerilla warfare, but this isn't it. Several years ago, it seems there was this large explosion which caused here to be. Terribly handy, as without it, the universe would be much smaller, and we'd be having a nasty time finding readers.
Babani Books are also available from the following retail outlets: Toronto: Arkon, Dominion, General Electronics, Electrotronic, Centro, Electronic Headhike, Kitchener, Orillar, Calgary: CM Electronics, E&J Electronics, The Computer Shop, Vancouver: Randall, Parel, Hanfield, Winnipeg: Vanguard Electronics, Longueil P.Q.: Masterov
Here's some more from Mr. Orr. Our circuit specialist looks at the development of bandpass design, switched capacitor techniques and some new ICs.

MANY MACHINES SUCH AS SPECTRUM analysers and vocoders use analysing filter banks; these are often quarter octave devices extending over six octaves. If quarter octave filtering is to be successful then the bandpass filter responses must be very sharp, having almost flat tops and a fast roll-off slope at either side. A poor slope would mean that the filter bank would not be able to resolve incoming signals; for example a sinewave might give a high output in several of the channels. Also, a very peaky response would give large interfilter dips in the overall response (Fig. 1). An approximation of the square ideal response can be obtained by using multiple tuned filters. The response of a single pole bandpass filter is shown in Fig. 2.

By Design

When designing bandpass filters it is important to decide what type of filters to use. Figure 3 shows two bandpass responses. Response A is a peaky filter, whereas B has a flat top to it, but still has the same roll off as A. One sensible design solution would be to use bandpass filters for A, and a highpass/lowpass structure for B. A rule of thumb for making this decision is to calculate the fractional bandwidth:

\[ \frac{F_U - F_L}{F_U + F_L} \]

If this is greater than unity then use lowpass/highpass filters; if it is less than unity use multiple tuned bandpass filters. Some standard bandpass filter designs are shown in Fig. 4. The multiple feedback circuit requires only one op-amp, but is limited to low Q operation (less than 5) and the centre frequency and Q are interactive.

The state variable design can produce high Q factors of the order of several hundred. Tuning is performed by changing the R and/or C components. The Q factor is independently variable and is invariant with changes in frequency.

The biquadratic design is similar to the state variable filter. Tuning is performed by changing the R and/or C components and the Q factor is determined by the ratio of Rq to R. As it is tuned to operate at higher frequencies the Q factor will increase linearly in proportion to that frequency.

A voltage controlled biquadratic filter is shown in Fig. 5. This employs the relatively new CA3280, which is a dual improved performance version of the CA3080. As the Q factor is a function of frequency, the useful operating range is about 20 to 1.
A simple analysing octave filter bank is shown in Fig. 6, this is implemented using double tuned filters with Q factors of five. The component values for two channels are shown in the table of Fig. 6a. Note that some compromises will have to be made in order to implement the design using low cost resistors. For example, a 255k resistor could be made using two 510k resistors in parallel. The filter bank is converted into a spectrum analyser by adding an envelope follower to each channel and then multiplexing the envelope voltages into an XY display (Fig. 6c).

Other Design Applications
Figure 7 shows a design for a parametric audio equalizer. This device has variable cut and lift and a resonance and frequency control. The resonance control is arranged such that as the Q increases, the input signal is attenuated (RV2a), thus maintaining the same overall gain at resonance, independent of the Q setting. The filter is a state variable design which is situated in the feedback/feedforward loop of an op-amp. Thus RV3 controls whether overall response is a bandpass cut or lift. The resonant frequency is tuned by RV1 and SW1 is used to switch frequency ranges. The Q factor is set by RV2.

Fig. 3. Two bandpass responses and how to realise them.

Fig. 4. Standard bandpass filter designs. a) Multiple feedback. b) State variable. c) Biquadratic.

Fig. 5. A voltage-controlled biquadratic filter. Note that the CA3280 has two +12V supplies (pins 14 and 11) but only one -12V supply (pin 4). (We don't know why either.)

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Fig. 6. An analysing filter bank suitable for a spectrum analyser. a) Circuit for each of the ten filter stages (A to J), and component values for two of the stages. b) Graph of the ten filter responses. c) Block diagram of the spectrum analyser and a suitable circuit for the envelope follower.

The TCA580N (Signetics) is an IC that can be used to simulate an inductance and in doing so may be used to synthesize many conventional LCR filter circuits (Fig. 8). The device has a pair of floating input terminals which generate the impression of being an inductor. This inductor is programmed by three passive components, R_{G1}, R_{G2}, C_2. By connecting a capacitor (C_1) across the input terminals, a parallel resonant circuit (C_1L) is produced.

Moving Story?
The SSM2040 is a four section mobile filter that can be exponentially voltage controlled over a 10,000 to 1 frequency range. The device contains an exponential function generator that controls four variable transconductance amplifiers each having their own output buffers. The IC may be used for electronic music synthesis, musical effects, tracking filters and many other applications where filter mobility is needed.

Fig. 7. A parametric audio equaliser with variable cut and lift and a resonance and frequency control.
A four pole lowpass filter for electronic music is shown in Fig. 9. Each stage is a single pole mobile lowpass filter, four of these filters are connected up in cascade and fed into an output amplifier. A resonance feedback route is provided so that the Q factor may be manually controlled. The voltage control of frequency is set to $-1 \text{ V/octave}$.

By modifying the external components, the device can be transformed into an all pass filter, (Fig. 10): This filter has a flat amplitude response and a phase shift that changes by $180^\circ$ as a function of frequency. As the SSM2040 has four stages, the whole filter has a variable $720^\circ$ phase shift. When the filter output is mixed with the original signal, two notches are produced in the frequency response occurring when the phase between the original and phase shifted signal is $180^\circ$ and $540^\circ$.

As the phase shift is slowly modulated up and down in frequency, the notches also move producing the characteristic phasing sound.

**Monomania**

Monolithic filters are becoming more and more common. One such device that lends itself to integration is the transversal filter. Fig. 11a. This device can produce a steep roll-off slope, a high out-of-band attenuation and most significantly a linear phase response. The transversal filter is a tapped analogue delay line. The input signal is sampled and this sample moves down along a bucket brigade delay line. Each bucket has a separate output so that the signal may be monitored at each stage via a weighting resistor. It is possible to weight the resistors such that they draw out the impulse response of the required filter performance.

When fed with an input signal that is being shifted down a delay line, this impulse response results in it being converted into a frequency response. The filter frequency is directly linked to the clock frequency, and thus it is impossible to make the transversal filter mobile.

It is necessary, as with all sampled data systems, to precede the device with an antialiasing filter and to recover the signal. There are now several transversal filters available, but they are still relatively expensive and are best used only where linear phase response is of prime importance.

**Fig. 8. A monolithic gyrator using the TCA580N. It can simulate inductances up to one millihenry.**

**Fig. 9. A four pole lowpass filter using the SSM2040. The transconductance amps are labelled G and their output buffers B.**
Fig. 10. The SSM2040 connected as a two-notch phasing unit.

Fig. 11. The transversal filter, with graphs of impulse and frequency responses for a lowpass design.

Fig. 12. Switched capacitor filters. a) Basic circuit. b) The equivalent resistor. c) Practical design using MOSFETs. d) Conventional integrator. e) Replacing R with a switched capacitor enables a filter to be easily produced in IC form.
Recent Monos
A more recent monolithic device is the switched capacitor filter, which can be used to implement many standard lowpass and bandpass filter structures, Fig. 12. The problem with producing monolithic recursive filters is that stable high tolerance components such as resistors and capacitors are very difficult to make, and the filter performance depends heavily upon these tolerances. However, it is possible to simulate resistors with switched capacitor techniques. With the switch as shown in Fig. 12a C1 is charged up to V1. When the switch is thrown to its other position the capacitor is discharged into V2. By continually switching the switch, a current I can be made to pass from V1 to V2. This simulates a resistance R (where R equals the period of the clock frequency).

where

\[ F_c = \frac{1}{2\pi RC_2} \]

but \( R = \frac{1}{C_1} \)

therefore \( F_c = \frac{C_1}{2\pi C_2 T} \)

Fig. 13. Switched capacitor filter bank using the R5604 from Reticon.

Note that \( F_c \) is linearly proportional to 1/T, which is the clock frequency.

Reticon make a switched capacitor bandpass filter which contains three filters at one-third octave spacing, thus making filterbank design relatively simple (Fig. 13). Maybe in a few years time it will be possible to purchase a wide range of low cost monolithic filters. If that day comes, you won’t need to learn how to design active filters!
His Master's Temper

Really, what good is a dog that sits around the house all day staring into a Victrola, collecting various fleas. Little Nipper, here, has been doing it for about sixty years. He might be dead; for all the use he is, he could very well have been stuffed back in '27. He doesn't even like cheese.

A while ago, Nipper's owner got a bit cross with his diminutive canine, and decided to jam his pointy little head into the speaker, to see if it would wake the little mutt up. Actually, it did, too. Nipper came out of his coma, and started wandering around the house, barking cheerfully and slamming the Victrola into the furniture. He pulverized the cat, smashed two completely authentic Ming vases from Sears, and very nearly did a double gainer off the sun deck into the pool (it's so difficult to judge just how hard you have to kick them to get them over the edge).

To date, no one has had any success extracting Nipper from the horn. Various techniques have been tried, including soap, freezing, a chain saw, pulling between cars, and, lastly, plastic explosives. However, nothing's done much good, and the remnants of this poor little dog are still in that thing.

We feel very sorry for Nipper, symbol of a megacorporation though he may be. Therefore, we have set up a fund to help get him out. Subscribe now to ETI, and, if Nipper is still alive by the time we get your order (unlikely, considering the size of the pile driver they plan to try next week), we'll contribute one dollar for each one year subscription (just $16.95) and two dollars for each two year subscription (just $29.95) to the "Buy an Atomic Bomb to Free Nipper Fund".

If he is dead, we promise to observe one minute of silence for each subscription order, after everybody has gone home for the evening.

So have a heart. If you want, you can probably have Nipper's, if you can find it (it was headed East, last time it was spotted). Subscribe now, and help this poor little animal. You'll feel better, and so will we. So would Nipper, if he were real.

ETI Subscriptions
25 Overlea Blvd., Unit 6
Toronto, Ontario
M4H 1B1
Computer Technician's Handbook
TAB No.554
$17.45
Whether you're looking for a career, or you are a service technician, computer repair is an opportunity you should be looking at. The author covers all aspects of digital and computer electronics as well as the mathematical and logical concepts involved.

Beginner's Guide To Computer Programming
TAB No.574
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Computer programming is an increasingly attractive field to the individual who wants to stay ahead of the curve. The main topic of this book has been developed in a logical sequence, from the basics to machine language.

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TUBES

Vacuum tube equipment is anything but extinct. Find out the basics of this hot, smelly, inefficient and mildly funky technology. By Steve Rimmer.

A LONG TIME AGO, back in the so-called ‘dark ages’, there weren’t any transistors. Instead they had another device, called the vacuum tube. This, in fact, lead to the phrase ‘dark ages’. The tubes drew so much current that if two or more people in the same town turned on their TVs simultaneously, all the lights would brown out. Most people who get into electronics these days run into tubes only as novel curiosities or as little crunching noises underfoot, and never have cause to be concerned about how the little monsters actually work. No great loss, this, for the most part; a digital watch made out of tubes would require a guy 1200 feet tall to wear it.

Oddly enough, though, after general abandonment for quite a while, tubes are enjoying a bit of a renaissance. This may be akin to that last bob to the surface before going down for the third time. However, even with the latest heavy trips happening in solid state technology, there are still a few things better done with vacuum tubes. There are also a lot of cases where in the grossly underbudgeted experimenter can find affordable tube-type equipment where solid state works would be cause for a trip to the loan counter.

It’s actually rather amazing exactly how much can be achieved with something as seemingly primitive as a tube. We’re going to have a peer at how these little monsters work, so the ol’ glass transistors won’t be a total mystery, and the next time Great Aunt Remora asks you to fix her mighty Prince of the Airwaves all band receiver and wax cyclinder player, you won’t have to have your arm set in a fake cast.

Skin a Cathode.

We’re not going to get too hairy into the theory of tubes . . . just enough to get by on. If you’re really hot to know more, there are dozens of excurtiatingly boring books on the subject available.

Your basic amplifying tube is called a triode, which, as you might expect, is an evacuated glass envelope containing three odes. Except, we don’t call ‘em odes, because it sounds silly. ‘Elements’ is more common. These are your ‘cathode’, your ‘control grid’ and your ‘anode’. They are represented diagramatically in Fig. 1. The cathode is a metal plate that gets hot due to its being near a small electric heater called the ‘heater’. . . clever name, right, or the ‘filament’, as in a light bulb. Away across the vacuum tube is another plate, quite like the cathode, except that it doesn’t get hot, having no heater. Because the cathode gets hot it spews electrons off into space, which will go streaming toward anything more positive than the cathode . . . a bit of bias voltage will qualify the anode for this distinction. Electrons can flow to the anode, but because the anode is cold, once they get there they can’t flow back, even if the anode were to go negative with respect to the cathode. Sounds like a sort of diode effect, doesn’t it?

I think I detect a pattern here.

With electrons streaking madly across the gap between the aforementioned odes, it is possible to regulate their quantities by inserting a third element in the gap, the control grid. Actually grid-like in structure, the control grid is placed quite close to the cathode and biased such that it is slightly negative with respect to it. Thus, electrons passing through the grid are repelled from it toward the anode. However, it takes very little negative voltage on the grid to restrict the electron flow, and, as it happens, quite a large change in the current from the cathode to the anode can be achieved with only a small change of grid voltage.

This is, of course, amplification, without which Jimi Hendrix would never have been possible.

As you may have heard, the operation of a triode tube is essentially similar to that of a FET. They are basically voltage controlled, high impedance devices as opposed to transistors which are current controlled and low impedance components. This is a very useful analogy . . . except that some tubes have more than one grid. These, however, will go away if you pretend you don’t believe in them.

Oh, very well. We’ll explain them. There are several conceptual problems with triodes, one of which is that they are unfriendly in some applications, especially at radio frequencies, because there is a lot of inter-electrode capacitance . . . capacitance between them odes we was speakin’ about a piece back. In order to break this up, another grid is inserted in between the control grid and the anode, called the ‘screen grid’. It gets biased (and decoupled) at some voltage slightly below that on the anode. The resulting concoction is called a tetrode.

Tetrodes, as it turns out, are not remarkably useful. The extra grid cures the capacitance problem, but causes a new one in its place. Electrons barrelling into the anode often cause other electrons to go flying back into the vacuum, in a process called ‘secondary emission’. These wind up on the screen grid, where they tend to make it do funny things. The only way to stop them from doing this is to install yet another grid, this one called the ‘supressor grid’, in between the screen and the anode. It is usually connected to the cathode, or, sometimes, to ground. Since it is negative with respect to the anode, it repels the secondary electrons back towards the anode before they can get into trouble.

Count up those odes. Everybody get five? Good. It’s a pentode. A bit of a kluge, I suppose, but it works.
Passing the The Plate

Having gotten this little bit of textbook stuff out of the way, let us now turn to the real, if slightly archaic world of tubes. Herein we're going to look at the generalities of dealing with these scorching little beasts. It should be stated, for any purists reading this bit and fuming at the ears, that these are genuine abbreviations of the truth for the sake of getting it all into three pages of text; its all good most of the time, but there are a few things left out.

Tubes come in three sizes; seven pin, eight pin and nine pin. The seven and nine pin deals are miniature types, having the pins protruding directly from the glass of the envelope. The eight pin, or octal types, have plastic bases which contain the pins. There are hundreds of different tube types in existence, but only a very few that are commonly encountered. These are as follows:

-6Y3,5U4,5X4, etc. A family of octal tubes having one cathode and two anodes, for use as full wave rectifiers.

-6AL5. A seven pin tube having two separate diodes, for use as small signal rectifiers and such-like.

-6L6,6F6,6V6, etc. A family of octal power pentodes, of which the 6L6 is the biggest. Fancier versions are known as KT66 and KT88. Usually found in the output stages of audio power amplifiers.

-12AT7,12AU7,12AX7, etc. A family of nine pin dual triodes, all identical except for different gain. The AX7 is the highest. The 12 volt filaments are tapped for use on six volts as well.

There are a few other sweeping generalities of tube lore that may prove useful. First of all, the anode is often called the 'plate', leading to 'plate voltage', 'plate current', and so forth. The control grid is usually just called the 'grid', with the other, now orphaned grids being called the 'screen' and 'suppressor'. Tubes often contain two additional elements, called the 'internal shield' and the 'getter'. The former is usually to separate the elements of dual tubes. The latter is a metal ring which is used in the initial evacuation of the tube. Neither of these need be concerned about in the general operation of tubes, except that odd things may happen if voltages are connected to them.

Some tubes are made with metal contacts up top, from which a wire hangs. This is usually the connection to the plate; the internal geometry of the tube makes it impractical to run it down to the base. The only common exception is an octal tube called the 6J7, where it's the grid.

Unlike in solid state devices, the numbers of tubes can tell you a few things. For instance, the first numerical digits tell you the filament voltage. 5Y3 has a five volt heater, 6AL5 has a six volt one. Well, 6.3 volts, actually, although the extra third of a volt doesn't make much difference. Some tube numbers will have extra letters tacked on the end, like 6L6GBA. These usually refer to the shape of the glass envelope . . . not too important, unless the tube is being held in by some sort of gadget that only works with one particular shape.

Lastly, you might run into tubes that appear to be made of metal. This is just a disguise invented by the military. If you drop them they'll break just like the regular kind.

Tubes are built to much tighter specifications than are solid state devices. However, their circuits are also usually much more finicky. Thus, especially in sophisticated RF and timing circuits, tubes from different manufacturers may produce different results . . . sometimes to the extent that some circuits will only work with some brands of tubes.

Powers That Be

The relative voltages on the elements of your basic tube are pretty well constant, and, as with transistors, if you know about what they are supposed to be, you can figure out what is wrong if they turn out to be something else. Here goes.

The cathode is held at or near ground. Usually it's a few volts positive, by virtue of a cathode resistor, often bypassed by a capacitor. Sometimes pentodes will have a connection from the cathode to the suppressor; it is usually the case, though, that this connection is made internally, and the suppressor is often not even drawn in.

The grid is usually a few volts negative with respect to the cathode. There aren't usually any negative voltages handy, at least with small signal amplifiers, so the same result is arrived at by setting the grid near ground and making the cathode positive. The grid usually has a large, 100K to 1M, resistor hanging off it to ground. This keeps it effectively at ground potential and gets rid of any stray electrons that somehow manage to stick to it.

The screen is usually fed from the plate voltage supply via a voltage divider, and will usually have a capacitor to ground to keep it from varying in voltage with the current through the tube.

The plate is connected through a load, such as a coil, transformer or resistor, to the plate supply voltage, called the B+. The B+ is usually between 150 and 350 volts, and the actual plate voltage anywhere between 90 and 250. Higher plate voltages produce higher gain, but also cause the tube to produce more noise, as the electrons smash into the plate at higher speeds. Pentodes, having more internals for the electrons to hit, produce more noise than triodes. In equipment having really small signal stages, the associated tubes usually get fed from a low B+ supply.

The heater is usually fed from the winding of a transformer. However,
because the AC voltage can couple hum to the cathode, tubes used in very small signal circuitry often have their filaments fed with DC.

**And The Hairy Bits**

In order to be able to give a decent explanation about how to deal with all the problems plaguing tube equipment, it would be necessary to boot all the advertisers out of this issue, abandon all the other features, and possibly devote part of next month to the conclusion. Absolutely nobody was in favour of this idea... I wasn’t even all that thrilled about trying to write the thing. Thus, we’re going to look at a few of the fundamental differences between tube and solid state circuitry. Armed with this priceless knowledge, the rest should be child’s play.

No children that you know of? They may be able to help you on the classified page.

Tube type equipment is built on metal chassis, as opposed to PC boards. The tubes are plugged into sockets that protrude through openings in the metal, and most of the passive components, such as resistors and capacitors, are strung between the lugs of the sockets. This is called point-to-point wiring, and, boy, is it messy.

The biggest hassle with tube equipment is heat. The tubes just cook. The heat dries out capacitors, shifts the values of resistors around, and breaks down all sorts of insulation. It causes the coatings on wires to get brittle, and, if you move the leads, they may just flake off into dust. It also causes a number of more or less harmless effects; for example, wax impregnated paper capacitors often form coatings of wax on their outer surfaces which makes them look really horrid, although they'll function perfectly well. Heat will also cause the colour codes on resistors to change colour very realistically, so you can’t always trust the markings.

On the other hand, tube equipment was built on production lines which, for the most part, were all hand wiring deals. As the devices came off the lines they were checked and, if the failure rate began to increase, due to simple bad luck with the way the tolerances were going, it was quite common to change the value of a part to bring things back into line. In other words, you gots ta have an updated schematic before you start clippin’ resistors.

The most important thing about dealing with tubes is to realize the inherent reliability of the tubes themselves. They fail less frequently than do the components they’re connected to. Shame, in a way, because they’re the easiest to change. The only really reliable way to test a tube is to replace it with a good one and see if the problem goes away. Tube testers, like transistor testers, only work under certain circumstances. In the case of the ones at the drug store, this is usually when the tube either has a migraine headache or the heartbreak of psoriasis.

**Powering Down**

All in all, I think tubes are pretty neat. A good way to look at them, especially if you are fairly poor, is to consider the specifications of the box they live in. If it will do what you want, it really doesn’t matter what it uses to do it with. And, with tube equipment, there is the added advantage that the cabinets can be used to warm coffee, or even to fry fish on.

Tubes are very highly funky, and even if you really have a tube amp because it was twenty-two bucks at a garage sale, you can let on that you’re into tube sound, which is very hip and underground. Tubes make useful nightlights, and, when they go gassy and start glowing blue, are entertaining to watch at parties.

Finally, tubes are ecological. When a transistor dies, it’s useless. However, dead tubes are fabulously functional, possibly even more so than live ones. If you have a bottle cutter you can make all the useless household paraphernalia you used to be able to make before coffee came packed in plastic. The bases can be recycled to hold relays. Even the internal elements can be removed and stomped on for a good time.

The likelyhood of Texas Instruments ever having to worry about competition from the vacuum tube division of Sylvania is probably fairly slim. However, tube type equipment is still very much alive, and may well be worth checking into.

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Circle no. 9 on Reader Service Card.
MUSICAL DOORBELL

An inexpensive programmable doorbell project for your home. This instrument will play any nine-step melody of your choice.

MODERN DOORBELLS come in two basic types, the simple electrical 'ding-dong' (chime) or the sophisticated microprocessor-controlled multi-tune (up to a selection of 5) different melodies to be programmed into the unit.

A feature of our doorbell is that it incorporates a bistable electronic switch that connects power to the unit in such a way that it consumes virtually zero power when in the 'standby' mode. Whenever the bell-button is pressed, the bistable connects power to the unit for the duration of the tune play and then automatically disconnects the power when the melody is complete; this facility ensures long battery life.

Construction

Construction of this unit should present very few problems, if the overlay is followed with care. Note that IC1 and IC3 are CMOS devices and are best mounted in suitable sockets. Also note that an insulated link is connected between pin 3 of IC2 and pin 14 of IC3 on the underside of the board and that Veropins are used to facilitate top-side connections on the PCB.

When construction of the PCB is complete, connect up a suitable speaker, battery and push-button switch and prepare to give the unit a functional check. When selecting a speaker, note that output volume is proportional to speaker impedance and that a high impedance unit will give the loudest results.

When you are ready to try out the unit, connect a flying lead from D1 to one of the A-E note-select points and press PB1 to test the first note in the sequence. You can then wire in the D2 to D9 note-select connections, one at a time, to establish the rest of the sequence, testing the unit at each step in the wiring sequence.

Once you've finished 'programming' your unit you can fit the PCB, battery and speaker into a suitable box, hang the unit on your front door and finally connect it up to a suitable push-button switch.

Fig. 1. Circuit diagram of the Musical Doorbell. The connections you make between diodes D1-D9 and the points A-E determine the tune that is played.
The circuit comprises a bistable (IC1) and a transistor power switch (Q1), two 555 astable multivibrators (IC2 and IC4) and a 4017 decade counter/divider (IC3). The bistable (IC1) is designed around two gates of a CMOS 4001B and controls the base bias of Q1, which in turn controls the positive power supply connections to IC2 and IC4, the two 555 chips.

Normally, the output (pin 4) of the bistable is high, so Q1 receives no base drive and is cut off. Under this condition, IC2 and IC4 consume no power; IC1 and IC3, being CMOS devices, also draw negligible power under this condition. The entire circuit, in fact, consumes a typical 'standby' current of only a microamp or so.

The circuit is activated by briefly pressing PB1, thereby causing the IC1 bistable to change state and connect power to the IC2 and IC4 astables via Q1. IC2 is wired as a low frequency astable (a few Hertz) and delivers clock pulses to IC3. IC3 is a 4017B decade counter/divider; it has ten decoded outputs, which sequentially go high on the arrival of successive new clock pulses, only one output being high at any given time. In our application, the first nine decoded outputs are used to sequentially select (via D1 to D9) timing resistors in a second astable, the IC4 tone generator, which drives a speaker via C7.

The first nine clock pulses from IC2 thus cause nine tones to be sequentially selected via the R7-11 resistor network. On the arrival of the tenth clock pulse, pin 11 of IC3 goes high and resets the IC1 bistable via R3 and C1, thereby cutting off Q1 and removing power from IC2 and IC4, thus completing the operating cycle.

The action of the IC1 bistable is such that, if PB1 is briefly pressed, the instrument plays a single sequence of nine notes (total duration is 2-3 s) and then automatically switches off. If PB1 is held closed, however, the sequence continuously repeats. Note that the owner can set up any tone sequence that he wishes by suitably interconnecting the diode outputs of IC3 to the 'A' to 'E' selection pins on the R7-11 note-selection chain.

**Parts List**

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<td>R6</td>
<td>C7</td>
</tr>
<tr>
<td>R8,9,10</td>
<td>C8</td>
</tr>
<tr>
<td>R11</td>
<td></td>
</tr>
<tr>
<td>R12</td>
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<td>R13</td>
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<table>
<thead>
<tr>
<th>Semiconductors</th>
<th>Miscellaneous</th>
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<tbody>
<tr>
<td>IC1</td>
<td>LS1</td>
</tr>
<tr>
<td>IC2,4</td>
<td>PB1</td>
</tr>
<tr>
<td>IC3</td>
<td>B1</td>
</tr>
<tr>
<td>Q1</td>
<td>Case</td>
</tr>
</tbody>
</table>

**Resistors**

- R1: 10kΩ
- R2: 4.7kΩ
- R3: 47kΩ
- R4: 6.8kΩ
- R5: 33kΩ
- R6: 680kΩ
- R7: 15kΩ
- R8: 9.1kΩ
- R9: 12kΩ
- R10: 56kΩ
- R11: 22kΩ
- R12: 100R

**Capacitors**

- C1: 1uF 63V electrolytic
- C2: 330n polycarbonate
- C3,6: 100n polycarbonate
- C4: 10u 63V electrolytic
- C5: 10n polycarbonate
- C7: 47u 25V electrolytic
- C8: 220u 25V electrolytic

**Miscellaneous**

- LS1: Any 8R to 40R speaker: see text
- PB1: momentary action
- B1: 9V
- Case: 

---

**How It Works**

The circuit is activated by briefly pressing PB1, thereby causing the IC1 bistable to change state and connect power to the IC2 and IC4 astables via Q1. IC2 is wired as a low frequency astable (a few Hertz) and delivers clock pulses to IC3. IC3 is a 4017B decade counter/divider; it has ten decoded outputs, which sequentially go high on the arrival of successive new clock pulses, only one output being high at any given time. In our application, the first nine decoded outputs are used to sequentially select (via D1 to D9) timing resistors in a second astable, the IC4 tone generator, which drives a speaker via C7.

The first nine clock pulses from IC2 thus cause nine tones to be sequentially selected via the R7-11 resistor network. On the arrival of the tenth clock pulse, pin 11 of IC3 goes high and resets the IC1 bistable via R3 and C1, thereby cutting off Q1 and removing power from IC2 and IC4, thus completing the operating cycle.

The action of the IC1 bistable is such that, if PB1 is briefly pressed, the instrument plays a single sequence of nine notes (total duration is 2-3 s) and then automatically switches off. If PB1 is held closed, however, the sequence continuously repeats. Note that the owner can set up any tone sequence that he wishes by suitably interconnecting the diode outputs of IC3 to the 'A' to 'E' selection pins on the R7-11 note-selection chain.

**Fig. 2. Component overlay.**

- Resistors
- Capacitors
- Semiconductors
- Miscellaneous

---

**The Prof**

- LS1: Any 8R to 40R speaker: see text
- PB1: momentary action
- B1: 9V
- Case: 

---

**ETI - December 1981**
"You fix TV's... what brand should I get?"

You're on the spot. Any set you tell your customer about has a chance of failing sometime.

But though we're not saying we're perfect, we'd like you to recommend RCA. Because we're sure your customer will love its picture performance.

You can find the problem and repair it quickly if anything goes wrong. Because with RCA's unitized chassis, failures are easy to handle.

RCA gives frequent hands-on workshops, as well as lectures. So when failures do occur, you'll be ready.

RCA has more than 500 parts distributors nationwide. We have this large network because we don't want you to have to wait too long for parts.

We also keep your inventory expenses lower by using components instead of modules, in most circuits.

We know your customers think you're responsible for everything about their sets. Good and bad.

And that's why we here at RCA are doing everything possible to make sure that when you finish a service call, everybody's smiling. Your customer's happy with your recommendation. And you're still the expert.

RCA
RCA IS MAKING TELEVISION BETTER AND BETTER.
The IEEE show is a yearly gathering of the brightest lights in electronics. John Van Lierde was there, and is still seeing spots before his eyes.

THE BEST WAY to find out what's happening in any given field of interest is to get out and find the people that are involved. The 1981 International Electrical, Electronics Conference and Exposition is a good place to start, being, among other things, a veritable lodestone for manufacturers, researchers, engineers and buyers.

This year’s IEEE Show took place on October 5, 6, and 7 at Exhibition Place, Toronto. During that time over 13,000 people passed through the doors to see and hear what's state in the state of the art. Manufacturers and distributors filled some 200 booths displaying the very latest electronic devices. Also during the show, over 100 papers were read, covering such diverse fields as biomedical instrumentation, satellite communications, computer music and speech synthesis, power systems and much more.

The exhibition itself represents a tremendous opportunity to see and handle equipment that previously one could only read about. Because the manufacturers and their representatives are right there, it's a good chance to learn firsthand what's new. Even if you're not looking for something, the browsing is quite enjoyable and there are plenty of literature handouts and some freebees to be had.

If you missed it this year, don't worry, it's an annual event. If you're doubtful, the photos tell a bit about what our advertisers were doing. Multiply that by about twenty and you can get some idea of the size.
New! Acorn Atom
12K Colour Computer

Telephone orders:
(416) 787-1448
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or American Express

GLADSTONE ELECTRONICS
SPECIAL INTRODUCTORY OFFER!

*FULL-SIZED KEYBOARD
*BASIC AND
*HIGH RESOLUTION
*SOUND
*USE WITH STANDARD
*PRINTER OUTPUT
COLOUR GRAPHICS
TV AND CASSETTE
*10 DIGIT ACCURACY

Fully Assembled
only $499

(2K Black and white model also available, only $349)

The Acorn Atom is a powerful, full facility computer at an extraordinary low price. It has a full size professional keyboard and a hardware/software combination of incredible power and versatility. And it's easy to use! Just connect directly to any domestic TV and you are ready to begin (AC Adapter optional extra)

FREE MANUAL
Free with every ATOM is a computer manual. The first section explains and teaches you BASIC, the language that most personal computers and the ATOM operate in. The instructions are simple and learning is a pleasure. You'll soon be writing your own programs. The second section is a reference section giving a full description of the ATOM's facilities and how to use them. Both sections are fully illustrated with sample programs.

THE ACORN ATOM 12K COLOUR
COMPUTER includes:

Hardware
*Full-sized QWERTY keyboard
*6502 microprocessor
*Rugged injection molded case
*12K RAM
*12K ROM
*Audio cassette interface
*TV output with high resolution Colour Graphics

Software
*32 bit arithmetic
*10 digit floating point math routines
*High speed execution
*43 BASIC commands
*Variable length strings (up to 256 characters)
*String manipulation functions
*27 additional arrays
*Random number function (useful for games & simulations)
*Mnemonic assembler
*16 letter file names
*PUT and GET byte
*WAIT command for timing
*DO - UNTIL Instruction
*Logical operators (AND, OR, EX-OR)
*PLOT commands, DRAW and MOVE
*Direct printer drive
*Link to machine code programs
*ASSEMBLER and BASIC may be combined

ALL THIS FOR ONLY $499
This special introductory offer will be in effect until end of December 1981. As of January 1982, price will be approximately $50 more. This special offer is to introduce this superb British computer to Canada!

Software on cassette.
With your order, full details and prices will be sent on cassette software. Tapes include games, applied mathematics, disassembler, and word processor.
It is our intention to introduce as quickly as possible a full line-up of ACORN support products including floppy disks.

MAIL ORDER TO: Gladstone Electronics, 1736 Avenue Rd., Toronto, Ont. M5M 3Y7

Name ___________________________
Address ___________________________

Total amount enclosed
Cheque ( ) Money order ( )

Card No. ___________________________
Expiry ___________________________

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<td>BASIC ATOM 2K RAM &amp; 8K ROM Black &amp; white version, fully assembled, complete with manual</td>
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Circle No. 19 on Reader Service Card.
AS MERELY ONE of many who have watched the swift evolution of broadcasting in Canada, I was intrigued by the fact all this has taken place in less than half the years of the nation's life-time. Recalling some of the early attempts by adventurers in radio and the primitive beginnings of others, it seems impossible today's giant had such a humble start.

Early in the post-war years, the second station in a little over a decade in which I was Engineer, CKBW Bridgewater, N.S., began broadcasting. Located on the south shore of that province, this station in 1947 plugged the previously sparsely filled radio spectrum in that area (due to peculiar local rock-strata formations which left only weak signals from neighbouring commercial

So you think all the furor over pay TV, satellite TV and suchlike is a relatively recent phenomenon? Not so. Hearken back to the early days of Canadian nationalism with Jim Essex and see the origins of broadcasting in Canada.

Halifax radio stations or even the powerful 50 KW transmitter of CBA at Sackville, N.B.) This local situation was, to me at least, illustrative of Canadian radio where, whenever powerful regional CBC stations failed to provide adequate signal strengths, commercial enterprise stepped in to fill the gap.

My impressions of the immense changes in Canadian radio (which saw the whispering voice of a mere handful of stations in the 30's grow to over 300 radio stations today) was exemplified by this experience.

Compared with my earlier experiences in radio in Ontario in the 30's, it offered the comparison needed to appreciate the vast changes to sophistication in broadcast equipment spanning a dozen odd years. The CKBW of 1947, in which I had taken my place in radio in the interval, first as engineer of the succeeding station of 10AK at Stratford (later CJCS), to that station 11 years later, offered a kaleidoscope of radio's change with the years. CKBW was an ultra-modern station: the experimental station of 10AK in Stratford in 1936 was not. But it was typical of the experimental stations of that age and a credit to the spirit of
As a 30th Anniversary Special we are offering the following FREE merchandise with every purchase over $10.00. Please circle the “FREE GOODS SPECIAL” number on the order form corresponding to the Free goods you would like:

#1 - SIX Hobby Motors
#2 - 50 Electrolyte Capacitors
#3 - TWENTY FIVE 500 MA - 200v Diodes
#4 - ONE HUNDRED Resistors
#5 - TEN Rolls Black PVC Tape
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**LED Chaser Kit**

Model # EK80LC016

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A very familiar sight seen at discos, department stores, and on neon signs. 16 LED's flash in sequence up-down or alternate. Adaptable to 120 vac. (Extra)

**Multi-mode Chaser**

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We're proud to add this to our line. It's similar to our 15 channel led chaser but with many extra features. There are over 60 selectable modes. A few are: Up, Down, Skip, Pulse, Scramble, Single Pulse, Multi Pulse and many more. An optional 120 vac board is available (Extra)

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for 120 VAC. Switching

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Model # EK80PLC120

A 120 volt power board which allows you to connect regular lamps to our LED Chaser Kits. 8 channels are supplied per board with 150 watts per channel. They can be easily interfaced for 16 channels.

**Colour Organs**

**Three Channel 500 W. Switching**

Model # EK80C500

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**Three Channel 1500 W. Switching**

Model # EK80C1500

$29.95

An excellent item for parties, dances, etc. Three individual controls let you vary the amount of light for Bass, Midrange and Treble. Each output is fused for added circuit protection and will handle up to 50 watts of audio input power. A 200 watt adaptor is available (extra).

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**0-28 Volt Power Supply Kit**

A true 0 to 28 volts capable of delivering 1 amp continuous. Full wave rectification, filtering and capacitance multiplication provides a clean dc source for sensitive audio and digital work. An ideal supply for the experimenter.

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M4Y 1Y5
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Student LOGIC TRAINER & Course

Trainer Consist of:
- 5 V.D.C. Power supply
- Proto Board
- LED'S & Switches
- 7 IC’S included

Student LOGIC Workbook covers:
- gates, clock, binary, decoder driver, & readouts with tests on each subject.
- A lot of research went in to this well illustrated book, large illustrations making LOGIC simple and easy to understand, each student works on his or her trainer building and testing LOGIC circuits.

MODEL: DLT-01 $55.95 EA.
with Cabinet and Supply $98.55

INTRODUCTION

Digital Electronics is a vast and ever growing field in the Electronic Industry. In fact, it is revolutionizing our way of life. From simple electronic games to the NASA space shuttle "Enterprise", digital electronics plays a major part. It is this reason Edu-Kit has prepared a basic digital course so the understanding of some of the basic components may be simplified. General topics discussed are AND gates, NAND gates, OR gates and NOR gates. A single digit counter has been added to supply a better understanding of how gates are applied.

5 Watt IC AMPLIFIER
Model # EK80A305
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A general purpose 5 watt amplifier with Thermal Overload and Short Circuit Protection. Because of its low operating voltage and high power output, it allows the user to use it as an add-on amplifier for car stereo.

Specifications:
- Frequency Response: 40Hz to 15kHz (1-3dB)
- Power Output: 5 watts at 4 ohms
- 7 watts at 2 ohms
- Distortion: 5% at 7 watts at 2ohms
- Load Impedance: 2 to 16 ohms
- V Supply: 12 to 15vdc

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Model # EK80SP001
$12.95

Anyone with a ceramic input receiver can enjoy the quality of a magnetic cartridge with this simple but very effective Stereo Phono Preamp.

Specifications:
- Frequency Response: Standard RIAA
- Input Sensitivity: 20Hz to 2KHz + 1.5dB
- Maximum Output: 5mv input for 500mv output
- Input Overload: 700mv rms
- S/N Ratio: 100mv rms
- Greater than 60dB

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THE HOME OF RADIO & ELECTRONIC SUPPLIES
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TORONTO, ONTARIO
M4Y 1Y5
# Controls

## 30th Anniversary Sale

### Controls

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## 1951 Prices in 1981

### Control Prices

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## Single Controls

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## Dual Controls

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### Single Controls

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### Dual Controls

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### Triple Controls

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### Dominion Radio & Electronics Company

DOMINION RADIO & ELECTRONICS COMPANY
535 Yonge Street, Toronto, Ontario, M4Y 1Y5
### CAPACITORS
#### AXIAL LEAD

<table>
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<tr>
<th>UF</th>
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#### DIPPED SOLID TANTALUM

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<td>5.0 μF</td>
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### TRANSISTORS RADIAL LEAD

- **ECG-103**
- **ECG-128**
- **ECG-199**
- **ECG-283**
- **ECG-165**
- **ECG-162**
- **ECG-121**

### POWER SUPPLY

- 1400 16  65-6000 Com 35  6.95
- 1600 16  65-15000 RPE 45  6.95
- 2200 16  75-12000 Com 40  6.95
- 2000 10  85-15000 Com 40  7.55
- Can 16  150-15000 RPE 10  4.50
- 4700 40  15000 Com 16  4.90

### TRANSISTORS NISETI POLYESTER FILM

- **ECG-103**
- **ECG-128**
- **ECG-199**
- **ECG-283**
- **ECG-165**
- **ECG-162**
- **ECG-121**

### STANDARD 4-PRONG WALL JACK TO MODULAR JACK

- **No. 547**

### SPECIAL BARGAINS

#### CMOS DIGITAL LOGIC

<table>
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<tr>
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<th>Description</th>
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<tr>
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<td>.25</td>
<td>Dual 4 input NOR</td>
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<tr>
<td>4006</td>
<td>.95</td>
<td>18 Stage Static Shift Register</td>
</tr>
<tr>
<td>4007</td>
<td>.15</td>
<td>Dual Complimentary Pairs plus Inverters</td>
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<td>4008</td>
<td>.95</td>
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<td>Dual JK Flip Flop</td>
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<td>.95</td>
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<td>Quad NOR S/R Latch</td>
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### ECOS MIRCOPROCESSOR

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<td>.75</td>
<td>.70</td>
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### MODULAR EXTENSION

- **No. 538**

### PLUG TO FOUR SPADE TIPS, FLAT CORD

- **454-7**
- **454-25**

### MODULAR "Y" ADAPTOR

- **495**

### FLUSH MOUNT MODULAR JACK

- **395**

### NO. 547 - surface mount jack for 2 telephones. Easy to install.

### WALL PLUG ADAPTOR

- **449**

### DOMINION RADIO & ELECTRONICS COMPANY

535 YONGE STREET
TORONTO, ONTARIO
MAY 1Y5
Micro, Slide, Push Button Switches

NORM ON/ OFF MICRO SW.  
BAT HANDLE TOGGLE SW.  
S.P.S.T. WIRED TOGGLE SW.  
CHERRY KEY BOARD SW.

75¢
V1005
LEVER TYPE MICRO SW.

75¢
V1008
Heavy Duty
S.P.D.T. ILLuminated
Has nice snap action.

1951 Prices in 1981

SPRING RETURN  
S.P.S.T. SLIDE SW.

25¢
V1011
rated 3A-125 V AC

SLIDE SWITCH  
D.P.D.T.

25¢
V1014
3P.D.T. SLIDE SWITCH
Position (1) A & B and E & F are shorted
Position (2) B & C and F & G are shorted
Position (3) C & D and G & H are shorted
rated 3A-125 V AC
Very useful see diagram

PUSH ON/PUSH OFF SW.

69¢
V1004
Built in neon indicator
red lens, black bezel
snap in mount

30th Anniversary Sale

DOMINION RADIO & ELECTRONICS COMPANY
535 Yonge Street, Toronto, Ontario, M4Y 1Y5
Switches

MINIATURE CARD EDGE
P.C. S.P.D.T. SW.

S.P.D.T. C & K PUSH SW

C & K SPRING RETURN
D.P.D.T. MINIATURE SW.

U1438
$1.95
P.C. mount

U1441
$1.95
Mounts in 1/4" hole
Extends 5/8" behind panel
Rated 3A-125 V AC

3 POS. Rotary Sw.

3 Positions:
(1) 3 shorting/select
(2) 2 shorting circuit and shorting circuit 2
(3) 2 shorting circuit and 2 select.
Shaft length 7/8" fits 1/2 round knob

V1088
25¢

U1439
$1.95

V1076
35¢

U1440
$2.50

V1022
35¢

U1445
$2.50

U1449
$3.25

3 Position Wafer Sw.
(1) In select one 2 in select one
(2) In select two 2 in select 1
Shaft 2" length 1/4" dia.

V1061
25¢

DOMINION RADIO & ELECTRONICS COMPANY
535 Yonge Street, Toronto, Ontario, M4Y 1Y5
30th Anniversary Sale

Multi-Function Sw.

NEW MULTI GANG BAR SWITCHES

Each sw. push to make or break
Two are S.P.S.T.
One is D.P.D.T.

49¢

Shaft centres
17mm overall length
100mm Depth from front panel 60mm.

Low profile solid built selector sw.
was used as a function sw.
4 switches are push ON/OFF
(a) D.P.S.T. A.C. sw.
5A 250V A.C. lugs
(b) & (c) D.P.D.T.
(g) 3 pole
D.T.
Cancel Type
(D) S.P.D.T.
(E) S.P.D.T.
(F) D.P.D.T.

Six GANGED Selector Sw.

Ganged function sw.
with gold contacts shoulder terminals. 5 switches are 4 pole D.T.
Each cancelling the other when pressed. 6th is
D.P.D.T. Push ON/Push OFF power sw. 3A-125V A.C.
These switches have been used for speaker
selectors, tape deck selector, tape source selector, and
unit selector knobs available on request
20mm shaft centres. Over all length 160mm.

1.49

Rocker Switches

3POS. D.P. ROCKER SW.

59¢

50¢

SP.2 POS. ROTARY SW

S.P.D.T. ROTARY SPEAKER SW.

S.P.S.T. ROTARY PWR. SW.

DOMINION RADIO & ELECTRONICS COMPANY
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<table>
<thead>
<tr>
<th>PLUGS</th>
<th>JACKS</th>
<th>ADAPTERS</th>
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<tr>
<td>RCA PHONO PLUG</td>
<td>$0.10</td>
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<tr>
<td>CHASSIS MOUNT RCA PHONO JACK</td>
<td>$0.30</td>
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<tr>
<td>ULTRA MINIATURE LONG BARREL PLUG</td>
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<td>ULTRA MINIATURE CHASSIS MOUNT JACK</td>
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<td>SHIELDED PHONE PLUG</td>
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<td>$0.40</td>
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<tr>
<td>STEREO PHONE PLUG</td>
<td>$0.89</td>
<td>A31</td>
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</tbody>
</table>

**30th Anniversary Sale**

Originally from an electric drill, this trigger control device is 120vac, 4 amp and has a locking switch. Limited quantity available.

<table>
<thead>
<tr>
<th>PLUGS</th>
<th>JACKS</th>
<th>ADAPTERS</th>
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<tr>
<td>SHIELDED STEREO PHONE PLUG</td>
<td>$1.89</td>
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<tr>
<td>STEREO PHONE JACK CIRCUIT CLOSING</td>
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<td>INLINE STEREO PHONE JACK</td>
<td>$0.99</td>
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<td>SHIELDED STEREO INLINE JACK</td>
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<td>EPOXY STEREO PHONE JACK</td>
<td>$0.99</td>
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<td>STEREO Y ADAPTOR</td>
<td>$3.95</td>
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<tr>
<td>CHROME CHASSIS MOUNT MIKE CONNECTOR</td>
<td>$0.59</td>
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<tr>
<td>PHONO JACK TO PHONO JACK ADAPTOR</td>
<td>$0.99</td>
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<tr>
<td>MINIATURE JACK TO PHONE PLUG ADAPTOR</td>
<td>$0.99</td>
<td>A42</td>
</tr>
</tbody>
</table>

**VARIABLE SPEED SWITCH**

$4.95 ea.

**DOMINION RADIO & ELECTRONICS COMPANY**

535 Yonge Street, Toronto, Ontario, M4Y 1Y5

A DIVISION OF DRECO ELECTRONICS LTD.

THE HOME OF RADIO & ELECTRONIC SUPPLIES
NO. 42 BULBS
15¢ ea.
3.2 Volt – 5 cp. 3000 hour average life. Base T-3 1/4 bulb screw type miniature.
Part No: U1400  Box 10 lamps
99¢

NO. 47 MINIATURE LAMPS
6.3 VOLT
15¢ ea.
U1401
6.3 volt – 150 ma replacement for Auto & Home Stereo Receivers.

NO. 49 LAMPS
15¢ ea.
Box of 10 pcs. 99¢  U1402

NO. 112 PRE-FOCUS LAMP
U1403  20¢ ea.
1.2 volt – 22 ma. 5 hr. average life style TL-3 Base miniature screw.

NO. SL-4T4 APPLIANCE BULBS
U1404  29¢ ea.
120 volts appliance 56 bulbs with cancelabra base. Clear bulb.

NO. 624 AUTO-LAMPS
U1405  29¢ ea.
28 volt – .37 amp. 6 cp. Type dual element style G-6.

NO. 502 MINIATURE BULB
U1406  15¢ ea.
5.1 volt – .6 cp. 150 ma. Style G4 G4-1/2 bulb miniature screw base

MINIATURE PIG-TAIL LAMPS
6.3 VOLT
39¢ ea.
U1407
6.3 volt – 150 ma replacement for Auto & Home Stereo Receivers.

NO. 1390 SPOT LAMP
59¢ ea.
U1408
48 volt – 20 watt 1500 hr. average life. Style R-12 single contact Bay Base

NO. NE-2 NEON LAMPS
10¢ ea.
U1409
For 120 V AC operation use 200k resistor.

NO. 6-7130 PUSH IN LAMP
U1410  79¢ ea.
6 volt Osram mini-Push In.

NO. 6A1 TELEPHONE LAMP
U1411  1.29 ea.
6 volt – 14 amp type T-2 end ft. candles 900. Longlife telephone type.

NEW! Antique AUTO Bulbs

Part No:
Style Voltage: Type: Candle Power:
U1416 1009 D.E. 12V Auto
U1417 1252 D.E. Auto
U1418 1615 S.E. Auto
U1419 1829 S.E. Bay Auto
U1420 1850 S.E. 5V Auto .07A
U1421 SL2331 D.C. RPII 6V Auto .09A
U1422 2336 DC 12-16V Auto 32/32 C.P.

NO. G17Q PROJECTOR
U1423 1.99
120 volts 150 watts pre focus built in reflector 4 pin locktal base.

DUAL CONTACT APPLIANCE LAMP
U1425 89¢
120 volt 15 Watt Bayonet Base dual contact base. Used in Vacum & Electric Brooms.

500W FOTO-FLOOD
U1424 99¢
MOGLE BASE
120 Volt 500W.
### BULBS, LEDs & LDRS

**NO. CHANDELIER BULBS**

- **U1426** 25¢
  - 130 volt 15 watts torpedo clear lamp with candelabra base.

- **MINIATURE BASE CHANDELIER BULBS**
  - **U1427** 25¢
    - 130 volt 15 watts torpedo clear lamp with miniature screw base.

- **NO. 7C7 APPLIANCE BULBS**
  - **Bayonet Base U1428** 25¢
    - 120 Volts 7W dual contact Bay Base style C7/7C7

- **NO. APPLIANCE BULB**
  - **Screw Base U1429** 25¢
    - 120 volts 7 Watt Candelabra Base style C7

**AQUARIUM LIGHT BULBS**

- **U1430** 49¢
  - 130 volts 40 watt frasted designed for aquariums to bring out natural colours.

**NO. PF208E/60 PHOTO LITE**

- **U1431** 99¢
  - 120 volts 500W photography lamp fits Reg. socket. Ideal for P.C. Board Developing.

**DECORATIVE LAMPS**

- **U1433** 99¢
  - 230 volts 60 watts lamps with mirror non glare refector for back lighting. Standard Base.

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**30th Anniversary Sale**

**CADMIUM SULPHIDE**

- **U1434** 99¢
  - 500ohms-5k ohms
  - CLAIREX No. 705L

- **U1435** 99¢
  - 100ohms-3kohms
  - CLAIREX No. 505 L

- **U1436** 99¢
  - 1kohms-10k ohms
  - No. CSD3

**Hardware**

- **RED LED LAMP**
  - **U1112** 49¢
  - Single Digit Display

- **B1100**
  - RED 29¢

- **B1101**
  - GREEN 39¢

- **B1102**
  - YELLOW 39¢

- **B1103**
  - RED 29¢

- **B1104**
  - GREEN 39¢

- **B1105**
  - YELLOW 39¢

**DOMINION RADIO & ELECTRONICS COMPANY**

535 Yonge Street, Toronto, Ontario, M4Y 1Y5
**MOTOR ITEMS**

**110V FAN MOTOR**
- for Exhaust Hood
- $2.95
- H1311
- 2 Speeds

**110V MOTOR**
- $1.95
- H1303
- 110 V
- 7800 RPM
- 1" x 1 1/2" Deep

**HOBBY MOTOR**
- $1.95
- H1306
- 3.9 V
- 3/4" x 1 1/2" Deep

**PHONO MOTOR**
- H1302
- $2.95
- 110 V
- 2" x 2" x 2 1/2" Deep

**HOBBY MOTOR**
- $1.49
- H1307
- 6-12 V
- 1" x 2" Deep

**Tape Deck MOTORS**
- H1304
- $2.95

**HOBBY MOTOR**
- $1.95
- H1308
- 6-12 V
- 1 1/4" x 1 1/2" Deep

**HOBBY MOTOR**
- 49¢
- H1309
- 6-12 V
- 1" x 1 1/4" Deep

**PHONO MOTOR**
- $3.95
- H1300
- 110 V
- 2 1/2" x 3" x 2 1/2" Deep

**110V FAN**
- $3.95
- H1301
- 110 V

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DOMINION RADIO & ELECTRONICS COMPANY
535 Yonge Street, Toronto, Ontario, M4Y 1Y5
Shaver Cords

Purchased from a well-known manufacturer, these portable shaver cords are always in demand. Pin spacing on the cheater end is 5 mm. Come in white, seven ft. rated 50 watts CSA.

Part No: U1450
Shaver cord.

Lite Cords

5 for $1.00

POWER line cords approx. 100,000 pcs in stock 20 ga. clear in colour with easy grip moulded plug. Ideal for small projects at school, lamp manufacture, or just as a replacement.

Part No: U1451
Clear cord.

Cheater Cord

PORTABLE equipment cord with key on the cheater end. Used on cassette recorders of many types. Comes in black only with classic receptacle.

Part No: U1452
Cassette cord.

Brand New! HEATING ELEMENTS

For: ELECTRIC Styling Combs, Blowers & Mist Units

* WITH: DUAL HEAT RANGE * 600w, 1000w, & 1200w. All listed below:

(A) 600w

(B) 1200w

Your Choice

99¢

(D) 1000w

(E) 600w

(F) 600w

30th Anniversary Sale

DOMINION RADIO & ELECTRONICS COMPANY
1 lb EPOXY G10 GLASS BOARDS
Double Sided COPPER CLAD $1.10
* 1/16" Thickness
* Size: 3½" x 7" approx.
* GREEN in COLOUR

GREAT! CARD EDGE RECEPT.
Miniature 4 mm Spacing
89¢
CARD edge receptacle allows signal or power take off from main buss or mother board comes in variety of styles. Female receptacles may be mounted side by side without changing 4 mm spacing. Pins soldered at right angle to board for parallel connection.
Part No: U1474
Buss socket . . . . . .

Card handle

12 CONDUCTOR CARD SOCKET
99¢
THESE card sockets are similar to amphenol 143 series with time plated tuning fork shape lugs spaced at 4 mm apart will accept up to 12 conductors. An ideal socket for add on circuitry for existing equipment modifications or updating.
Part No: U1475
12 pin socket . . . . .

15 CONDUCTOR 90° CHASSIS CARD SOCKET
99¢
THIS 15 conductor right angle socket should prove handy. Made by molex nylon Holder with brass silver plated cantilever contacts with crimp style lugs for easy insertion. Made for ribbon or individual wire lead.
Part No: U1476
15 pin molex . . . . .

26 CONDUCTOR INLINE RIBBON SOCKET
$1.95
THESE double edge master flex card sockets come with a 4.5" copper ribbon of 26 conductor for easy mounting of surface mount sockets. Each socket has pin location of 2.5 mm or .1" spacing to 28 pins. Overall length of each socket 104 mm or 4 1/8" long x .5" or 12.5 mm width.
Part No: U1477
Dual 28 pin sockets . .

Wire type 43 PIN X 2 DUAL EDGE CARD SOCKET
1.95
THESE edge board connectors accept boards from .054" to .071" thick. With precise spacing of gold plated cantilever contacts permits trouble free termination. These sockets are a must today for any enthusiast building his own computer. Each socket has a double row of 43 contacts of 4 mm spacing over all length 193 mm or 7 5/8" approx. With 12 mm or .5" solder lugs are 7 mm or .25" length each edge socket bottom has alpha numeric marking for pin location.
Part No: U1478
43/86 socket . . . . .

CARD SOCKET
PC type
$2.95
Terminal socket with open lug are 10.5 mm or 7/16" length.
Part No: U1480
43/86 socket . . . . .
the men who operated them, encumbered as they were with homebuilt equipment and inadequate studio facilities. That they programmed at all and maintained a modicum of a schedule still makes one wonder.

For example, at one time the studio at Stratford were housed over a little used hotel annex. Whenever they unloaded beer kegs downstairs for weekend customers, the thumping on the floor caused the homebuilt turntables to jump, sending pickups sprawling and interrupting programs. These hazards, to me, typified early Canadian Radio where, often as not, studios were nothing more than a back room in a radio service shop and the associated transmitter was downtown, compared with the rural location of today with thin, vertical towers pointing to the sky.

Our own 10AK in ‘36 used wire strung between the chimney of the local steam laundry (the tallest point in the area) and the back of the Higgins Radio shop in downtown Stratford. It was an achievement, when kids, to be able to pick up old 10AK on a home-built crystal receiver. This station boasted a 50 watt transmitter, a carbon microphone and a phonograph.

Radio had been growing in a national way before 1930. Key stations were being opened right across Canada by the CNR, whose interest was illustrated by their early success in radios installed in Pullman cars. It soon became apparent Canada was developing two forms of radio; the local, independent station which, though commercials were still local, soon became apparent Canada was going to maintain them, at least identified their character, as being apart from the CNR’s operation, which was Government supported.

The inevitable question was asked: should Canada have its own national system or leave it to private enterprise to develop? Why couldn’t we keep listening to U.S. stations which, since KDKA’s early success in 1921, all but set the listening habits of thousands of Canadians, or, for that matter, use the local. But things had already been moving, national wise.

The Aird Commission was set up on December 6, 1928, to try to find an answer. Sending delegates to Europe for a start, they conducted enquiries throughout the continent and found countries there who were also searching for the same thing: a form of national broadcasting “in the public interest”. Returning, they conducted hearings in Canada (like our past B & B Commission?) to pursue the question further.

Train Radio

Sir Henry Thornton, an early advocate of radio for Canadians and at the time President of the CNR, placed a private railway car at the Commission’s disposal, facilitating their travels, which took in 25 Canadian cities. The conclusions of their findings was that a majority felt broadcasting should be on a public basis.

In the meantime, a growing rival who was to prove a difficult adversary of the majority’s opinion, the CPR (with its extensive network wired facilities), felt broadcasting should be on a commercial basis. Championed by the Toronto Telegram and the old CKGW Toronto radio station (now defunct), they almost succeeded in having their way. This, despite the fact the CNR already had the basis of a successful network.

![Fig. 1 Sir Henry Thornton](C:24236/Public Archives Canada)

Sir Henry Thornton, who did so much to promote early Canadian radio and who succeeded in fostering a sense of national identity, with the CNR network carrying the sound of the Peace Tower Chimes from Ottawa across Canada, for example, was caught in the middle of the growing controversy. In 1932, he recommended a Royal Commission to investigate all phases of the operation.

Two men appeared on the scene about this time Graham Spry and Alan Plaunt, both under 30 years of age and in the enthusiasm of youth saw what others failed to recognize in the possibilities existing for Canadian radio. Both had attended university in England and there had come in contact with the then young BBC. Together with eminent Canadians who shared mutual interests in Canada they formed the Radio League, out of which broadcasting in Canada, as we know it, had its genesis.

Spry appeared before the Duff Commission on behalf of the Radio League on January 14, 1932, arguing the railways were the principal program-builders in Canada (representing as they did half of all the coast-to-coast broadcasting at that time). He emphasized the value of the railways’ wire services as indispensable to national programming, pointing out the many experimental stations could not hope to duplicate such a service. He made his point and the philosophy of a national system — augmented by commercial interests — followed. It was from this beginning that he enjoyed the assistance of Alan Plaunt and a man who proved their most impressive witness at hearings, Mr. Gladstone Murray from the BBC, who later became general manager of the CBC.

This new service was the first counter-force to the growing flood of programs now inundating Canada from the U.S.

The early forerunner of Canadian radio and the CBC — the Canadian Radio Commission — is lost in antiquity and never was resurrected, although it actually had the difficult and thankless task of taking over the vast network facilities of the CNR, suffering much abuse from politician and broadcaster alike. It laboured under much political acrimony, which involved both the Liberal and Conservative Parties under their respective leaders, W.L. Mackenzie King and R.B. Bennett. Sir Henry Thornton, who did so much to promote early Canadian radio, left Canada, and died in this native country.

Thornton’s talks, heard by some of us at the height of his popularity over “this” CNR radio, were summed up by John Nelson writing in MacLean’s of February 1925 and reported in Austin Weir’s book, “Struggle for National Broadcasting in Canada”. Nelson said of Henry Thornton: “His talks, really fireside chats, were friendly, intimate, timely and dealt with a great variety of topics.” He described how they were directed at acquainting employee and public alike of the CN’s hopes, plans, successes and policies. Compliments received by customers, for example, about a certain porter, were relayed across the network, and every porter took pride in his work.

It was claimed at one time that it was the CNR’s efforts in radio as ear-
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INTERNATIONAL SCHOOL OF ELECTRONICS

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Circle no. 25 on Reader Service Card.
Topping the Competition

There were many laughs interspersed with the paths of those days. For example, that same 10AK which preceded CJCS had something of a record in another sense distance. For even with 50 watts, its radio voice far outweighed its own pecuniary circumstance. Perhaps out of pride in the achievement of being heard as far away as Detroit, Mich., over 150 miles distant, or merely being egged on by the desire to counteract the growing might of the U.S. stations now getting more powerful (in 1932 WLW Cincinnati went to 50,000 watts and hammered into Stratford, 10AK boasted a regular Saturday Night "Olde Tyme Show" over its 50 watts. Second to none, they proclaimed and to add emphasis the announcer said it originated from the 44th floor of their studios in downtown Stratford. Of course there were no buildings there over three stories, let alone 44! That the blarney had the necessary effect is evidenced by at least one intrepid fan from Detroit arriving in Stratford one day to ask where all the tall buildings were!

These earnest, if humble and comical efforts to add prestige to Canada's early broadcasts could not make up for the growing imbalance of power between Canada and U.S. stations. The total power of Canadian stations, even up to 1932, was less than a present day 50 KW transmitter, compared to a total of 680,000 watts for American stations 30 years later! And more than a third of our stations were concentrated in Toronto and Montreal, leaving great isolated areas served from the U.S. It is to the credit of the early visionaries who doggedly pursued the argument of a national broadcast system for Canada that this has been changed. Their success is attested by the fact that nearly 90% of Canada now enjoys Canadian coverage. We are also in second place (next to the U.S.) for density of number of receivers, having approximately 58 receivers per 100 population, according to G.A. Coddington's book "Broadcasting without Barriers", published by UNESCO. The U.S. have 88 receivers per 100 population, while the United Kingdom have 28.5 per 100. The USSR have about 16.5 per 100 population, with a bottom, in India, of only 0.3 per 100, though with its large population this still represents over 1 million sets.

Through the efforts of men of the calibre of Thornton, Spry, Plaunt, Austin Weir (commercial Manager, CBC, 1937-50), A.R. McEwan, Canada also set a record of "firsts" in communications. Among these was the experimental use of radio on trains as early as October 13th, 1902, ten months after Marconi's epic first trans-Atlantic wireless message, when Dr. Ernest (later Sir Ernest) Rutherford and Dr. Howard Barnes successfully demonstrated the transmission of radio signals to a moving train with receivers located on board the "International Limited".

On October 9, 1923, the British Prime Minister, David Lloyd George, touring Canada at the time, was shown how newscasts could be picked up, via radio, aboard a moving train.
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The first trans-Atlantic broadcasts were begun by CNR radio in 1928, which saw the beginning of the "Empire" broadcasts over the same system in 1932, facilitated by The Canadian Marconi Company (without any remuneration) from its stations at Yamachiche and Drummondville, Quebec.

The concept of a bi-lingual network was begun in Canada with the first recorded program in language (French phonetics) being aired in 1931.

The early use of "Multiplex" (whereby more than one program could be sent over a pair of wires) was pioneered by the CNR in Canada to accommodate the growing demand for program carrying network facilities.

For sheer drama the coverage, in 1930, of the arrival of the R-100, Britain's huge dirigible which crossed the Atlantic in that year, can't be beaten. A leviathan nearly 800 feet long, its arrival in Quebec City was carried by the network in fact both, as the CNR and CPR had wires prepared with coverage from Montreal (where the mooring base was located at St. Hubert's) by a little known announcer named Foster Hewitt. Andy Ryan handled the CN network, and described the R-100's arrival in nearly inspired words, as the giant hovered over the city at dusk to the sound of every ship whistle, bell, and siren in the city.

Culture-wise, Canada registered a landmark with an early history series designed to acquaint Canadians with their own exciting past (the centennial efforts were something new?) and securing one of the top men of the day to run the series - Tyrone Guthrie who later became Sir Tyrone Guthrie of Stratford Shakespearean fame.

The establishment of the CBC in 1936 saw the residue irritants of the old CanadianRadio Broadcasting Commission removed, and Canada moved into a new era of broadcasting with the parallel growth of the CAB (Canadian Association of Broadcasters) the commercial arm of radio broadcasting. How many, for example, can forget the early "Good-Morning Sheriff's Hour", with their bright music and fun early each morning, or the "Happy Gang" whose lighthearted entertainment helped counteract the otherwise sombre war years?

Perhaps the great men of Canadian Radio are as the voices of radio itself — ghosts if you will — who speak even now. Many had died, like Alan Plaunt, still young at 37, with years of service unfulfilled. Plaunt was subsequently remembered by the "Alan B. Plaunt Memorial Lectures", established by Carleton University in 1958 and delivered annually.

Graham Spry — after leaving Canadian Radio — retained an active interest in it from his post in London, England where he served as Agent-General for Saskatchewan. Later, he frequently wrote on the subject for the Queen's Quarterly Review, retiring in 1968. As Austin Weir said of these two men who did so much for early Canadian radio, "it was commonplace for Plaunt and Spry to dig into their own pockets to provide needed funds for that early organizational work".

And perhaps this is as good an epitaph for the legions of men and women who, in a thousand different ways and varying capacities of service, have contributed to the growth of a once struggling child to the giant that is Canadian Radio today.

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INTO LINEAR IC’S
(Part One)

Now that Into Electronics has finished, Ian Sinclair again puts pen to paper and tackles the awesome task of describing the habits of that family of ICs known as Linear ICs.

If you’re just getting into this electronics caper, perhaps you think that you’d better avoid ICs. Can’t say we blame you — ICs are small, with lots of connecting pins laid out a bit too close for comfort, and the circuits which use ICs look strange in comparison to the more familiar circuits which use transistors. Just to make life a bit more difficult for the unfortunate beginner, books for beginners very often don’t mention ICs at all, and books which do mention ICs seem to assume that you know all about them already.

This series is designed to change all that. We’re going to start off by introducing you to the types of IC which are classed as linear — and we’ll explain what that means in a moment. Later — much later — we’ll look at the other type of IC, the digital IC. In addition, the series will be built around practical work — we’re not going to spend too much time on the theory of ICs. Reason is that what goes on inside an IC is not of so much interest as what goes on outside — it’s not like a transistor circuit in which we can change any component we like. That doesn’t mean we won’t explain how the circuits work; we will, honest, but we won’t explain the details of the circuits inside the ICs.

IC THE DIFFERENCE

What is an IC anyway? The letters stand for Integrated Circuit, which doesn’t tell you much more than the phrase ‘silicon chip’ which you read in the papers — and they usually manage to add an ‘e’ to silicon as if it were a furniture polish. What the IC means is that a complete electronic circuit can be made on a small piece of silicon as easily and as quickly as a single transistor. Transistors are made from thin silicon pieces, called wafers, measuring about 1.25 mm square, by a set of manufacturing processes which include heating in various gases and evaporation of silicon and metals. Now as it happens, we can make resistors and capacitors by the same processes in a different sequence, so by using shields (or masks) over the silicon we can control what sort of component we make on each part of the wafer. By evaporating metal, we can then make connections between different sections, so constructing a complete circuit.

What’s the advantage? It’s not just that the whole circuit is smaller to an incredible extent, though that can be handy. The big, big advantage is that all the connections are made during the manufacturing process. Let’s explain that. Suppose we made up a 5 transistor circuit (Fig. 1a) using separate components — the name for a circuit made this way is discrete circuitry. There are a lot of connections to make in this discrete circuit. Making each connection takes time, and each one is a possible source of trouble, like dry joints. mistakes, short circuits, the lot. Even if you get all of these connections right, there’s a fair chance that one out of all these components may break down and fail at some time, and the more components you use, the greater the chance of at least one of them failing. An electronic circuit is like anything else — the more components it uses, the less reliable it is.

Fig. 1. A transistor amplifier circuit (a) and an IC circuit (b) with the same performance.

PINNED DOWN

Now if we make the same circuit in integrated form, as an IC Fig. 1b, there’s just one component — the IC. All the components which make up the circuit are there, but because they were made in one operation and at the same time, they behave with the reliability of one component. There are now fewer connections to make; in the example shown, we’ve replaced 21 components and 42 connections by two components, the IC and resistors and seven connections. That’s a big improvement, and because the IC is a single component, it can be tested more easily and more quickly than would be possible if we had to test each component of a discrete circuit separately, then the whole circuit once it was assembled.

That’s not all, either. The IC is produced by the same sort of factory methods as are used to make transistors, so that making one IC costs about as much, once we get production going, as making one transistor. Because of
that, the IC is usually cheaper than the components it replaces. Just to complete the list of advantages, the IC is not so easily damaged by mechanical shock (he means they still work after you've dropped them, lad) as a complete circuit made from separate components.

Any snags about all this? Well, yes, there's one. If you make up your circuits from separate components, you can make any circuit you like. Using ICs, aren't you limited to what the manufacturers think is worth providing? The answer is yes and no! A readymade circuit is a bit of a restriction, but the types of circuits that are made as ICs are so designed that they can be used in a huge number of ways, making them practically as versatile as separate components, as you'll see when we get round to trying out some circuits. To keep prices low, ICs have to be made in very large quantities, so that an IC must be useful for a lot of applications so as to earn a bit of bread for all the people who make it.

### Linear and Digital

So far, so good. Now we come to the two main types of IC. Apart from a few specialised ICs, they're all either linear ICs or digital ICs, so now we have to explain what the difference is. Any electronic circuit usually has an input and an output, and we put a signal into the input and take a signal from the output. If the output signal is a copy of the input signal then the circuit is a linear circuit, an amplifier in fact. Why linear? If we plot a graph of the output signal voltage against the input signal voltage, the graphs shown in Fig. 2, then the graph shape is a straight line for a linear circuit — and that's where the word linear comes from. When an amplifier is perfectly linear, the graph line plotted as we've just described, is perfectly straight, and the output signal is a perfect copy (though to a different scale) of the input signal.

ICs that are designed for use as amplifiers are linear ICs, each part of the circuit inside the IC is a linear amplifier. A few other types of ICs are also classed as linear ICs, even though their output signals look nothing like their input signals, just because they contain linear amplifier circuits. We'll be looking at one of these ICs, the 555 timer, later in this series.

### Linear ICs

How about digital ICs, then? Very briefly, because there's another series on digital ICs coming up, these ICs use the same types of signals for both input and output, and what we are interested in is what combination of signals or sequence of signals we have. Much more of that later, in the next series but for now we're concerned only with linear ICs.

---

**Fig. 2.** Linear graphs (a) Inverting amplifier, (b) non-inverting amplifier. The graph lines usually bend noticeably at the ends, hence the use of bias to use only the straight portions.
What goes on inside the IC then remains a mystery until often used is the triangle (Fig. 6) with input(S) at the flat design and produce the IC! The symbol which is most these days to get a symbol accepted than it does to symbols for linear ICs, mainly because so many linear around for a long time. There aren't many standard each component and most of these symbols have been after you've seen the data sheet.

Good ol’fashioned transistor circuits use a symbol for the correct one to use is the one which is more deeply cut into the plastic.

Fig. 4. Typical DIL packages.

**PRACTICALITIES**

Let's be practical for a moment. If all of your construction has been with transistors up to date, you’re going to notice a difference. Transistors have thin leadout wires which can be bent and shaped to suit your circuitboard. ICs have thicker, flattened pins, and the circuit board has to be shaped, with solder pads 2.5 mm apart in lines 7.5 mm apart, to take the IC without bending the pins. On most solderboards, this presents a few problems because with lines spaced only 2.5 mm apart, your soldering has to be pretty neat if you’re to avoid shorting tracks together with the solder. It's a great advantage to have a soldering iron with a really small bit, and to use fine-gauge solder — more of this in Part 2.

**SYMBOLS**

Good ol’fashioned transistor circuits use a symbol for each component and most of these symbols have been around for a long time. There aren't many standard symbols for linear ICs, mainly because so many linear ICs would need special symbols, and it takes longer these days to get a symbol accepted than it does to design and produce the IC! The symbol which is most often used is the triangle (Fig. 6) with input(S) at the flat end and output from the sharp end. This symbol is used to represent an amplifier, and since most linear ICs contain amplifiers or are amplifiers, it's the most useful thing to have a symbol for. Other linear ICs simply use a square or rectangular block symbol, with, input, output and power supply lines going in and out of the block. What goes on inside the IC then remains a mystery until we take a long hard look at the data sheet — and until you've finished this series it may remain a mystery even after you've seen the data sheet.
DC COUPLING

Now the odd business about direct coupling is that we can’t bias each transistor in an amplifier separately by itself. If all the transistors are connected together, collector to base, without the use of capacitors to isolate the DC, then the collector voltage of one transistor is the base bias voltage for the next one, and the only way we can control all of this is to have the bias for the first transistor in the amplifier set correctly, and design the amplifier so that setting the first one will ensure that all the others are correct also.

The only way we can bias a linear IC, then, is by applying a steady bias voltage at an input terminal. We can’t take the circuit apart to get to any of the transistors inside, we simply have to assume that the designer of the IC knew what he was doing (and they do, folks, they do) and arranged things so that with the correct bias on the input each stage of the IC would be correctly biased.

We can ensure that we have the correct bias for linear action by using negative-feedback bias. As we’ve seen, a signal fed back from the output of an amplifier to the + input is positive feedback, but a signal fed back to the – input gives negative feedback. A linear amplifier IC can be correctly biased by connecting a resistor to act as a feedback path between the output and the – input terminal. This feeds back DC, and works only because the amplifier is completely direct-coupled.

How does it work? Let’s take a look at a typical circuit (Fig. 8) which uses two separate batteries to operate a linear IC amplifier. Now using two batteries as this circuit does may look a bit complicated, but in fact it makes amplifier circuits a lot simpler, as we’ll see later. In the diagram, the + input of the amplifier is connected to earth, which is also the return path for both batteries, and the output of the amplifier is connected through a resistor (any size, 10K to 10M) to the – input. This automatically sets the amplifier to the correct bias.

HOW IT WORKS

Here’s how it works. Remember that the circuit inside the linear IC is quite an elaborate one, containing a lot of transistors and with a very large voltage gain, 100 000 or more. In addition, the voltage that is amplified is not just the voltage at one input but the voltage difference between the inputs — if both of the inputs are at the same voltage there’s nothing to amplify. We’ve shown the + input connected to ground, so unless the – input is also at ground voltage (give or take a bit, as we’ll see), there will be some voltage difference between the inputs and this will be amplified to appear at the output. If the voltage at the + input is higher than the voltage at the – input, the output voltage goes high (to +9 V in the diagram) and if the voltage of the – input is higher than the voltage of the + input, the output voltage goes low (to –9 V in the diagram).

So far, so good, now we have to get back to the negative feedback. If we raise the voltage at the – input above earth voltage (which is the voltage of the + input), then the voltage at the output will drop below ground voltage. If we lower the voltage at the – input below ground voltage, then the output voltage will rise well above ground voltage. The output voltage is free to swing either above or below ground voltage because we’ve used two power supplies in this example.

With the output connected to the – input, the only thing that can happen is for both the – input and the output to settle at ground voltage. Why? Imagine that the – input voltage rises to 0.00001V above ground voltage. With a voltage gain of 100,000, and the usual inversion, this would cause an output voltage of – 0.00001 x 100,000 = –1 V. This amount of voltage at the output, connected back to the – input by a resistor, would whip the input voltage back to zero pretty quickly. Imagine it the other way round — that the – input voltage has dropped to –0.00001 V. Once again, the combination of high gain and inversion produces a voltage, this time of +1.0 volts, at the output, and the feedback ensures that the voltage drops back to zero again. If the + input voltage is exactly zero, the same as the voltage that the + input has been set to, then there’s no difference between the input voltages, nothing to amplify, and the output voltage remains at zero — which is exactly halfway between the supply voltages, just the condition to ensure that the amplifier is correctly biased.

INPUTS AND OUTPUTS

Why can’t we just connect both inputs to ground? The reason, once again, is the very high voltage gain of the IC amplifier. The slightest voltage difference between the inputs, as small as 10 microvolts, will cause an output of a volt or so, and so and slight differences between the transistors inside the IC will cause a change of output voltage even with both inputs grounded. This sort of difference is called an offset. We can’t, even in an IC make transistors which match each other perfectly, so that this offset always exists. Using negative feedback for bias solves this problem, because the feedback action

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The Essential Computer Dictionary and Speller
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A must for anyone just starting out in the field of computing, be they a businessman, hobbyist or budding computerist. The book presents and defines over 15,000 computer terms and acronyms and makes for great browsing.

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AB019 $9.45
This workbench guide can show you how to pinpoint circuit troubles in minutes, how to test anything electronic, and how to get the most out of low cost test equipment. You can use any and all of the time-saving shortcuts to rapidly locate and repair all types of electronic equipment malfunctions.

Please order in writing or use the order form in this issue. Send to ETI Magazine, Unit 6, 25 Overlea Blvd., Toronto, Ont., M4H 1B1. Prices include shipping; there is no sales tax on books. Normally books are dispatched within 48 hours but please allow six weeks for delivery.
IF YOU ARE IN A BAND and your PA has a range of inputs you may wonder why you need a mixer. Well one of the advantages is that when your bass player thinks he is not loud enough to be heard over the rest of you, it’s up to someone else to turn him up! Otherwise, you can so easily get that snowball effect where one musician turns up the volume only to be followed by all the rest and so on until every sentient being within earshot suffers premature deafness (pardon?).

Many bands these days seem to have started on nothing and are maintained on a shoe string. If yours falls into this category, then this is the project for you. No-one is going to claim it’s hi-fi but it is cheap. Using 741 op-amps will produce plenty of power versus cost.

**Construction**

We built our unit into a small plastic case and mounted all the pots on the aluminium top cover, making the required connections with shielded cable. Take care not to produce a ground loop when connecting up. The remaining components can be mounted on our PCB; only three wire links are required to supply the op-amps negative supply. We used polycarbonate capacitors mostly, taking advantage of their small size and good characteristics,

**HOW IT WORKS**

The heart of the circuit is IC2, an op-amp connected as a conventional virtual ground summing amplifier. This stage mixes the input signals and also has a gain of 10 to compensate for the insertion loss of the passive tone control network. There are three high level inputs and one low level which is input to IC1. This stage provides non-inverting amplification with a gain of about 20. Independent volume controls are provided for each input and the signals are mixed in IC2 before being passed to the tone control network. This provides a 40 dB range of control with an insertion loss at midband of — 20 dB.

This output from the tone control is AC coupled to unity-gain voltage follower IC3. AC coupling avoids the problem of wiper 'track noise', which would result from the irregular capacitor charge and discharge currents. R16 is inserted in the output of IC3 to isolate the op-amp from the large capacitive load presented by a long length of screened cable. Potentiometer RV7 provides overall volume control and capacitors C14 and C15 decouple the power supply lines. Two 9V batteries provide power for the unit and current consumption will be just a few milliamps.
though polyester types can be substituted. There are no special precautions to take. Just make sure you put the ICs in the right way up and get the polarity of the two tantalum capacitors right.
Remember, if you ever reverse-bias a tantalum cap by more than about 3 V it's dead certain that you'll have blown it up and it'll no longer be a capacitor, more a low-value resistor with the inevitable effect on circuit operation. No problems with this project, though. Simply build it, fix it and mix it!

**PARTS LIST**

<table>
<thead>
<tr>
<th>Resistors all ¼ W 5%</th>
<th>Capacitors</th>
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<tr>
<td>R3</td>
<td>C3,11 100n ceramic</td>
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<td>R4,5,6,7</td>
<td>C4,5,6,7,8 100n polycarbonate</td>
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<tr>
<td>R6,9</td>
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<td>C12,13 15n polycarbonate</td>
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<tr>
<td>R11,14</td>
<td>C14,15 47u 16V tantalum</td>
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<td>IC1,2,3 741</td>
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<td>Case, connectors, batteries, DPDT</td>
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<tr>
<td>RV7</td>
<td>switch, etc.</td>
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</table>

Capacitors

Semiconductors

Miscellaneous

The PCB (above) tucks neatly away at one end of the case. Make sure the case is deep enough to allow clearance of the batteries and potentiometer bodies.

Front panel control layout (left).
SPEAKER DESIGN

If you ever wanted to know, in a practical fashion, what is involved in the design of a loudspeaker system, then here's a down-to-earth insight — ending in a real design. By David Tilbrook.

MORE MONEY can be saved by the construction of a pair of loudspeakers than any other single component of the hi-fi system. Unfortunately, they are also the most important hi-fi component! Unless the turntable or amplifier is particularly poor, the loudspeaker will undoubtedly determine the overall sound of the system. For this reason it is disappointing there are so few really good kit loudspeakers.

The fact that a "correct" loudspeaker doesn't exist is to be expected, since the principles of loudspeaker operation are enormously complex. Every loudspeaker model makes certain assumptions to simplify the mathematics and to make the model manageable. If these assumptions are overdone the model rapidly loses relevance, becoming incapable of making worthwhile predictions about the real loudspeaker. For this reason it is disappointing there are so few really good kit loudspeakers.

The most common loudspeaker consists of several moving-coil direct-radiating drivers mounted in an enclosure. These cover different frequency bands within the audio spectrum. A crossover is used to separate these frequency bands and feed them to the appropriate driver.

Most of these problems can be summarised with one word... inertia. This is that property of nature whereby things resist change. We can't really complain too strongly about inertia since it is responsible for much of the order that exists in the universe. Nevertheless, in loudspeaker design it causes real problems. The signal voltage from the power amp, the magnetic field around the voice coil, the movement of the coil and loudspeaker cone, all resist change. Since the objective of loudspeaker design is to convert an electrical signal into its exact acoustic counterpart, these sources of inertia cause errors resulting in distortion. The effects of inertia don't stop at just slowing down the system. The resistance to change of motion by the cone for example results in some parts of the cone moving before others. Sound waves start to travel along the cone itself, travelling radially out from the voice coil. Depending on the nature of the flexible surround between the cone and the chassis this sound wave will be partially reflected back down the cone. This causes constructive and destructive interference with the original sound wave propagating up the cone.

Figure 1. An exploded view of a moving-coil loudspeaker showing the various components in its construction. Compare this with the cutaway view of a speaker at right (Pic: courtesy Bose).

Figure 2. Cutaway view of a speaker unit showing internal construction (Pic: National).
resulting in colouration. Clearly, this is not something the home constructor can do much about, since it depends on the manufacture of the particular driver concerned, but it indicates the sorts of problems that will be encountered.

The Moving-Coil Direct-Radiating Speaker

The vast majority of drivers used in loudspeakers are of the moving coil type and as such all operate in a very similar way. Fig. 1 shows a typical moving coil loudspeaker. Signal voltages from the power amp give rise to signal currents that flow through the voice coil. This is simply a coil of wire wound on a hollow circular former. In normal 8 ohm drivers the dc resistance of the voice coil is around 8ohms, but the driver will only represent this resistance to the power amp at one specific frequency, the actual impedance of the driver varying widely as the frequency is varied (see Fig. 2). A given signal voltage level will therefore produce different signal currents for different frequencies. The signal current causes a varying magnetic field to be produced around the voice coil. This field interacts with an intense magnetic field from the drivers' pole piece and magnet assembly causing a force to be exerted on the voice coil and loudspeaker cone.

As the cone moves it will compress or rarify the air immediately in front of it, creating an area of either increased or decreased pressure. These pressure variations comprise a sound wave that travels from the driver to our ears. The electrical impedance of the driver is caused by several phenomena each one dominating in a specific frequency band. One of the most significant mechanisms is the back EMF (EMF stands for electromotive force, i.e: voltage) of the driver. The movement of the voice coil in the magnetic field acts as a generator causing a current to flow in the voice coil. This current is of opposite polarity to the applied signal current (another natural application of the principle of inertia) causing the decreased current flow in the voice coil for a given signal voltage. This is seen by the amplifier as an increase in the drivers' impedance.

EMF is given by the simple equation:

\[ E = Biv \]

**EQUATION 1**

where 'E' is the back EMF in volts

'B' is the magnetic flux

'\text{i}' is the length of wire in the magnetic field

and 'v' is the velocity of the cone

Since the magnetic flux and the length of wire in the magnetic field can be considered as constants, the equation shows that the amount of EMF generated is directly proportional to the velocity of the cone.

So the electrical impedance is a secondary phenomenon, is certainly not constant, and does not relate directly to the radiated acoustic power. The amount of back EMF will be determined by the velocity of the cone, and this is a function of nearly every major parameter of the loudspeaker box.

The force exerted by the voice coil on the loudspeaker cone is given by the equation:

\[ F = BiI \]

where 'F' = force on the voice coil

'B' = Magnetic field intensity

'I' = current in the voice coil

and 'I' = length of wire in the field

Again, regarding 'B' and 'I' as constants, the equation shows that it is current and not voltage that determines the force on the voice coil. Since the voltage contains the signal information from the power amp, it would be necessary for a perfectly linear relationship to exist between applied voltage and resulting signal current flow if a distortionless signal is to be produced. The impedance would have to be a constant and this is not the case. Fortunately the movement of the cone is not directly related to the current in the voice coil in the simple way shown above or the frequency response of a loudspeaker would simply be the inverse of its rather lumpy impedance curve.

In order to understand the parameters that determine the acoustic power actually radiated, it is necessary to look at the sources of mechanical rather than electrical impedance.

Converting Energy

In the operation of a moving-coil direct-radiating driver there are really two energy conversions going on simultaneously. First the electrical energy is converted into mechanical energy of the voice coil and cone. Secondly this mechanical energy is converted into acoustic energy by the interaction of the cone with the neighbouring air molecules. Both these conversions must be accurate if the final result is to be a low distortion replica of the input voltage waveform.

The laws that apply to mechanical and acoustic forces are directly analogous to those of electrical forces and for this reason we can represent what happens in any acoustic or mechanical problem by a circuit diagram. In mechanics and acoustics there are direct and simple relationships like Ohm’s law in electronics. It is only the complex arrangement of mechanical or acoustic circuit elements that makes the picture look complicated. Just as an electronic circuit can look complex, but can be broken down into smaller and simpler circuits, so too can any acoustic or mechanical problem.

We can represent a complete picture of a dynamic loudspeaker by a circuit diagram showing electrical/mechanical and mechanical/acoustic conversions (see Fig. 3a).

The power amplifier is connected via a net series resistance Rg, to the terminals of the loudspeakers. This resistance is the result of the internal resistance of the power amplifier and connecting cables. Since the voice coil is a coil of wire it possesses both inductance and resistance. The applied electrical signal sees these two in series and we represent this by the resistance Re and the inductance Le. The "E" simply implies that these are electrical quantities. Current flowing in the voice coil...
gives rise to the magnetic field that causes mechanical movement of the voice coil and cone assembly. This conversion of electrical to mechanical energy is represented in the circuit diagram as a transformer. Voltage across the primary is represented by the letter ‘e’ and gives rise to velocity ‘v’, of the voice coil and cone assembly at the secondary of the transformer.

The total force applied by the voice coil (‘F’) is shown in the mechanical stage as ‘flowing’ through the ‘wires’ just as current would flow through the wires of an electrical circuit. This force sees three mechanical components in parallel, a mechanical capacitance \( M_M \), a mechanical inductance \( C_M \) and a mechanical resistance, \( 1/R_M \). The mechanical capacitance \( M_M \) is caused by the mass of the cone. As frequency rises inertia comes into play and it becomes increasingly difficult for the cone to follow the input voltage waveform. The mass of the cone causes a frequency response roll-off at higher frequencies. This could be represented either by an inductance in series or a capacitance in parallel with the load. In Fig. 3 this has been shown as the parallel capacitance, \( M_M \).

A loudspeaker cone has a certain springiness, due to the nature of the cone’s suspension and the overall construction of the particular driver. We specify this springiness by a spring constant, which is simply a number, represented by the letter ‘k’. In loudspeaker technology we more often use the term compliance rather than spring constant. Compliance \( C_M \) is defined as:

\[
C_M = \frac{1}{k} \quad \text{where 'k' is the spring constant.}
\]

The compliance impedes large movement of the cone. Since bass frequencies require longer cone excursions the compliance of the driver causes a frequency response that falls as frequency decreases. This can be represented as a capacitance in series or an inductance in parallel with the load. In Fig. 3 the compliance \( C_M \) is represented as an inductor in parallel with the load.

The remaining term in the mechanical part of the loudspeaker circuit diagram is the mechanical resistance. Just as all circuit elements in an electronic circuit have resistance, so too does the mechanical circuit. The resistance is seen in series with the whole mechanical circuit and could be represented as a series resistor or a parallel inverse resistance. If \( R_M \) is the mechanical resistance of the circuit, an inverse resistance is defined as:

\[
\frac{1}{R_M}
\]

In Fig. 3a force is shown as ‘flowing’ in the mechanical ‘wires’. The total available force is shared into four major parts; the forces needed for the mass \( M_M \), the compliance \( C_M \), the mechanical resistance \( R_M \) and the load. If we define these four forces as \( F_1, F_2, F_3 \) and \( F_4 \) respectively, we can say that

\[
F = F_1 + F_2 + F_3 + F_4
\]

with the load, to illustrate the way it obtains its part of the total available force (F).

In this case the load is the primary of the mechanical/acoustical transformer. Of course this transformer doesn’t actually exist. It is merely a way of representing the conversion of mechanical energy to acoustic energy by the interaction of air molecules with the surface of the loudspeaker cone. Mechanical force in the primary of the transformer is converted into sound pressure ‘p’, in the acoustic circuit.

In Fig. 3a it is assumed that the loudspeaker is mounted in an infinite baffle. This is a partition that extends to infinity in all directions, cutting the universe into two halves, with a hole in which the loudspeaker is mounted. This is just a little impractical, but the only important thing is that no sound produced by the back of the speaker cone can interact with the sound from the front.

In order to move air molecules, the cone must do work so the air impedes movement of the cone. This impedance is called the acoustic impedance and is represented in the circuit diagram by \( Z_A \). Since the loudspeaker is mounted in an infinite baffle the acoustic impedance is the same on both sides of the cone and becomes \( 2Z_A \).

We are now in a position to understand the causes of variations, in the electrical impedance and acoustic radiated power. As was shown earlier, the back EMF is one of the dominant forces acting to increase the driver’s impedance. It is related to the velocity of the
louderspeaker cone as was indicated by Equation 2. If the motion of the cone is impeded, i.e.: if the cone is held, the velocity must decrease, causing a decrease in the amount of back EMF. The decrease back EMF will cause a drop in loudspeaker impedance. So an increase in mechanical impedance causes a decrease in electrical impedance.

With this in mind the electrical/mechanical/acoustic circuit diagram of Fig. 3a can be converted into the all electrical circuit diagram of Fig. 3b.

This circuit predicts the impedance characteristics of the driver. A generally increasing impedance with frequency is caused by \( L_e \), while \( M_m \), \( C_m \), and \( R_m \) form a damped resonant circuit. We would expect a sharp increase in impedance at one frequency, dropping to the dc resistance of \( R_e \) and \( R_a \) and then slowly rising as frequency increases. This is exactly the response as shown in Fig. 2 which is the measured impedance response of a typical 12 inch (300 mm) woofer. This resonance point is called the fundamental resonance of the driver, and being a function of the compliance of the driver, can be expected to decrease in frequency a little as the driver wears in. This is the reason some loudspeaker experimenters "run in" the driver before measuring resonant frequency.

A more accurate model

The model of the loudspeaker developed so far has assumed that the shape of the loudspeaker cone remains unchanged and moves as a "rigid piston", following the input signal. This rigid piston theory works well at predicting the characteristics of drivers at low frequencies. At high frequencies inertia again comes into play and the cone can no longer be considered as a rigid piston. If the driver remained a rigid piston throughout the audio spectrum its frequency response would fall off at a rate of 12dB/octave at high frequencies. It should be noted that the velocity of sound depends on the medium in which the wave is propagating. The velocity of sound in the loudspeaker cone will be substantially different to that in air. Using this equation we can calculate the frequency at which the wavelength of sound approaches the radius of the loudspeaker cone. For a 300 mm (12 inch) loudspeaker this frequency is around 400 Hz and it is at this frequency that the rigid piston theory starts to come unstuck. Above this frequency the sound wave propagates up the cone, hopefully to be damped in the rubber surround. The sound wave is attenuated as it moves through the cone, and this attenuation effect increases with increasing frequency, causing a decrease in the effective cone diameter. This is the effect that enables a single cone loudspeaker to operate over a wide frequency range, since the decreasing effective cone diameter decreases the inertia presented to the coil assembly at higher frequencies. It should be noted that, in this range of the frequency spectrum, the rim and the cone will be radiating in antiphase with the coil assembly. The way the cone material and suspension react to this multiple wave propagation is one of the biggest differences between a good driver and a poor one. It is for this reason that metal cones for instance are so often unsuccessful. Their ability to damp multiple resonances is generally poor in comparison to materials like paper or plastics.

Damping and Q-factor

In midranges and tweeters the drivers can be operated in frequency ranges that exclude their fundamental resonances. The crossover points are usually chosen so that at least one full octave exists between the crossover point and the fundamental resonance. In the case of bass drivers however it is necessary to operate the driver at the below the resonance of the woofer.

This is the main reason so many different bass loading principles have been developed. The fundamental resonance of the bass driver must be damped so that an acceptably flat frequency response can be established. If the resonance is not damped adequately, the all too common 'one note bass' sound results. This is a particularly noticeable and fatiguing loudspeaker fault and considerable effort must be spent on obtaining a smooth bass end response.

Since the loudspeaker is a resonant circuit the amount of damping can be specified by quoting the Q or quality factor. Q is defined by:

\[
Q = \frac{f_0}{f_1 - f_2}
\]

where \( f_0 \) is the frequency of the fundamental resonance, and \( f_1 \), \( f_2 \) are the 3 dB points.

Figure 4 shows a graph of bass-end frequency responses at a variety of Qs. Although the flattest response appears to be given by the case when the \( Q = 1 \), this is not the optimally damped case and some boomy bass often occurs in bass systems with Qs around unity. The best Q is probably about 0.5. The bass is not boomy but is also not over-restricted which can happen if the Q drops to around 0.2 or 0.3. The best damping for any specific case needs to be established by experiment and ultimately, as always, the ear must be the final test.

Loudspeaker compliance, the total mass of the cone and the net series resistance with the voice coil, all determine the response of any loudspeaker system and any or all of these can be adjusted in order to achieve the optimum damping and frequency response. In practice, adjustments to the Q of the system are done by modifying the compliance and acoustic mass and resistances caused by the loudspeaker enclosure rather than modification of the driver itself.

The enclosure

The circuit in Figure 3 has been developed assuming that the driver is mounted in an infinite baffle. The air load on the cone of the loudspeaker is represented by an impedance of value:

\[
\frac{1}{2A}\frac{1}{f^2}
\]

When the driver is mounted in a practical loudspeaker enclosure, this acoustic impedance becomes a little more complicated and the circuit in Figure 5 replaces the simple resistor of Figure 3. This new impedance is made up of two major components. The radiation impedance from the front of the box (\( M_{6AR}, R_{AH} \)) is related to the size of the baffle and is independent of the volume of the box.

The volume of air that the driver has access to is related to the effec-
SPEAKER DESIGN

tive radiating area of the cone and to the size of the baffle. Since bass frequencies have a greater dispersion than higher frequencies the volume of air accepting the radiated sound increases at lower frequencies. So the impedance on the front of the cone will be greatest at high frequencies. If the size of the baffle is large in comparison to the radiating size of the driver the box approximates an infinite baffle down to a lower frequency. This is to increase the stiffness of the loudspeaker cone resulting in an increase in the fundamental resonance of the enclosure.

The second component of the radiation impedance is caused by the enclosed volume of air within the box. If we consider a sealed enclosure the volume of air within the box will be compressed by the driver. So the enclosure volume will affect the overall compliance of the loudspeaker system. This acoustic compliance is represented in Figure 5 by the capacitance $C_{AB}$. The effect of this is to increase the stiffness of the loudspeaker cone resulting in an increase in the fundamental resonance of the enclosure.

The volume of air in the box will also have an equivalent mass represented by the inductance $M_{AB}$. This mass will also affect the resonance of the system by increasing the overall mass of the cone. The acoustic resistance with the enclosure is shown in Figure 5 as $R_{AB}$.

The final resonant frequency of the driver in the box is a function of the total effect of all the compliances and masses in the system. If the total mass is represented by $M_a$ and the total effect of the compliances is $C_a$ then the resonant frequency of the system will be given by the equation

$$ f_0 = \frac{1}{2\pi \sqrt{M_a C_a}} $$

The equation shows that a decrease in either the total mass or compliance will cause an increase in the resonant frequency of the loudspeaker system.

**Resonances**

The acoustic circuit in Figure 5 represents the reactances caused by the enclosure around the resonant frequency, but as usual in loudspeaker science things get more complicated as frequency increases. As the wavelength of the sound wave produced inside the enclosure becomes shorter the box no longer acts as a simple spring. The produced wave travels from the back of the driver towards the rear and sides of the cabinet, where it is reflected back towards the driver. This sound wave will interact with the cone, either reinforcing or impeding the motion of the cone depending on the particular frequency. This results in successive rises and dips in the frequency response and for this reason it is important that this reflected wave is damped as much as possible. In order to absorb this unwanted energy the enclosure is usually lined with an absorptive material such as bonded mineral wool, acetate fibre or bonded hair felt.

We have discussed the sealed enclosure, leaving explanations of other bass loading techniques to a later time. One of the most common enclosures is the bass reflex, which uses a port cut in the baffle to augment the bass radiation of the driver. The acoustic circuit diagram must show the effects of the mass, compliance and resistance of the port in addition to those shown for the rest of the box, making the loudspeaker equivalent circuit even more complicated. Both the bass reflex and the sealed enclosure are capable of very good results and it is not possible to state simply which is better. We have omitted a detailed discussion of the principles of the bass reflex loudspeaker simply for the sake of simplicity.

Next month we will deal with the problems of mating a collection of drivers to form a completed loudspeaker.

Don't miss it!

**References**

Hi-Fi speaker systems; D. Hermans and M.D. Hull, Philips applications bulletin 35/1 and 35/2.


Loudspeakers in ventilated boxes: A.N. Thiele.

To be continued.
HEYE SOMETHING NEW.

This month, we’re inaugurating a column to deal with micro-computers and micro-computing for the users of the popular small systems. In the months to come, we’re going to be looking at both hardware and software for TRS-80s, PETs, VICs, APPLES, OSIs, and a really neat, if incredibly slow, way to play space invaders on an abacus. At the moment, we’re planning future bits on speech synthesis, machine language programming and computer music, plus a lot of other stuff even we haven’t thought up yet.

ETI readers are invited to contribute to this column. If you have a favourite bit of computing you’d like to share, we’d be most interested in checking it out, and, of course, we’ll pay for anything we use. Complete fine print is at the end of this column.

VIC WITH CHARACTER

One of the things that we touched on in the VIC review last month was the capability of the machine to produce programmable characters, that is, for the user to decide what the letters on the CRT should look like. This is a capacity not found in the PET computers, which preceded the VIC, and, as well, not even mentioned in the VIC’s manual. However, it can be done, as we shall see.

You are probably familiar with the basic notion of character generation, but, if not, heretofore, (or heretofore thirty in Newfoundland) is a brief explanation. Skip ahead if it’s already lodged in your brain.

The characters you normally see on the screen live in a ROM, or Read Only Memory. This is a chip that spews out a pre-defined pattern of bits for any given input code. The input code, in this case, would be a function of the character code being called up, i.e., the ASCII value of the character, plus the position of the CRT beam at the moment in question. Obviously, the bit pattern changes as the beam scans downward. In the case of the VIC, with characters being defined by an 8x8 dot matrix, each character in the ROM can be thought of as being eight eight-bit words, or eight bytes.

When the VIC wants to generate characters, all it does is to vector over to the location in memory where the ROM lives, add to this the character code, and call up the required pattern of bits, which thereupon modulates the CRT beam. A bit simplified, but that’s about it. On sequential lines, as the beam descends, it must be constantly adding to the character code to get the required bytes out of memory.

Now, changing the characters is actually pretty easy. All you have to do is change the bit patterns in the ROM. Gad zooks! Hardware modifications... never. Okay, how about making the computer thing you’ve done it. Ya, that sounds better.

The VIC’s character generator ROM lives at 32768 decimal (oddly enough, the screen location in old PETs). Among other things, location 36869 holds the address of this ROM, so the computer can find it. When it wants to get the bit patterns for characters, it simply goes to this location, and vectors over to wherever it tells it to go. A bit complicated, I suppose, but there is a perfectly good reason for doing it this way. You see, while the ROM up at 32768 cannot be changed under software command, the number in this address location can. It can be set such that the VIC chooses as its character ROM a chunk of RAM, which can be loaded with whatever data we choose... including, of course, character patterns.

The way to get basic programmable character capability in the VIC is, first off, to define some RAM as exclusive character pattern RAM. Actually, we need quite a lot of this. The only place where there’s enough is in the user RAM (which, yes, is small enough as it is). We must make sure that BASIC doesn’t interfere with the character codes... and BASIC is noted for trampling over things. Thus, what we need to do is to make the VIC think that the top of its BASIC RAM is somewhat lower than it actually is. The difference will be used to contain the characters.

The top of memory pointer is at location 55 and 56 in page 0. The way this works is that the top of memory is defined by PEEK(55) + 256*PEEK(56). In order to reserve enough memory to produce a programmable character set of useful proportions, we’re going to need at least a K, and preferably a K and a half. The register at location 56 adjusts the pointer in increments of 256 bytes, or 1/4K, which is convenient. It is usually at 30: we’ll POKE it to 24 (6 * 256, or 1.5K).

The beginning of this new ersatz character ROM will now be at 6144 decimal.

Next, we want to change the address of the character ROM to fool the computer into looking at the RAM block at 6144 instead of its ROM at 32768. This is done by POKeing the address register at 36869 with 254.

This, as you will know if you’ve just tried it, will produce a screen full of garbage. This is because there is just random stuff in the RAM at this point, which the VIC is presently using for character codes. Hit RUN and RESTORE simultaneously to get out of this condition.

With the memory location reserved, before or after changing the vector (probably easier to do before, although it’s less fun to watch) the characters must be moved from ROM into the character code RAM. This is just a matter of writing a simple FOR... NEXT loop to PEEK each location in the ROM and POKE the resulting data into the appropriate RAM locations, beginning at 6144.

Program 1 shows the basic mechanism for doing all of the above in its first subroutine. It takes about a minute to complete, and looks really wild, as it fills the screen up with garbage, and then gradually replaces it with letters.

Now, although the screen may not look any different, it actually is being filled by a completely different set of characters. Only thing is that they’re the same ones as in the character ROM.

To figure out where any particular character lives in this RAM, do the following. Clear the screen and home the cursor. Type the character in the first location on the screen. This is location 7680 decimal in RAM. PEEKing this location will give you...
the PET ASCII code for the character. This differs a bit from real ASCII, so don't just use the ASCII function. The code for "A" for example, is 1. The location of the first byte for the letter "A" in RAM is given by 6144 + 1 * 8, with the next consecutive seven bytes being the rest of the character.

Numbers

If you PEEK the first byte of the character "A", you will get 24. Now, how do these numbers correspond to the bit patterns, you cry forlornly. Well, you could if you tried. Oh, very well; be upper crusty and dignified about it.

If you check out figure 1, you'll see an eight by eight matrix that contains the letter "A". The top line is the byte that happens to be 24. Now, if you were to weight each vertical column of the matrix in ascending powers of two, as in a hexadecimal format, you'd get some of the bits in that line off and some on. Add 'em up: they do actually come out at 24.

The numbers from 0 to 255, expressed as powers of two, can produce every possible combination of eight bits. Thus, poking this byte with any desired dots in the matrix. If you POKE it with 255, the top line in the "A" will become a bar, with all the dots on.

POKing the character codes in by hand is something of a pain, but, fortunately, there is an easier way. You can store the codes as DATA, and use a program to load them in for you. The second subroutine in program 1 handles this. It begins at 6664, the location of the spade symbol, or shifted "A", and POKEs the RAM with all the data it finds until it READs a 999. The DATA is located from statement 1000 on.

The DATA which is contained in the program listing will produce a treble clef using the shifted "A" through "G".

Generating the codes can be done with 8x8 graph paper, but this, too, is a royal pain, and, happily, not all that necessary. Program 2 is offered by Paul Higginbottom of Commodore. It can be used to figure out the character codes, which can be written down, and later included in the program. Through "G", the program listing will produce a treble clef using the shifted "A" through "G".

Continued on Page 70
There is a very strong 500Hz multiplex signal on the function switch lines so this distance must be at least 2 in.
Yes, I am "into Electronics" how did you guess?

This is a very good logic state analyser and it also solves crossword puzzles.

If you can possibly avoid it, try not to mention to the customers that we count "on" and "off" as two functions.

It says "Warning – this is a low profile socket and can only be used with incognito IC's."

Do you find Electronics funny? Send in your own cartoons – we'll pay for any we use.

Well if you can't get me a 5 megahertz triggered-sweep, solid-state oscilloscope with Z-axis modulation, trace rotation and 10X sweep magnification, then how about a teddy bear?
IN MUCH OF AUDIO design we see a great deal of preoccupation with big things.

For example, with amplifiers we are often concerned with circuit topologies, the kind of output stage used, the input circuit, amount of feedback, which active devices are better than others, and so forth.

Similarly, speaker designers make much of such parameters as driver size, type of enclosure, box size, number of drivers, magnet weight, total Q, even the number of elements in the dividing network, to the point of counting fuses as elements.

Turntable platter weight, type of drive, speed control system, pickup operating principle, cantilever material, all of these are frequent topics of discussion.

To be sure, all these are important matters. After all, it wouldn't do to try to build a bass reflex speaker without consideration of driver Q and driver/box compliance ratios. And certainly the shape of a stylus is a matter of some significance whether you're a pickup designer or simply setting out to buy one.

But all too often we tend to give so much attention to the big things that we leave little details to look after themselves. Or we take them so much for granted that we never bother to learn their function, and so never maximize their usefulness.

Consider, for example, the ubiquitous Zobel network!

An Exercise In Simplicity

The Zobel (or Zoebel) network, so named after its inventor, is a deceptively simple little circuit consisting of a capacitor in series with a resistor, which is connected across the output or input terminals of a circuit or device (Fig. 1). Its primary function is load stabilization and the neutralization of inductance. Although it has applications in other areas, such as servo control systems, in audio it is usually found in audio amplifiers where it is used to provide a phase lag in the output circuits of amplifiers which must drive long lines at low impedances, and across the input terminals of loudspeaker drivers.

Its importance in the latter application was brought home quite clearly to me many years ago and, considering its ease of application, I'm amazed that so few speakers feature this means of impedance correction. Instead, too many designers seem to proceed on the simplistic assumption that driver voice coil inductance can be allowed for in the design of the dividing network.

Unfortunately, such efforts usually result in an impedance curve which looks like a roller coaster, a characteristic which seems all too common with the bulk of the speakers on the market today.

Several years ago, while working on a particular speaker, I discovered that the cross-over network didn't work. Each driver, bass, midrange, tweeter appeared to deliver in a smooth wide range signal. It was my first try at a first order network, which is supposed to be inherently phase linear.

![Fig. 1. R & C form a Zobel network.](image)

![Fig. 2. Driver impedance curve.](image)

**An Exercise In Simplicity**

**Fig. 1. R & C form a Zobel network.**

**Fig. 2. Driver impedance curve.**

**This Is Eight Ohms?**

Examination of Fig. 2 will disclose the cause of the difficulty.

Fig. 2 is an impedance curve representative of what is usually encountered with a dynamic unit. This is alleged to be an eight ohm unit, but at what frequency does it exhibit this impedance? Why, at the lowest point on the curve, that's where. As you can see, this is a very narrow band.

In addition, the only frequencies at which the impedance is resistive are the minimum impedance to which I just referred, and the low frequency fundamental resonance. At all other frequencies the impedance is reactive.

Of particular interest to us is the high frequency rise. This is due largely to voice coil inductance and if you know its value it’s a simple matter to neutralize it. To find the value of inductance, simply connect a suitable value of capacitance across the voice coil terminals and measure the frequency at which the combination resonates. Inductance can be calculated from the formula:

\[ L = \frac{1}{2\pi} \times F \times C, \]

where \( F \) = Voice Coil inductance, and \( r_e = Voice Coil DC resistance, and R_{Zobel} = r_e \).

The final network may not be entirely correct, either because of inaccuracies in measuring the inductance, or the fact that the inductance may actually vary with frequency because of acoustical loading effects. Nevertheless, it can yield excellent correction.

This network can be fine-tuned by driving the driver/network combination from a square wave...
generator, and observing the waveform on an oscilloscope. The capacitance can be varied to obtain the nearest approximation to a square wave. In any case, it will be a vast improvement over Fig 3, which shows what a square wave looks like across an uncompensated driver.

In case you think that such a network will roll off the highs, try connecting a corrected and uncorrected driver directly to an amplifier. A reactance does not dissipate energy; it takes energy from the source, then returns it. The resulting phase angles of the inductive and capacitive elements exactly balance each other, so that no phase shift occurs, the condition which exists if the network is resistive.

Testing The Whole Network.
A constant resistance dividing network only performs as specified when each output is terminated at its design resistance. An inductive load does not provide for this condition. It is, therefore, essential that each driver behave as a resistance, even in its stop band.

It follows from all this that a correctly designed and terminated dividing network can be connected across a signal source without deforming a square wave. This provides a useful test of such a network.

To test the network itself, each output should be terminated by a resistor of the required value. Deformation of the leading edge of a square wave indicates problems in the high frequency network, while deformation of the trailing edge indicates problems in the low frequency network.

A hump or trough in the flat top region indicates mid-range problems, while any sign of ringing indicates oscillation.

Examination of the pass band with sine waves will pin-point the frequency at which problems are occurring and appropriate measure can be taken.

Now For The Lines
After wiring up your system and verifying that all is well, using the above tests, try sending a square wave down the line which will be connected to the amplifier, only using a high impedance (say, 500 Ohms) generator, with the speaker attached at the far end. Observe the waveform at the generator output.

Surprise, surprise! It will bear a remarkable resemblance to our old enemy in Fig. 3.

What happened?
Simple. Wire has self inductance. When two conductors are close to each other and run parallel, serving both the send and return sides of a circuit, their magnetic fields oppose each other and tend to cancel. The closer the conductors the greater the cancellation and the less the net inductance.

Since this constitutes an inductance in series with a resistance (the load), the answer is a Zobel network at the input to the line, or the output of the amplifier.

In fact, most amplifiers incorporate the network in the equipment. However, since the manufacturer has no way of knowing exactly what is going to be connected to his product, the final circuit may not always be optimum, but will be satisfactory for an anticipated worst condition.

But, if you're building your own amplifier, or you don't mind tampering with a commercial product, it's quite possible to establish the optimum network values.

Usually you won't have enough data to compute the inductance of your line, so it's simpler to do so experimentally. Connect a dummy load to the receiving end equal to the intended impedance load. Send a square wave of sufficiently high frequency (around 10kHz) as to allow a clear view of the spike on the leading edge, from a high resistance generator, and observe the waveform on the scope. Connect across the line at the generator a Zobel network consisting of a resistor equal to the dummy load, and try various capacitors until the spike is eliminated, but without rounding the leading edge of the wave form. The value required will probably be between 33n and 200n.

Finally, you may have concluded that since the resistance in the Zobel network is equal to the load resistance, the importance of maintaining constant impedance in the load has been sadly neglected.

How very true.

Finally, as far as this session is concerned, to matters practical. Reading about what ICs do is fine, but there's nothing like experimenting for yourself, and your understanding of what linear ICs do becomes a lot more complete when you've tried out some circuits and found out for yourself how they behave. There are going to be a lot of circuits shown in this series, and I wouldn't suggest that you try out each and every one of them, but at least one or two from each part of the series is about par for the course, keeping you up to date in the practical side of using ICs. One of the pleasant things about working with ICs is that you quite often don't need many other components — the bias circuit of Fig. 8 demonstrates that. On the other hand, if you want to show exactly what a circuit is doing, you need some way of testing it. If you have access to such goodies as signal generators and oscilloscopes, great — you can check out any of the circuits completely. If you don't run to this sort of laboratory equipment, then we'll try always to include circuits which can be tested with simpler methods, like cheap crystal microphones and earpieces, old loudspeakers, LEDs and the like. One really useful aid, though, is a decent voltmeter or multimeter with at least 20,000 ohms per volt on its DC ranges.

Now the next thing is how to construct the circuits. You could, of course, solder up each one, spend a fortune on ICs, and end up with an awful lot of small bits of board, each with a different circuit on it. A much simpler way is to use one of these very useful devices, a solderless breadboard. This way there's no soldering problem, circuits can be assembled very quickly, taken apart afterwards, and the components re-used. We can even arrange our circuit diagrams (and we have, too) so that you can check each connection in the circuit — it's as near to electronics-by-numbers as you'll ever get. More about all that next month, and also about soldering and power supplies. We'll also take a brief look at how you can design a circuit layout for yourself — stay with us.

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Seven Channel Lightshow

J. McCauley

NOTE:
IC1 IS 555
IC2 IS 7493
IC3 IS 7447
IC4 IS 7805
01 IS 8F244B
D1,2 ARE 1N4001
SCR 1-7 ARE C 106D

INPUT
RV1 5k0

When used with an audio input this circuit gives a very effective display, using seven 75 W coloured spot lamps for disco work or smaller ‘pygmy’ bulbs when used as an addition to a home audio system. Alternatively the 7447, which is a display driver, can drive seven LEDs directly.

As can be seen from the truth table there are 16 different arrangements for the sequence of switching. This helps give the impression that the bulbs are randomly switched.

The 555 timer is connected here as a VCO with the control voltage on pin 5 derived from the audio input via the FET input buffer circuit. The variable length pulses from the VCO are then used to clock the 7493 which is connected here as a binary counter.

The outputs from the 7493 are then decoded by the 7447 decoder (BCD to seven-segment). The outputs from this IC are used to trigger the SCRs, thus turning on the appropriate lights.

All that is necessary to operate the circuit is adjustment of the input level control (RV1) to give the best visual display. When switching low power loads ie 75 W, RFI suppression circuitry should not be required; however, with greater loads (absolute max 750 W per channel) such circuitry will be necessary.

Relay PSU Protector

This circuit may prove very useful when trying out a project for the first time. Any power supply shorts will pull the supply voltage (Vi) down, turning the transistors on and tripping the relay. This then causes the 10 k resistor to latch the circuit in the 'tripped' mode. The relay is connected so that it disconnects the supply to the circuit being tested. The circuit can be reset by pressing the momentary-contact switch shown.

R1 is selected so that Vi/R1 is greater than Vs/R2. R2 must be greater than R1 and Vs/R2 must be large enough to turn the first transistor on.

The circuit works with Vi ranging from 3 to 18 volts.
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---

Oscilloscope Probes

Part No. 900-95-522

SP 100 Oscilloscope Probe Kit

This passive probe incorporates a three-position slide switch in the head and has a cable length of 1.5 metres.

<table>
<thead>
<tr>
<th>Position</th>
<th>Bandwidth</th>
<th>Input Resistance</th>
<th>Input Capacity</th>
<th>Working Voltage</th>
<th>Cable Length</th>
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<tr>
<td>x1</td>
<td>D.C. to 10 MHz</td>
<td>1MΩ (oscilloscope input)</td>
<td>40pF</td>
<td>600 Volts D.C. (including Peak A.C.)</td>
<td>1.5 Metres</td>
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<td>Ref.</td>
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<td>x10</td>
<td>D.C. to 100 MHz</td>
<td>1MΩ (oscilloscope input)</td>
<td>40pF</td>
<td>600 Volts D.C. (including Peak A.C.)</td>
<td>1.5 Metres</td>
</tr>
</tbody>
</table>

Position x1
- Bandwidth: D.C. to 10 MHz
- Input Resistance: 1MΩ (oscilloscope input)
- Input Capacity: 40pF. Plus oscilloscope capacity
- Working Voltage: 600 Volts D.C. (including Peak A.C.)
- Cable Length: 1.5 Metres

Position Ref.
- Probe tip grounded via 9MΩ resistor, oscilloscope input grounded

Position x10
- Bandwidth: D.C. to 100 MHz
- Appearance: $51.20
- Risetime: 3.5 nanoseconds

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<table>
<thead>
<tr>
<th>MODEL</th>
<th>ATTEN.</th>
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<th>PRICE</th>
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<td>IP20</td>
<td>x1</td>
<td>20 MHz</td>
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<tr>
<td>P100</td>
<td>x10</td>
<td>100 MHz</td>
<td>35.85</td>
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<tr>
<td>2P150</td>
<td>x10</td>
<td>150 MHz</td>
<td>48.10</td>
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<tr>
<td>2P250</td>
<td>x10</td>
<td>250 MHz</td>
<td>63.50</td>
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<td>SP100</td>
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<td>100 MHz</td>
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<td>2LCP100</td>
<td>x100</td>
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<tr>
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<td>Detector</td>
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<tr>
<td>Wire Wrap adapt. above probes</td>
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</tbody>
</table>

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Car Lights Warning  
A.M. Tucker

This circuit gives an audible warning if the car lights are left on when the ignition is switched off. If necessary, the lights can be switched off and then on again, and the alarm will be cancelled.

Operation is as follows: the ignition switch is connected to buffer IC1a, Schmitt trigger R4-IC1b-IC1b and inverter IC1d. R1-C1-C2 and R2-C3 are filters. If the lights are on and the ignition is switched off, a negative pulse is applied through C4 to IC2b and the junction of R5 and D3 goes high, causing the flip-flop to change over. This enables the slow oscillator IC2c-IC1e (approximately) 4kHz oscillator IC2d-IC1f, causing audible bleeps in the piezo-electric transducer. If the lights are off, the input to IC2a is held low via D3 and R7, inhibiting the oscillators. D1 and D2 deal with unwanted transients, while R12 is chosen to give the required warning level.

The circuit can be adapted for positive ground vehicles by reversing the diodes and electrolytic capacitor, reversing the connections to pins 7 and 14 of the ICs, and substituting a 4001 NOR IC for the 4011 NAND IC. With this modification, there may be a short bleep when the ignition is switched off and the lights are not on.
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Circle no. 20 on Reader Service Card.

Circle No. 14 on Reader Service Card.
Simple Frequency Response Display
M. Harrison

This circuit was originally designed to test audio filter circuits, but has several other uses such as demonstrating the properties of tuned circuits, or testing graphic equalisers. The circuit consists of a low-frequency oscillator with a triangular wave output which is used to frequency modulate a VCO, while also being fed to the X input of a scope (the signal is about 2 V peak-to-peak, so further amplification may be needed for some scopes). The VCO output level against frequency, with the frequency decreasing from left to right. SW1 sets the frequency range of the display, and RV1 sets the scanning speed; it is adjusted to give a good display, and does not affect the actual shape of the display. As well as being simple this circuit is cheap, the 76477 only costing about $5. Q1 and Q2 are any NPN silicon transistors with a reasonable gain, for example 2N3904.

NOTE:
IC1 IS SN76477
Q1,2 ARE 2N3904 OR SIMILAR
Q1 IS 1N4148
ZD IS 6V8 ZENER

Four-Input Mixer
D. Marzolla

This mixer circuit has very low current drain and can give an operating life of three to four months from a No. 216 9-volt battery with moderate use. The input impedance is 47k and the gain of the mixer is 3 dB. Perhaps a good use for those old germanium transistors you were going to throw out but knew they would come in handy sometime!
in mind, though, that even if you reprogram the appearance of a character, it will still be interpreted by the machine in the same way. For instance, if you convert a shifted "2" so it looks like half a Martian, it will still set the quote mode when hit, and, thereafter, all subsequent cursor control keys will be printed, instead of directly moving the cursor.

Programmed characters can be used to create special character sets for math, chemistry, electronic design, music, and, of course, games. The character loader program, program 1, can be run prior to actually loading the main program, as once the characters are in RAM and protected by bringing down the pointer, nothing can hurt them unless you RESTORE. You can execute NEW or CLR without any hassles, as these commands only refer to BASIC, and, by bringing the pointer down below the character RAM, we've put them outside the memory BASIC can deal with. It's worthwhile doing this two program approach, as it means you don't have to tie up useful working RAM with the loader, which isn't really much good for anything after it's been run once.

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1. Long BASIC programs are generally not wonderful, because, in our experience, not many readers ever bother to use them. Short BASIC programs are conditionally wonderful if they do something really unusual.
2. Machine language utilities and other ML stuff with reasonably practical applications are generally wonderful.
3. We need listings. Don't send us cassettes, disks or paper tape, because, in the vast majority of cases, we won't be able to do anything with them. Hand written or typed listings are not all that wonderful, as they lead to errors. Printed listings are wonderful, especially when done with fairly new ribbons. If you haven't got a printer, you can usually harrass the store where you bought your computer into doing a listing for you.
4. Hardware add ons and mods are quite wonderful if they aren't too crazy.
5. The PDP 11 is not a home computer. Neither is the IBM 1130, even if you did get one at a junk sale. We're trying to restrict wonderfulness to reasonably well known small machines, as it will be applicable to the greatest number of readers. Obviously, if you're writing machine code for a bizarre computer with a common CPU, it's still wonderful as it will work for anyone else having that CPU.
8. Please send your stuff along with a self stamped and addressed envelope. This is really wonderful, so we can tell you what's to become of it.

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