Cable fault locator
Making your own PCBs
Setting LC oscillators
Super-regen applied
VHDL primer

Win a Hitachi Worldscape radio worth £149

Circuit ideas:
Circuit ideas: motorbike gear display, three-component voltage doubler and more...
The HS801: the first 100 Mega samples per second measuring instrument that consists of a MOST (Multimeter, Oscilloscope, Spectrum analyzer and Transient recorder) and an AWG ( Arbitrary Waveform Generator). This new MOST portable and compact measuring instrument can solve almost every measurement problem. With the integrated AWG you can generate every signal you want.

- The versatile software has a user-defined toolbar with which over 50 instrument settings quick and easy can be accessed. An intelligent auto setup allows the inexperienced user to perform measurements immediately. Through the use of a setting file, the user has the possibility to save an instrument setup and recall it at a later moment. The setup time of the instrument is hereby reduced to a minimum.
- When a quick indication of the input signal is required, a simple click on the auto setup button will immediately give a good overview of the signal. The auto setup function ensures a proper setup of the time base, the trigger levels and the input sensitivities.
- The sophisticated cursor read outs have 21 possible read outs. Besides the usual read outs, like voltage and time, also quantities like rise time and frequency are displayed.
- Measured signals and instrument settings can be saved on disk. This enables the creation of a library of measured signals. Text boxes can also be added to a signal, for special comments.

Genesis of a Digital Utopia

What a piece of work is man, how noble in reason, how infinite in faculties, In form and moving how express and admirable, in action how like an angel, in apprehension, how like a god;

-Hamlet II. 2

nearby five billion multiplications and additions per second; all this, in the space of 37 years.

This degree of digital power represents not merely a quantitative, but a qualitative change in our relationships with scientific problems, enabling us to unlock the quantum secrets hidden within the very heart of our universe. Just as the currency of our thoughts, so too the currency of digital components is superfluous. So now we can effectively reverse the flow of information in a way that was possible only conceptually forty years ago; an engineer or scientist from this time would be struck dumb by the feats we can now achieve. Despite all this, the digital computing revolution is still in its infancy.

And what of the science of genes? We know that the sequence of bases on a gene is the code that instructs a cell how to manufacture a single protein; by altering this digital code of AGCT, we can alter the gene and change the organism, safely or, if we wish, radically. We have indeed become God. Mice have already been genetically modified with enhanced memory and problem-solving skills, and human medical applications are simply too numerous to list.

Make no mistake, this is just the start. The computer revolution has been with us for less than sixty years, and it has a billion-fold increase in power since it began. We can probably not yet conceive of the advances that will be made in the science of human genomics over such a span; the idea of human immortality is not only a wild and ridiculous fantasy.

Three things are however clear. First, both these digital revolutions represent a paradigm shift in our understandings of the physical world, for by altering code sequences, we can rewire our very reality. Second, developments in computing and genomics will consist exponentially and fuel the advances in almost all other sciences during the 21st century. Finally, and worryingly, our global political systems have not moved forward at a rate commensurate with the enormous leaps in these areas.

Hamer successfully observed in action, in man as a god but he admitted to mention that he could also be the very Devil. The benefits or cautions these things will bring us we very much depend on our systems of government, which now often across the globe, are underpinned by greed and an all-consuming lust for power. It is up to us whether we create a hell, or now a new Eden, and it is too late in the day to change this.

Patrick Geddes
**New multiplier algorithm is twice as fast**

A multiplier algorithm developed by Oxford start-up Automatic Parallel Designs is twice as fast as existing designs, the company claims.

AutoPD also has a floating-point multiplier that is currently being evaluated by “two of the largest CPU companies”, and algorithms under test at two other “major” CPU manufacturers.

According to its chief technology officer Sunil Talwar, the firm’s efficient arithmetic building blocks are based on “mathematics dating back to the Indians in 1000AD, developed by the Chinese in 1303, and coming together with Pascal’s Triangle in 1709.”

“People currently only know how to add three numbers efficiently in a column,” said Talwar. “If they want to add more numbers they build [adders] out of these basic count-up-to-three building blocks. It’s very slow, lots of logic levels, plus very bad wiring.” AutoPD’s multiplier designs enable customers to choose between a one-and-a-half times reduction in area or increased speed, versus existing multiplication schemes. The modular designs are optimised for silicon and available as either reference RTL or licencable IP.

“We are negotiating with one large FPGA company – they’re chasing the DSP market at the moment,” explained Talwar. “We’re under evaluation at all the major DSP companies, but we’ve just seen a real slow-down in the industry there.”

As well as the arithmetic building blocks, the company has also devised an encryption algorithm, for which it has a licence. “Things are nice,” mused Talwar.

A mathematician, Talwar founded AutoPD in 1998 with Tony Curren Smith, an economist. Initially funded by a SMART award, last year they raised £2.5m from venture capital firm Quester, with a further £500,000 from the seed backers and £200,000 in DTI awards.

With 12 full-time staff, the company has a sales office in Austin, Texas, and does all its business in the US. Dr Earl Swartzlander, a leading authority on computer architecture, has recently been appointed as a technical adviser.

**Mini speakers have low resonant frequency**

Nothing escapes scrutiny in the effort to make mobiles smaller and better. With this in mind, Matsushita has announced a range of mini-handspeakers for 3G phones.

The problem with existing designs, says the company, is the air gap between speaker and ear that ruins low-frequency reproduction. Countering this, the new speakers do not rely on a seal between phone and user, but have an inherently low resonant frequency on their own.

The key is a new diaphragm material, a special amorphous polymer with a low elastic modulus and high internal loss. These tens are available, the best one achieving a 380Hz resonant frequency – close to the bottom of the spoken range.

The largest one in the picture is 10mm in diameter and 2.6mm thick. Mass is 0.52g. Production should begin this July.

**Save time testing CAT 5 network cables**

Just plug one end of your cable into the Atlas IT and the other into the Atlas Terminator and press “test”! In seconds the unit will identify the cable type (straight through, crossover or token ring) and verify every connection. If there are any faults then they are clearly explained on screen. Socket testing is possible too thanks to the special patch cables included in the outfit.

Swapped lines, missing lines, shorted lines are all uniquely identified together with the full connection pattern!

What’s more, if you want to know how to make up a special network cable, the Atlas can instruct you, even down to cable colours! The Atlas IT is supplied in a robust carry case complete with a spare terminator and spare battery.

Visit www.peakelec.co.uk to download the full data sheets and copies of independent reviews. Feel free to contact us for a comprehensive data pack. You can pay using a cheque, postal order, credit or debit card and even pay online. Please contact us for overseas or volume orders - you will be pleasantly surprised!
Get a Master's degree on the Web

Scotland's Institute for System Level Integration (ISLI) has extended its groundbreaking Master's degree in system level integration to Web users. The online version of the degree will be aimed at part-time students already working in the industry and those from overseas.

"We had a lot of interest in flexible learning from industry," said Professor Steve Beaumont, director of the ISLI. "We also have a lot of interest from overseas." Beaumont expects that most students would complete the course in around three years.

"We’re going to provide a lot of e-mail, telephone and online support plus online library facilities," he said. Like many Open University courses, the ISLI degree will still have a residential element for some of the lab work.

Eventually the concept could be extended to the Institute's four-year long Engineering Doctorate, which took its first students in October 2000.

Located at the Alba Centre Campus in Livingston, the ISLI is an academic collaboration of four Scottish universities; Edinburgh, Glasgow, Heriot-Watt and Strathclyde. It opened its doors to students in March 1999 and offers both full and part time MSc degrees.

www.sli-institute.ac.uk

One-stop PCB prototyping

The Kwikboard division of Signetronics, the Scottish PCB machine company, is launching its nationwide UK network of one-stop prototyping outlets.

"The company is doing deals with PCB manufacturers around the country, leasing Kwikboard machines to them so they can offer rapid PCB prototyping," said a spokesperson for the company. "Four have already signed up and we are looking to sign up 15 by the end of the year."

Kwikboard claims that a finished PCB can be produced in less than three hours.

The prototyping system is additive, rather than subtractive with a copper polymer being printed onto the PCB. "You can still do all the normal soldering operations that you can do on conventional PCBs," said the spokesman. Its printer is made up of four stations micro engraving, polymer application, curing and illuminating. Unlike the conventional PCB process, no acids or etchants are used said Kwikboard.

1.3Tbit/s over an 8400km optical fibre

In a test using a single optical fibre and 65 signals of 20Gbit/s each, Mitsubishi has succeeded in sending 1.3Tbit/s over 8400km of optical fibre.

This is the highest transoceanic class transmission capacity achieved to date," said Takashi Mizuochi, head researcher at Mitsubishi.

The record required four developments, said the company: effective fibre area management, symmetrically-collided transmission, 20Gbit/s equipment and hybrid optical repeaters.

With distributed Raman amplification, effective fibre area – Aeff – is an important parameter as amplification efficiency is proportional to the power density in the fibre core. Previous type of fibre design, Fig. 1a), arranges the smaller Aeff fibre in the final section. Raman gain is concentrated in the final section.

Mitsubishi shifted the smaller Aeff fibre to the middle section, Fig. 1b). The company says this improves the optical signal-to-noise ratio, because the smaller Aeff fibre provides the major part of the Raman gain in the middle section, light amplification becomes more closely ideal distributed amplification.

Symmetrically-collided transmission is important as higher bit-rate signals are easily degraded by fibre non-linearity induced by pulse collision between the different wavelength channels.

Once optical pulses having different wavelength collide with each other, Fig. 2a), fibre non-linearity causes significant signal distortion.

If collisions are intentionally made again, signal distortion is cancelled out as shown in Fig. 2b).

Asymmetric collisions are the rule because the variations in fibre loss, dispersion and repeater gain along the transmission path combine to destroy the symmetry. Mitsubishi makes symmetric collisions by optimising the dispersion map and the ratio of distributed Raman amplifier to Erbium doped fibre amplifier gain. The resulting controlled pulse collisions reduce the pulse distortion

NXT launches disposable cardboard speakers

Cheap, cardboard loudspeakers from Cambridge audio technology firm NXT perform as well as conventional models costing "three to four times" as much, according to the company.

The £30 SoundPaX speakers are delivered flat-packed, and fold into a 700mm tall pyramid. NXT’s marketing director Andrew Williams said the new speakers would be ideal for parties and barbecues "if they have to be thrown away afterwards, it’s no big deal."

Using the firm’s SurfaceSound technology, an electromagnetically excited coil on the inside of one face forces vibrations across the whole structure. The B2 units can be produced with any pattern, although the first models have a picture of a traditional looking speaker cone on the front. Eventually they will be supplied with their own 15W amplifier. Low-range frequency response, seen by some as the weakness of the NXT technology, is around 66Hz.
Rad-hard processor has hardware error protection

A French design firm has created a radiation hardened processor that uses extra hardware to prevent errors occurring in logic and memory. Moreover, it’s claimed to have proven the extra circuitry does not impact performance.

“The ROIC/S design error detection and correction circuits for memories and logic circuits to avoid single event upsets (SEUs) caused by cosmic radiation. This shift to more advanced processes means SEUs and other soft errors, such as logic races and glitches, are appearing not just in space borne equipment, but also in earth bound electronics.”

“Today our solutions can eliminate the vulnerability of electronic systems to transient errors which affect their availability and reliability,” said Eric Dupont, presidency and CEO of ROIC.

The firm built 0.25um test chips of both its ROC/S design and LEON, the Sparc V8 32-bit Risc processor on which it based its design.

Both devices were stressed by a cyclotron to stimulate errors, which were observed in LEON, but not in the ROC/S device. Moreover, the extra circuits, around 17 per cent extra, needed to detect the transient pulses did not slow the chip, said Dupont.

“This review the test results and am convinced that this approach offers designers the ability to achieve cost savings while bringing a protected system to market much faster,” said Joseph Borel, a VLSI expert and formerly director of design automation at STMicroelectronics.

At 0.13um, iROC reckons SEUs and other soft errors, such as glitches, races, crosstalk and ground bounce, can come at the rate of one every few hours. While other error correction systems concentrate on memory, iROC claim logic is just as vulnerable. Memory can be checked through standard error correction schemes, logic has no such fallback.

The aerospace solution of replicating logic several times over is unsuitable for modern electronics, especially in the price sensitive consumer world.

Procesor works in highly radioactive environments

If you happen to be building a satellite, you may want to get hold of RAD750 – claimed by maker BAE Systems to be the most powerful radiation-hardened general purpose microprocessor ever developed for space.

“The processor has successfully passed manufacturing and environmental testing and is ready for civil, military and commercial satellite applications,” said Dale Hutchison, executive v-p at BAE.

Ultra-bright electroluminescent displays

The Nottingham researchers decided they must have taken another look – forgetting full-colour and pushing the technology for what it really is good at: high-intensity. Essentially a sandwich of two conductors with a insulating phosphor between, TFEI displays rely on exciting phosphors with capacitively-isolated AC fields - typically 250V 5kHz.

Dr Wayne Cranton of Nottingham said a problem with conventional TFEI is the high refractive index of the phosphor, which tends to trap light – up to 90 per cent – in the phosphor layer. Light escape can be boosted by surface treatments, but Cranton has turned the problem of trapping on its head and made a virtue of it. He increases the phosphor layer and uses the phosphor layer to guide emitted light to an angle of transmission. The mirror bounces light out of the display at right angles.

Intensities of 17000cd/m2 at 50mm have been demonstrated – compared with around 4000cd/m2 for a TV turned up to full brightness – using zinc sulphide doped with manganese (ZnS: Mn). This is the most efficient TFEI thin film phosphor and 68000cd/m2 has been squeezed out of an array of mirrors and phosphor.

5000 ft at 5kHz (17,000 cd/m2)

Light is piped sideways to a mirror by a high refractive index emissive phosphor film between 0.5 and 1mm thick. Phosphor planes 100μm wide make the most effective use of light. For narrower angles of emission, lenses can be made in the passivation layer.

A laterally emitting thin film electroluminescent (LFEI) chip 4mm across. Each line is an aperture with a mirror running down the centre. It controls the intensity of the phosphor coated displays where it appears to hang in space.
IoW firm wins second Government SMART award

Signal processing specialist RF Engines, based on the Isle of Wight, has won a second Government SMART award.

The company's first grant was used to develop a pipelined frequency transform (PFT) architecture, which the firm has now patented. The PFT can perform broadband filtering and Fourier transformation in standard programmable logic chips.

The money from the latest SMART award will be used to develop a tuneable version of the transform.

"We qualified for the maximum award which is £45,000," said John Summers, sales and business development director at the firm. "The standard PFT operates by creating a filter bank, and filters are spread evenly across the bandwidth," he said.

"In a tuneable PFT the user can focus down on frequencies of interest. The user can create the shape and type of filter needed."

This enables Fourier analysis to concentrate on specific frequencies, throwing away unwanted data prior to processing.

The company said a tuneable PFT has applications in defence and communications. "It would apply in certain 3G applications but also in 4G," said Summers.

It could be useful in pulling signals out of low-power spread-spectrum comms, with implications for defence and security.

The firm also develops intellectual property for Fourier transforms particularly in complex front-end designs, where real time analysis is important. The standard cores include wide and narrow band designs.

New FM radio chips remove the need for trimming

You can make an FM radio without having to trim it at all, following the release of two new chips from Philips.

The hi-tech radio devices are specifically aimed at adding FM reception to portable electronic devices including phones, MP3 players and PDAs. As such, they do need a host processor to operate.

We have made a significant cut in the number of external components needed to build radio function into a cell phone," said Keef Joosse of Philips.

A complete radio from aerial signal to in to line level audio out, according to Joosse, can be built onto a 9 by 9mm patch of PCB if both sides are used. "Only 15 to 17 external components are needed," he said, and despite none of them being precision components no adjustment whatever is needed to make an FM radio.

The BiCMOS chip is a low-IF design, using an intermediate frequency somewhere between 100 and 200kHz. Quadrature mixing is used in the frequency conversion stages. The on-chip synthesiser gets its reference from the host processor, several frequencies are supported including watch-chip crystals and 13MHz.

The new chip includes a fair amount of intelligence and will automatically scan up or down on command from the host processor. It includes station presets and all control it through a serial bus. One version of the chip is purely I²C, the other also includes a three-wire control bus.

The price is around £3 in 10,000 quantities. The TEA5767 is due out very soon, the TEA5768 slightly later.
Cable Fault Locator

David Huddart's first fault locator, presented a few months ago, was remarkable in that it allowed you to pinpoint faults along the length of coaxial cable at very low cost. David's first reflectometer relied on a fairly fast oscilloscope for displaying its output. His latest version is stand-alone...

This cable fault locator allows you to locate faults in coaxial cables using time-domain reflectometry. It is low cost, very portable and yet easy to use and reasonably accurate.

The design was developed from a previous time-domain reflectometry design which, while very simple, needed access to a fast oscilloscope to use — a little inconvenient in dusty loft spaces!

Background

A time-domain reflectometer sends a very fast-edged pulse into a cable and then looks for reflections. If the cable isn't correctly terminated by its characteristic impedance, a return echo will be observed that is delayed by twice the transit time of the cable (go and return).

If the cable is accurately terminated, no return echo will be seen. The extremes of cable faults are of course open or short circuits.

When a fast edge pulse enters a transmission line, the initial impedance is the characteristic impedance of the line. This is logical as, at that time, the electrons have no way of knowing what lies ahead of them at the end of the transmission line. Energy is therefore entering the line from t = 0 according to:

\[ V = Z_i \]

Once the pulse reaches the end of the line an open or short circuit termination will dissipate no power so the energy stored in the line must now return to the start and be dissipated in the signal generator output impedance.

In the case of an open circuit, this is seen as a doubling of the applied voltage. Energy is stored in the line capacitance to be returned to the signal source on the falling edge of the pulse. Fig. 1. In the case of a short circuit the transmit voltage drops to 0V. Fig. 2, and energy is stored in the line inductance until the falling edge of the pulse.

As no cable is totally without loss, the actual values may be reduced especially on long cable runs and for short-circuited lines.

How the TDR meter performs

This TDR meter generates the fast pulses needed, then measures the echo time delay and calculates the distance. It is capable of resolving distance to an accuracy of approximately 5%, if carefully calibrated. It has a maximum range of 20km and is usable down to about 5m.

The idea for the design came from comments made about my previous article and some thinking of a low cost but self-contained solution. My initial ideas centered on fast digital counters to measure time delay, with some form of high-speed sampling device such as a very fast comparator. After a few sums, though, followed by a search for available fast CMOS logic devices, I decided that any resultant device would be expensive and possibly not as portable as I had in mind.

I then started to think how my oscilloscope measures time. Its time base consists of a linear ramp generator and trigger circuit. Some hours of contemplation later and I was on the track of a device that would generate a square-wave with fast edges and would sample the line voltage at an adjustable time period after the positive-going edge.

By adjusting the time delay, I could look for the sudden change in voltage on the line indicating a return echo. Once the echo point was located manually using a meter to display the sampled voltage, it was just a matter of displaying the time interval, or better still, the distance to the cable fault.

The final solution is a simple design that has performed well in the field. It is not the most accurate of instruments, but it is perfectly adequate for the intended application of locating cable faults to the nearest couple of meters.

In my experience, by the time you are in the correct room, the source of the problem is usually only too obvious. In any case, if you knew the distance to the nearest 10cm, would you then use a tape measure to trace the path of the cable exactly anyway?

How it works

Figure 3 is a black diagram of the unit. An oscillator, \(V_1\), generates a square wave with fast edges of less than 3ns. These edges are coupled to the line via a buffer and 50Ω coupling network.

Sampling gate \(S_1\) is switched on when the positive going pulse is transmitted to line and so allows the parasitic capacitance of a FE input buffer amplifier to charge to the actual line voltage.

A timing circuit comprising \(C_1\), \(R_1\), and \(IC_1\) switches the sampling gate off. This timing circuit is varied from 0 to 3µs by \(RV_1\). When the gate turns off, the instantaneous voltage on \(C_1\) is held. Capacitor \(C_1\) is discharged every cycle by \(S_1\).

In the final design the on duty cycle for the sample gate is very low — less than 1% — and so the average voltage across \(C_1\) is very close to the sampled voltage.

To measure the distance to an echo, \(RV_1\) is adjusted while observing the return echo voltage on the meter until a sudden drop or increase is seen. This will be the echo.

TABLE 1. Circuit operating conditions

<table>
<thead>
<tr>
<th>Di-electric type</th>
<th>Velocity coefficient (V) at (20k)</th>
<th>10m range</th>
<th>25m range</th>
<th>50m range</th>
<th>100m range</th>
<th>200m range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>0.84</td>
<td>1709.4ns</td>
<td>97.37ns</td>
<td>190.41ns</td>
<td>396.63ns</td>
<td>793.65ns</td>
</tr>
<tr>
<td>Foamed polyethylene</td>
<td>0.78</td>
<td>85.47ns</td>
<td>1004.4ns</td>
<td>231.91ns</td>
<td>427.23ns</td>
<td>854.70ns</td>
</tr>
<tr>
<td>Air-spaced polyethylene</td>
<td>0.75</td>
<td>85.47ns</td>
<td>1004.4ns</td>
<td>231.91ns</td>
<td>427.23ns</td>
<td>854.70ns</td>
</tr>
</tbody>
</table>

Fig. 1. Reflections in an open-circuit line. Upper trace is the transmitted signal. Lower trace is the pulse at the far end of cable. Note how the voltage at the far end is twice the initial transmitted voltage to the line.
Switching $S_2$ to “measure”, i.e. position 2, allows the distance to be read off. Distance is proportional to the echo time but also depends on the velocity coefficient of the cable (more of this later).

The duration of the sample gate pulse is therefore proportional to distance. Provided voltage levels are stable, the DC derived from the filter, $V_1$, $C_6$, will also be proportional to distance. With $S_2$ in the “measure” position, the distance setting of $RV_1$ is displayed on the meter.

In the final design, range is changed by switching the clock frequency. As the pulse width from $IC_1$ is controlled only by the echo delay, but the voltage across $C_1$ is a function of the pulse width and frequency, it is possible to change range by changing the clock frequency.

To compensate for the differing velocity coefficients of cable types, the gain of $IC_1$ is switched to give accurate distance measurements. Details of this are given in Table 1.

**Table 1**

| C1, C2, C3. | 47uF 16V electrolytic | 100nF multi-layer ceramic |
| C5, C6, C7, | 1nF ceramic | 2000pF ceramic NPO |
| C8, C9, C10, | 10pF ceramic NPO | 100pF ceramic NPO |
| R1, R2, R3, | 180R 10W, bead | 100uF 10V electrolytic |
| R4, R5, R6, | 1k ceramic multi-layer | 220F ceramic multi-layer |
| R7, R8, R9, | 220F ceramic NPO | Integrated Circuits |
| IC1, IC2, IC3 | 74AC14 RS 169-0036 | 74AC240 RS 169-0036 |
| IC4, IC5, IC6 | 74LS05 RS 665-196 | 74LS06 RS 665-196 |
| IC7 | 74LS14 RS 665-196 | Multi-layer ceramic |
| D1 | LED 5mm | Miscellaneous |
| D2 | 9V, 9PP | 48V, 48V01 |
| D3 | 50V, 48V02 | BNC socket |
| D4 | 220V, 48V02 | IC1, IC2, IC3 |
| D5 | 1000R, 48V02 | Capacitors |
| D6 | 1000R, 48V02 | 470R, 48V02 |
| D7 | 1000R, 48V02 | 100k, 48V02 |
| D8 | 1000R, 48V02 | 10k, 48V02 |
| D9 | 1000R, 48V02 | 220k, 48V02 |
| D10 | 1000R, 48V02 | 1M, 48V02 |
| D11 | 1000R, 48V02 | 10M, 48V02 |
| D12 | 1000R, 48V02 | 220M, 48V02 |
| D13 | 1000R, 48V02 | 1000M, 48V02 |
| D14 | 1000R, 48V02 | 10k, 48V02 |
| D15 | 1000R, 48V02 | 100k, 48V02 |
| D16 | 1000R, 48V02 | 1M, 48V02 |
| D17 | 1000R, 48V02 | 10M, 48V02 |
| D18 | 1000R, 48V02 | 220M, 48V02 |
| D19 | 1000R, 48V02 | 1000M, 48V02 |
| D20 | 1000R, 48V02 | 10k, 48V02 |
| D21 | 1000R, 48V02 | 100k, 48V02 |
| D22 | 1000R, 48V02 | 1M, 48V02 |
| D23 | 1000R, 48V02 | 10M, 48V02 |
| D24 | 1000R, 48V02 | 220M, 48V02 |
| D25 | 1000R, 48V02 | 1000M, 48V02 |

Reflections into a mismatched 75Ω open-circuit cable show that measurements can still be made.
Table 2. Coaxial cable characteristics

<table>
<thead>
<tr>
<th>Cable type</th>
<th>Manufacturer</th>
<th>Impedance</th>
<th>Velocity coefficient</th>
<th>Dielectric coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG58A</td>
<td>Belden 9513</td>
<td>50</td>
<td>0.84</td>
<td>ASPE</td>
</tr>
<tr>
<td>RG58B</td>
<td>Belden 8263</td>
<td>75</td>
<td>0.66</td>
<td>PE</td>
</tr>
<tr>
<td>RG59</td>
<td>Belden 8219</td>
<td>50</td>
<td>0.78</td>
<td>FPE</td>
</tr>
<tr>
<td>RG59C</td>
<td>Belden 8262</td>
<td>50</td>
<td>0.66</td>
<td>PE</td>
</tr>
<tr>
<td>RG59D</td>
<td>Belden 8216</td>
<td>50</td>
<td>0.66</td>
<td>PE</td>
</tr>
<tr>
<td>RG59E</td>
<td>Belden 8257</td>
<td>50</td>
<td>0.66</td>
<td>PE</td>
</tr>
<tr>
<td>RG59F</td>
<td>Belden 8258</td>
<td>50</td>
<td>0.66</td>
<td>PE</td>
</tr>
<tr>
<td>PE</td>
<td>Belden 9273</td>
<td>50</td>
<td>0.66</td>
<td>PE</td>
</tr>
</tbody>
</table>

Velocity coefficient

The following formula gives the relationship between factors involved in measuring cable length using timedomain reflectometer.

1 = \sqrt{\frac{c}{X \cdot C}}

Here, \( f \) is the length of cable in metres, \( t \) is the time from transmit pulse to echo in seconds, \( c \) is the speed of light and \( X \) is the cable's velocity coefficient. The speed of light is \( 3 \times 10^8 \) m/s.

The velocity coefficient is the ratio of the speed of signals through cable to the speed of light. It varies depending on the dielectric used in the cable but is usually between 0.6 and 0.8.

The meter is deliberately short-circuited. This is an age-old trick to provide mechanical shock protection to the meter movement. The theory is that any movement of the needle will cause an emf to be generated by the meter coil cutting the magnetic field (the reverse of normal operation of a moving-coil meter).

If the coil is shorted current flows and sets up an opposing magnetic field. This resists movement and so prevents damage to the mechanism. As an apprentice, this was drummed into me as essential good practice so I can't resist passing it on.

Putting it together

It is necessary to use good quality multi-layer ceramic capacitors for \( C_{A,3,5,8} \) to reduce spurious ringing and use good high frequency layout practice. Any common impedance in power or signal rails increases ringing and this in turn will limit the range and accuracy of the unit. I have found to my cost that it is a false economy to use 'economy grade single-plate capacitors for decoupling in fast logic circuits.

The effect of unwanted ringing would be to blur return the echo somewhat. In use the echo is very clearly seen as an almost instantaneous rise— or fall— in voltage as \( RV \), is adjusted. This is possible only because of the very fast and clean edges generated by \( f_c \) of the echo. I have used an AC rather than HC version of the 7414 for better performance. This performance increase will not be realised though unless good decoupling and layout are used. The breadboard version built on Veroboard just would not work. A second breadboard built on a piece of copper-clad PCB performed well.

To assist those of you interested in building this design, I have designed and tested a double-sided plated through hole PCB. Details on this are given separately.

Setting-up

Assuming that the circuit has been assembled correctly and is functioning, only calibration is necessary.

Finally the offset voltage of \( IC_0 \) must be zeroed. Set \( SW_2 \) to position 2, \( RV_3 \) to minimum. Check that the voltage across \( C_3 \) is less than \( 1\,\text{mV} \). Now adjust \( RV_3 \) until a reading is obtained on the meter. Carefully adjust this to \( 0\,\text{V} \) but stop immediately when \( RV_3 \) is reached: this is a single rail system, negative values cannot be displayed.

To calibrate the range, measure 50m of a known dielectric cable using the correct dielectric constant on \( SW_1 \) and adjust \( RV_3 \) for the 50m range.

Alternatively, set the unit for \( 50\,\Omega \) and poly dielectric, monitor \( RV_3 \) with an oscilloscope and adjust \( RV_3 \) to make the positive pulse width 505ns. Now set \( RV_3 \) for the 50m range. All other ranges and dielectric settings should now be calibrated, but using Table 2, it is possible to check every range and dielectric setting.

Using the meter

Polarity of the echo indicates open or short circuit (\( + \) or \( - \)) in the cable. Positive echoes indicate high impedance to ground. The time delay can be used to estimate the distance to the cable where a fault is. The unit will indicate the distance to any cause caused by cable faults or poor joints.

Connect the cable under test and switch to the 100m range and measure \( RV_3 \) to zero and observe the reading. This is \( 0\,\text{V} \) to line. Turn \( RV_3 \) clockwise and the reading will jump to a new level. This is the 1V to line signal at \( 0\,\text{V} \).

Continue to turn \( RV_3 \) till the voltage doubles, representing an open circuit, or to \( 0\,\text{V} \) representing a short circuit. If this is the distance required to be measured, switch \( RV_3 \) to the appropriate dielectric position and \( SW_1 \) to obtain a reading.

The TDR has given good service in locating faults in coaxial cable runs, detecting dubious coaxial connections. It is able to display the charge on the capacitance of an unknown line by adjusting the termination impedance of a length until minimum reflections are observed. As mentioned earlier, it may be modified for use on other impedances by scaling \( R_{2,3,4} \). In practice, this has not been found to be necessary for use on 75Ω systems.

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I. David Hodder, Cable Fault Locater, Electronics World March 2001
Applications for super-regeneration

Complementing last month’s article on how super-regenerative receivers work, Eddie Insam now discusses how you can apply the technique, and presents some practical examples.

At the end of last month’s article, I mentioned that many tricks have been used to improve detector performance and that the general aim is to keep loop gain as small as possible at the onset of oscillations.

Most well known, standard oscillator configurations can be adapted to provide self quenching. Figure 1 shows a simple circuit with two transistors back to back. Feedback is provided by connecting the collector directly to each other’s base, ensuring a low amplitude limited signal. This results in low power consumption and low radiation.

Designing a receiver

If you want to develop your own circuit, start with a standard oscillator configuration. You can find many examples in the literature mentioned at the end of this article. Choose a circuit where you can understand the purpose of each of the components. This is not so easy with many of the circuits.

Next, you must identify how the components control loop gain. You can do this by arranging the oscillator to be switched on and off from a square wave source: think of this as external quenching.

While switching is taking place, watch the rise and decay of the self-oscillations on an oscilloscope as you adjust components or bias values. The slower the rate of rise, the lower the loop gain, and the better the resulting receiver. Do not worry about self quenching until you have a reliable and efficient externally quenched design.

Feel free to use CAD programs to emulate the operation, but be aware that the time-scale of the simulation must be at the radio frequency. Some CAD programs cannot handle slow events (quenching) riding on top of fast ones (RF oscillations).

Figure 2 shows an interesting variation. A CMOS 4069 inverter is used as a gated oscillator with a ceramic resonator. This can be used in a simple radio control receiver or MSF time code receiver.

The external quenching action is provided by a microprocessor – the same one that may be used for processing the signal. The microprocessor starts the oscillator, and by sensing its Schmidt trigger input, measures the time period at which the oscillations have reached a threshold of about 1.5 volts. Then the microprocessor resets the oscillator, and after a suitable delay period, starts again. This circuit could also be used with a crystal but the quench frequency will be too low for other than very low speed data recovery.

Figure 3 shows a typical receiver circuit using a SAW delay line. I have not shown any component values, as these will strongly depend on layout and parts used. A SAW delay line has a much lower Q than a SAW resonator. I have found it quite difficult (although it is possible) to modify a standard key fob type SAW transmitter to act as a super regenerative receiver. The loop gain of these devices is fairly high, and access to the SMD components is rather tricky.

Interesting applications

In theory, any active component that has negative feedback can oscillate. Therefore, there is no reason why such active component should not work in the super-regenerative mode.

Gunn diodes exhibit negative resistance characteristics, and can be used as the basis for receivers in the gigahertz range. The easiest way to get started is by commandering an old domestic radar-intrusion detector. A popular model is the Mullard CL96S, although most modern types are very similar (Fig 4a). This unit consists of a microwave cavity with two side by side internal sections, one with the Gunn diode, and the other with a mixer diode used for detecting the combined Doppler signal.

The cavities are designed to resonate at about 10.69GHz. By operating the Gunn diode in the negative resistance region, continuous wave oscillations are generated (Fig 4b).

Fig. 2. Unconventional MSF receiver. A CMOS inverter can be used, together with a 60Hz ceramic resonator in an unorthodox, but rather simple time-code receiver. Here a microcontroller is used to control the quenching action by gating a CMOS inverter to enter the linear state. The gate will start oscillating after a time depending on input RF excitation at the antenna. Oscillations are rectified and fed back to the micro as pulse widths for detection. The circuit can work up to 30MHz with suitable components. A crystal could also be used in this design, but with a rather limited quench rate. See text.

Fig. 3. A SAW delay line can be used to effect in the circuit shown. The various reactive components ensure a 180° phase shift between input and output. No part values are given, as these depend on actual unit used and layout.

Fig. 4. Another interesting application showing the use of a domestic radar Doppler module as a very sensitive 1GHz receiver. Using another module as the transmitter, range can be several tens of metres. The mixer diode is not used in this instance.
Self quenching can be obtained by starting the supply with a series resistor and storage capacitor to ground. Simply connect the device as shown in the figure. You may need to experiment with the values as different modules may have different characteristics. You should hear a loud “hiss” from the amplifier and loudspeaker. You will need another Gunn unit as the transmitter. The range can be quite impressive, especially if you attach an antenna box to the flanges. You can arrange for external quenching if the use of a free self-quench. Just switch the supply on and off at the desired quench rate. You may need a hefty switching transistor as the Gunn device can take up to 200mA.

One thing you cannot use this circuit for is as a Doppler radar module. The receiver only samples incoming radiation at the quench rate. It also radiates pulses at the same rate, but just after the detector was active, so the two signals do not meet.

Having said that, here is a simple experiment you might like to carry out. I have not tried it by the way.

An electronic tape measure
You will only need one Gunn device for this test. Arrange for the quench rate to be around 10kHz or more. You may need to use a very small value for the quench capacitor. C Alternatively, use external quenching, and arrange to measure the current into the Gunn diode, say by measuring the voltage drop across a series resistor in the supply line.

Peel the two signals into an oscilloscope. The delay between the application of power and the current spike will indicate the oscillation trigger point.

Place the unit at a wall or solid obstacle about 15 meters away. This distance should be such that a quench RF pulse will have enough time to travel to the wall and back to coincide with the exact time when the next RF quench pulse starts.

The echo signal will then react with the detector at the exact points when the next oscillations start, and produce some kind of output on the oscilloscope. What we have here is a quite accurate distance measuring device. Again, I have not tried this, but it would be interesting to see how sensitive it can be.

Long-range transponder
Lastly, Fig. 5d shows a concept for a long-range miniature key fob transponder device. A resonant 1/4-wave strip line is used as both receiving and transmitting antenna.

An active device source is used to sense incoming radiation by applying short duration, controlled negative conductance loads to the strip. This active source will have to be a very accurate, programmable device, such as a combined gyroradiometer in a chip.

The sense rate can be very slow to conserve power, say once every second. When radiation is detected from a transponder enquiry source—sense ramps are applied more often to increase the sampling rate, and to decode any incoming addressing codes. When the unit is ready to reply, a much larger negative load is placed on the strip to provide power for radiation.

The diagram above shows a dielectric resonator placed close to the microstrip. Such resonators are effectively stable, high-Q RF cavities constructed from solid dielectric material, and can be used to stabilise the frequency characteristics of the strip. Such a unit may work at a range of 30-50 meters.

Self on Audio

The cream of 20 years of Electronics World articles (focusing on recent material)

A unique collection of design insights and projects—essential for all audio designers, amateur and professional alike.

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Douglas Self has been writing for Electronics World and Wireless World over the past 20 years, offering cutting-edge insights into scientific methods of electronics design.

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Readership: Audio electronics enthusiasts; Professional amplifier designers; Power amp users

Paperback

Pages: 416pp
Two-step LC tuning

Peter Fry explains his method for simplifying the tuning of LC oscillators.

If, like me, you set up an LC oscillator by adjusting the L and C trimmers until the calibration is about right then you might find the following method not only saves time but also gives a better understanding into the processes involved.

At the outset, my aim was purely academic. I was taking frequency measurements from an out of calibration oscillator and then using these values to calculate the exact setting for the final C and L adjustments.

The results were worth the effort though in that I now have a method that is very satisfying to use. It also proves, before final calibration, that the capacitor values will produce the desired frequency maximum to minimum range. In addition, it minimises the times you have to touch the dust iron cores, which is always a good thing.

In the industrial instrumentation world, my background, we would normally expect to find non-interactive ‘zero’ and ‘span’ calibration adjustments rather than the highly interactive L and C trimmers on a typical LC oscillator.

With a few simple frequency checks and a pocket calculator, it is possible to break the interaction between the L and C trimmers. The final calibration then consists of a single adjustment of the C trimmer to a calculated frequency and then a single set of the inductor to achieve a close calibration of the radio or oscillator.

This method does assume that the instrument or radio has been correctly designed such that the variable capacitor characteristics match the printed scale.

The method

Most LC oscillators can be simplified to the basic circuit as in Fig. 1. Here, calibration is achieved by setting C1, the trimmer, and L, the inductor, which is assumed to be variable. Other circuit capacitances, designated as ‘stray’ will always modify the actual frequency downward from the theoretical values.

The frequency ratio of maximum/minimum is set by:

\[
\frac{C_{\min}}{C_{\max}} + \frac{C_p + C_{\min}}{C \cdot C_{\max}}
\]

The inductor controls the frequency with the capacitor but it plays no part in the maximum frequency ratio. This is fundamental to the calculations that follow.

Before taking a look at the actual circuit used in the practical tests, Fig. 2.

The circuit is from a simple AM signal generator that was used to check the calculations in this article. This schematic and traces were taken from a Micro-Cap 5 simulation. The waveform in Fig. 3 is close to the actual generator signals, which gives confidence. I have not however included the modulation on the schematic. In the commercial generator, this is applied to the base of T1. This is not good practice as it modulates both the amplitude and the frequency however for 10-15% AM modulation. Considering that the generator was to be used for bench testing AM broadcast radio, then this is just about acceptable.

In order to cover 400kHz to 1600kHz, the generator had a waveform switch that brought in a second section on the variable capacitor and a second inductor. The section shown is the 925kHz to 1600kHz range. For clarity this is not shown.

Calibrating the oscillator

What needs to be done is to test the limits of the oscillator in its uncalibrated state and then determine if it will be possible to calibrate it without adding or subtracting extra capacitors. It is also necessary to determine a setting for C1 that will give a one-off setting. Final calibration is by a single adjustment of the inductor, assuming that it can be varied in some way.

Step 1. The first step is to ensure that all mechanical parts of the tuning mechanism are in good order. Check that the scale pointer moves from end to end as the capacitor varies fully mesh and un-mesh and that all shaft screws are tight. Any problems here must be solved first or the whole process will be invalidated. Be careful with any string and pulley type pointers as they can be very difficult if not impossible to re-string.

Step 2. Set up a frequency counter or calibrated receiver to measure the oscillator frequency. Counters should always be coupled via a buffer stage. Alternatively, they should be coupled as loosely as possible using a pick up coil of a few turns connected to the end of a probe or a 10 probe connected to a low impedance part of the oscillator.

Step 3. Choose two calibration points, near, but not right at the ends of the tuning scale. Depending on the quality of the oscillator there can be inaccuracies right at the extremities of the range.

Also remember that if this is a radio local oscillator then the IF frequency will need to be added or subtracted. Assuming a normal broadcast receiver that is basically functioning, this frequency can be determined by measuring at the detector stage with a strong broadcast or injected if signal peaked for max amplitude.

Step 4. Draw up or copy the table as in Table 1.

Table 1. Use this table as an aid to calibrating your oscillator. See Table 2 for clarification.

<table>
<thead>
<tr>
<th>Chosen dial setting</th>
<th>IF applicable</th>
<th>Frequency at Cmax</th>
<th>Frequency at Cmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Output from the oscillator, aj, and modulated signal, bl. Y scales are volts V scales microvolts in aj and millivolts in bl.
Table 2. Setting-up table including values from a simple test oscillator.

<table>
<thead>
<tr>
<th>Chosen dial setting</th>
<th>±IF applicable (kHz)</th>
<th>Frequency at ( C_{\text{max}} )</th>
<th>Frequency at ( C_{\text{min}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_max</td>
<td>1.400MHz</td>
<td>1.567MHz</td>
<td>1.397MHz (FB)</td>
</tr>
<tr>
<td>F_min</td>
<td>0.950MHz</td>
<td>1.065MHz</td>
<td>0.9674MHz (FB)</td>
</tr>
<tr>
<td>Ratio</td>
<td>1.4737 (Z)</td>
<td>1.525 (X)</td>
<td>1.4235 (Y)</td>
</tr>
</tbody>
</table>

Next set the dial to your upper chosen setting and with the trimmer capacitor set to minimum, i.e. if it's a compression type, slacken the compression screw or if small vane type, un mount it. Measure the frequency and enter the value in the table at the maximum dial \( C_{\text{max}} \) location (1.567 in the example).

Leaving the trimmer alone, set the dial to the chosen low point and enter the frequency into the minimum dial \( C_{\text{min}} \) location (1.027 in the example).

Leaving the dial at the chosen low point, adjust the trimmer for maximum capacity. If it is a compression type slip the screw up, but not too tightly. If it is a vane type fully mesh it. Now measure the frequency and enter the value in the chosen low point \( C_{\text{min}} \) position.

The main dial to the high chosen point and enter the value into the table in the remaining high-dial point and \( C_{\text{min}} \) location.

Now divide each column highest frequency by the lowest to reveal the actual frequency ratios.

This bit is important. The actual ratio of minimum to maximum tuning range is set by the square root of the capacitor minimum to maximum values regardless of actual frequency. If you are designing the circuit yourself, this is of concern and is dealt with in basic LC theory.

In this example though, we are measuring frequency ratios. As a result, we do not need to be concerned with the mathematics of the LC oscillator. If the ratio under the chosen dial settings is not within the range of ratios in the Max and Min \( C_{\text{max}} \) and \( C_{\text{min}} \) columns, then it will not be possible to calibrate the oscillator without some change to the pad capacitors.

You may be able to squeeze a bit more out of the adjustment if you pull up the trimmer a bit harder and repeat the \( C_{\text{min}} \) calculations but take care! The values shown in Table 2 are those from my simple bench test oscillator. All that now remains is to set the dial to the high chosen value and to calculate the spot frequency that will be set by \( C_{\text{T}} \). This will not be the dial setting frequency but will be a frequency that gives the precise frequency ratio, value \( Z \) in the table.

Referring to the table for the variable identifiers calculate the spot frequency using:

\[
\frac{f_{\text{set}}}{f_{\text{max}}} = \frac{f_{\text{min}}}{z} = \frac{(f_z-f_x)+f_y}{x-y}
\]

For my example this gives

\[
\frac{1.4737 - 1.4235}{1.525 - 1.4235} = 1.417\text{MHz}
\]

Using my example, set the dial to 1.400 and use the \( C_{T} \) trimmer to set the oscillator to 1.471MHz.

All that now remains is to set the inductor to give 1.400MHz precisely. This setting could equally be done at any point on the scale as it brings the whole scale calibration in line.

Providing that the dial scale matches the variable capacitor characteristics and that the calculations were done accurately, then you should find the scale setting to be reasonably accurate and no further trimming may be required.

It is quite easy to set up a simple spread sheet to further simplify the procedure. Doing it this way also removes any chance for calculation errors.

**Reducing flyback stand-by power**

Jonathan Adams of International Rectifier looks at how to wind down the stand-by losses of flyback power supply circuits using the IRIS40 range of integrated switchers.

There is an increasing amount of emphasis on the stand-by or no-load consumption of electrical equipment. This is being driven by various environmental agencies, which are focusing their efforts on reducing the losses and power wastage of electrical equipment. These efforts include programmes and initiatives that define criteria for appliances and equipment. Examples are the Energystar program in the USA and the Blue Angel Program in Germany. These are both being adopted worldwide.

Meeting the criteria for these programmes allows manufacturers to place marking like the Blue Angel and the Energystar Logo on their equipment, signifying the environmental saving measures the devices incorporate.

These programmes and initiatives are becoming universally adopted. Soon, they will apply to all electrical equipment. As a result of this it is important the Power supplies for these pieces of equipment are energy efficient and consume very low power in the Standby or off states. This design tip shows you how to implement a circuit to reduce the no-load/stand-by losses of a flyback power supply.

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power supply using IRIS40xx series integrated switches. In Figures using a circuit to change the mode of operation of the IRIS device depending on the load, quasi-resonant mode for higher loads, and pulse-ratio control, or PRC, mode for light load and no-load conditions.

Changing to PRC for light or no-load conditions would set the circuit to operate in a frequency range of 13-20kHz. This would drop the no-load losses from a typical 2.5W with a 230VAC input to about 0.2W. Quasi-resonant mode at no-load through would cause the circuit to operate around 340-350kHz, which leads to higher switching losses.

Stand-by circuit operation

The circuit shown in the next page in Fig. 1 shows a typical single output flyback power supply using the IRIS40xx series integrated switcher. It is different from the circuits in the other application notes in that it has been added to facilitate lower-power operation at no-load and standby conditions.

This additional circuitry consists of Q3, R13, C13, and D10. These five components form a switching circuit to either pass or disable the supply from the quasi-resonant signal from the bias winding B to the feedback pin of the IRIS40xx.

Operation of the circuit in stand-by mode is fairly simple and will be explained here. Components D3, R12, C12, and D12 form the delay circuit which determines the mode of operation of the IRIS40xx to detect when all the energy has been transferred from the primary to the secondary, and when the frequency falls to the lowest point for softer switching.

Transistor T1R is placed in the path to act as a switch to enable or disable the feedback. This effectively changes the mode of operation of the IRIS40xx from quasi-resonant mode when the feedback is enabled to the lower-frequency pulse-ratio control mode when the feedback is disabled.

The circuit monitors the bias winding voltage to determine when to switch between modes. At normal load, the bias winding voltage would be higher. Also, the mode-switching circuit would have its level set so that under these conditions Q3, R13, and the quasi-resonant feedback/relay circuit is enabled. When the circuit drops to a no-load or standby load condition the bias winding voltage would drop below the set level and disable the feedback/relay circuit. Components R13, C13, and D10 form a voltage divider to set the switching level of the standby mode-switching circuit. The switching level is determined by the voltage across R13 and D6.

When the bias winding voltage is high enough current will pass through the delay circuit D12, R12, and D12. This causes a voltage drop across R12, which in turn is seen across the emitter-base junction of the n-p-n transistor T1R. As this voltage starts to rise above 0.6V, current is injected into the collector-emitter junction of T1R and it will turn on.

If the voltage across R12— and in turn the emitter-base of Q3— is less than 0.6V due to a lower voltage at the bias winding, less or no current flows through R12. As a result, Q3’s collector-emitter junction is not sufficiently forward biased, so Q3 cannot turn on and the feedback/delay signal is disabled.

Design procedure

I’ll present an example to show you how you can design and implement this part of the circuit. I’ll assume that the rest of the circuit has already been designed using the other application notes.

First, take an example where the normal designed Vf is 17V. If the rectifier for the bias winding is something like a 1N4148, then the bias winding voltage would have been designed to be 18V. So under normal load conditions there is 18V bias winding at X, during the energy transfer cycle.

Now it’s time to select the voltage at point X to change the mode of operation. This will obviously be below 18V. Consequently, select a voltage that is a few volts below the expected bias voltage to ensure it will switch at light load, but can also start up into quasi-resonant mode when there is a full load condition. Let’s select 15V.

The bias winding voltage drops at light load, so due to the higher feedback current from the output control circuit.

If there’s 15V at point X, then the voltage at the emitter of Q3— point Y — will be 1V below this due to the forward voltage of D12. So at Y, there’s 1V.

Transistor T1R will turn on at the point where the voltage across the emitter-base junction. Therefore set R12 to 602Ω. Now, Q3 will turn on when there is 968V across R12. So if you want Q3 to turn on when point Y is at 14V, it can see a lower voltage for D12 and turn on from $V_T = (V_G - 0.6)$.

Here, $V_G = 14V$ in this example, and $V_G = 968V$. If you make D12 an 11V Zener diode, then R12 will be 2.4k.

The circuit shown above will be able to change modes to the low power standby with a load change from any load above 1A to a load of 0.05A or less.

Circuit waveforms

In Fig. 2, the waveform shows how the circuit changes from operating in the quasi-resonant mode to pulse-ratio control mode as a result of a load change.

When the load current changes from full load to no-load, as shown on CH1, the feedback level increases as the output voltage increases to try and move the energy produced. Eventually, under this condition, the feedback level increases a point where the FB stops switching as shown by the flat part of the drain waveform on CH1. At the same time the FB pin (CH3) no longer sees the quasi-resonant information. Also, the $V_{CC}$, $V_{CH2}$, will fall as the bias winding is now not supplying energy.

As shown above, the circuit control ability stabilizes. The FET starts to switch again, but this time it is operating in the pulse-ratio control mode. This results in a reduced $V_{CC}$. Also, there is no quasi-resonant signal at the FB pin, as shown by the reduced voltage on CH3.

During operation under these conditions, there will be a higher feedback level. This is due to the no-load conditions at the output. As a result, the circuit only needs to transfer a very small amount of energy from the primary to the bias and output to keep the circuit in equilibrium until there is another load change.

Optional external override circuit

Figure 3 shows how an external override switch can be used to make sure the circuit goes into the pulse-ratio control mode. FET Q2 could be a logic-level FET, such as a driving signal from a microcontroller or other source.

The implementation of this circuit is very simple. Transistor Q2 is usually off, which allows the circuit to operate as normal when the mode of operation is determined by the load current. When Q2 is turned on, point W is tied to ground, which shorts out the quasi-resonant signal and prevents the circuit from going into the quasi-resonant mode. Therefore the circuit will default to operating in the PRC mode.

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**Gang your own pots**

A very low-cost method for ganging multiple potentiometers.

It is possible to gage potentiometers using just cardboard, a few strips of wood and some lengths of spindle. John Farbrother kindly sent a contraption to Electronics World to illustrate the point.

Strips A and C are identical. They’re about 5mm thick on the prototype. Strip B is similar, but a little longer. Strips A and C are linkage arms from cardboard.

The drawing only shows the mechanism for two pots. Strip A is fixed to the potentiometer shaft at one end and to one of the linkage strip at the other. The potentiometer is fixed. Similarly, the knob fixes to one end of strip C, the other end of which connects to the other linkage strip.

Although the knob and potentiometer aren’t directly linked, as you can see from the side view, the pot turns when the knob is turned due to the action of strip B and the linkage strips. The linkage strips cause any other A, B, C combinations connected to it to turn by the same amount.

Further pots can be added along the linkage strip. We couldn’t detect any noise in the prototype triple-ganged version by the way.
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This competition is sponsored by Nevada Communications, UK distributor of the WorldSpace radio. You can telephone Nevada 02392 313090 or visit worldspaceradios.co.uk for more information on the radio. Nevada Communications, Unit 1, Fitcherbert Spur, Fareham, Portsmouth PO6 1TT.

Win an Hitachi WorldSpace radio worth £149

What is a WorldSpace receiver? Lists to over 40 channels of crystal clear, fade-free digital audio programming direct from geostationary satellites around the world with the Hitachi KH-W51 WorldSpace Digital Receiver. In addition to the satellite WorldSpace programming, it receives regular terrestrial AM, FM and SW broadcasts.

Personalising available programs The Hitachi KH-W51 WorldSpace receiver displays a scrollable menu of available channels. You can then customise the types of channels the receiver shows by preselecting preferred language and program types. For example, an Arabic speaking user who wants to receive a wide variety of global news can preset the receiver to display only the WorldSpace array of Arabic language news channels.


WorldSpace satellites are located more than 35,000 kilometres above the equator. Using powerful spot beams, each of which can support more than 50 services, the satellites transmit to three overlapping coverage areas approximately 14 million square kilometres each.

Earth Stations WorldSpace satellites use on-board processing to enable program reception from many stations. Content providers on the WorldSpace system can upload their programs via the traditional dub method, sending broadcast signals to a central location for processing before transmitting them to the transparent part of the satellite.

A second mode enables use of a smaller, more mobile feeder link uplink stations. Onboard processing technology converts these multiple signals at the satellite, combining them into a single downlink signal before transmitting them back to earth.

Hitachi's WorldSpace radio features:
- WorldSpace satellite plus FM/MW/SW1/SW2
- L-band satellite 1453.381-1490.644MHz
- FM: 87.5 - 108MHz
- SW: 522 -1650MHz
- SW1: 2.3 - 7.3MHz
- SW2: 9.5 - 26MHz
- Memory: 10 WorldSpace satellite/30 radio channels
- Last station memory
- 3W output (PMPO)
- Built-in monaural speaker 0.5W output
- Portable, battery power (6V 4x cell batteries) with AC adaptor
- DC input jack= 6V DC
- AC mains = 110-127V, 220-240V
- Stereo headphone socket
- Stereo line out connectors for integration with your stereo or home theatre system
- Built-in easy-to-use antenna
- Decryption and narrowcast capability
- Programmable by language and category
- Clock display/timer function
- 1-line 8 character LC display
- Port for easy attachment to the WorldSpace PC card to enjoy multimedia services - not yet available in Europe
- Easy to set up and operate
- 246.2 x 162.5 x 39mm (9.7 x 6.4 x 3.6in) including antenna and handle
- Weights 1.5kg (4.1lb) without batteries

Hitachi WorldSpace Radio
The Hitachi WorldSpace radio gives fade-free, crystal clear digital stereo programming direct from WorldSpace satellites around the world.
Receive over 40 channels of digital programmes from home or as you travel almost anywhere in Europe, Africa, the Middle East and Asia. The Hitachi is easy to use and maybe linked to your headphones or to a system to give stunning digital stereo sound.

Hitachi WorldSpace receiver:
- FM/WB/SW1:
- L-band satellite 1453.381-1490.644MHz
- FM: 87.5 - 108MHz
- SW: 522 -1650MHz
- SW1: 2.3 - 7.3MHz
- SW2: 9.5 - 26MHz
- Stereo line out connectors for integration with your stereo or home theatre system
- Built-in easy-to-use antenna
- Decryption and narrowcast capability
- Programmable by language and category
- Clock display/timer function
- Port for easy attachment to the WorldSpace PC card to enjoy multimedia services

*AfriStar* *AmeriStar* *AsiaStar*
Dear Editor,

I am writing in response to the article "Improved Outlook" by Mr. Wilshere in the latest issue of "Electronics World". While I appreciate the positive outlook presented by Mr. Wilshere, I would like to express some concerns regarding the claims made in the article.

Firstly, the article suggests that the introduction of new technologies and standards will lead to a significant increase in productivity and efficiency. However, I believe that the success of these initiatives will depend greatly on the implementation and adoption of these technologies by the relevant stakeholders.

Secondly, the article mentions the importance of training and education for the workforce. While I agree that this is a crucial aspect, I believe that we should also consider the role of government policies in creating an environment that is conducive to innovation and growth.

Lastly, the article highlights the need for collaboration between different industries and sectors. This is indeed essential, but I am concerned about the potential for over-reliance on foreign suppliers, which could have negative implications for national security and economic autonomy.

In conclusion, while the positive outlook is certainly welcome, I believe that we should also be prepared to address the challenges and limitations that are likely to arise in the implementation of these initiatives.

Yours sincerely,

[Signature]

[Name]

[Title]
Motorcycle gear display

Many motorcycles have six gears - some models even have seven - but they rarely, if ever, have a gear display. At first, making a display seems to be simple enough; on closer inspection, the problem turns out to be quite complicated for motorcycle and some mechanical-ear sensitivity. Using electronics and microprocessor logic, this problem is easy to solve.

The problem and the sensors needed to solve it

My friend bought an old motorcycle with six gears. He wanted to know which gear was selected via a seven-segment display. A motorcycle's gearbox is controlled using a rocker-type foot pedal. Pushing it down from an original neutral position selects first gear; pulling it up or pushing down toggles the gear box first back into neutral, then to second gear, then third, fourth, fifth and sixth position.

For position sensors, we decided to use three micro switches: one for neutral, one for up and one for down. The gear lever operates these switches according to the sequence described above.

Microprocessor and display

A 25mm-high seven segment display is more than adequate for most motorcyclists in daylight and at night. A Kingsbridge SCI001-2 display has seven segments and a decimal-point LED with its own anode. This display has common-anode connection. Its common-cathode counterpart requires a small modification for microprocessor program. The modification is explained later.

A flash PIC16F84A with 13 I/O pins is enough for eight display outputs and three micro switch inputs. Port B connects to the display through a resistor network. Port A is used for micro switch inputs.

The processor and display use a 5V supply power. A standard 7805 regulator drops 12V battery input to 5V. Power supply rails should go through HF filters to the ignition switch and ground.

PIC microcontroller program

The program logic might seem simple, the real-world interface adds complications. Switch bounces, power-on/off and special conditions like starting or stopping while the bike is in gear all have to be taken care of.

A program is a state machine in which the only way to get to the next state is to fulfill the right switch combination with the right amount of debounce time. After reset, the program goes to zero state and shows a zero digit at the display. Between each state there must be a 50ms debounce time.

Each switch has a hardware debounce timer involving an RC circuit. This precaution prevents problems from interference caused by the ignition system.

A seven-segment display is decoded directly by the seven-segment table that contains the values to turn the right combination of LEDs on. A CCS PIC C compiler is used for the software. The software size is about 300 compiled words. List 1.

Because the program doesn't use any interrupts, timers or any special PIC peripheral, it is easy to implement the code with any microcontroller, including Intel's 80C51 compatible processor.

Using an 80C51 would require a driver though in order to produce a bright display, so the PIC is right selection for this application. An even better solution might be the PIC16F872. It has internal RC oscillator which removes one component. This part is not yet readily available as the "PB4 or "PB5A in truth.

Putting the idea together

It is possible to make the whole unit on one double-sided circuit board. Because this was a spare-

---

List 1. A seven-segment display table with same test combinations together with a code snippet for using the table based on a PIC C compiler.

<table>
<thead>
<tr>
<th>Value</th>
<th>Segment 0</th>
<th>Segment 1</th>
<th>Segment 2</th>
<th>Segment 3</th>
<th>Segment 4</th>
<th>Segment 5</th>
<th>Segment 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
</tr>
<tr>
<td>1</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
</tr>
<tr>
<td>2</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
</tr>
</tbody>
</table>

---

Motorcycle gear display

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May 2002 ELECTRONICS WORLD
Hex code for the PIC16F84A controller:

<table>
<thead>
<tr>
<th>000000000010D007E76000106010902100801F0F0</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000000011E007D67000106010902100801F0F0</td>
</tr>
<tr>
<td>000000000012F007C66000106010902100801F0F0</td>
</tr>
<tr>
<td>0000000000130000100000020000000000000000</td>
</tr>
</tbody>
</table>

The Hex code for the PIC16F84A controller is shown above.

**CIRCUIT IDEAS**

Complete circuit for the microstepping gear-selection indicator.

**Hex**

100000000010D007E76000106010902100801F0F0

The Hex code above is used to program the PIC16F84A microcontroller.

**ABC Mini 'Hotchip' Board**

Currently learning about microcontrollers? Need to do something more than flash a LED or sound a buzzer? The ABC Mini 'Hotchip' Board is based on Atmel's AVR 8051 RISC technology and will interest both the beginner and expert alike. Beginners will find that they can write and test a simple program, the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the Atmel microcontroller, as well as the ease with which the little Hotchip board can be "designed-in" to a project. The ABC Mini Board 'Start-up Pack' includes just about everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled microcontroller PCB board with both parallel and serial cables for connection to your PC. Software includes on CD-ROM feature on Assembler, Basic compiler and in-system programmer. The pre-assembled boards only are also available separately.

**ATMEL 89xxxx Programmer**

Powerful programmer for Atmel 8051 microcontroller family. Read and lock bits are programmable. Connects to parallel port. Can be used with any computer. Operating systems: MS-DOS, Windows, Windows NT. Includes programming software: AT91C511, AT91C511, AT91C591, AT91C51, AT91C521, AT91C522, AT91C525, AT91C550, AT91C560, AT91C560, AT91C580, AT91C580, AT91C580. No special software needed - uses any terminal emulator program (built Windows).

**PC Data Acquisition & Control Unit**

Use a PC parallel port as a real-world Interface. Unit can be connected to a mixture of analogue and digital inputs from pressure, temperature, movement, sound, light, intensity, weight sensors, etc. (not supplied) to sensing switch and relay states. It can then process the input data and use the information to control up to 11 physical devices such as motors, sirens, other relays, servomotors & two-stator motors.

**FEATURES:**
- 8 Digital Outputs: Open collector, 50mA, 33V max.
- 16 Digital Inputs: 20V max. Protection 1K in series, 5V Zener to ground.
- 11 Analogue Inputs: 0-5V, 10-bit 8-bit (8-bit x 1Watt).
- 1 Analogue Output: 0.5V or 0-10V, 8-bit (20mA x Watt)
- All components provided including a plastic case (140mm x 100mm) with pre-punched holes and all screw terminals, screwdriver panels, to do a professional and attractive finish (see photos).

The PC Data Acquisition & Control Unit is available at £99.95.

**Advanced 32-bit Schematic Capture and Simulation Visual Design Studio**

The Advanced 32-bit Schematic Capture and Simulation Visual Design Studio is available at £74.95.
Switching EHT generator for ES loudspeakers

Originally developed to power an electrostatic loudspeaker, this circuit replaces the original 60V, 50Hz transformer.

A single-transistor ringing choke oscillator forms the heart of the converter. This oscillator drives a pot core. Network R3/C7 forces the oscillator to start at power up. Resistor R7 limits base current to a safe value.

The transformer feeds a voltage multiplier to produce a final output of around 520V. This voltage is divided by R5-R6 and compared to the reference. D2 by IC1.

Output from IC1 drives power transistor Q0, hence altering the supply to the converter. To allow for supply regulation, the converter should give its maximum required output at a supply of 10V Components C0, C1 and R0 are there to keep the control loop stable.

I altered the core gap experimentally to achieve maximum efficiency. On the prototype, a gap of 0.1mm gave the best efficiency, with an operating frequency of about 30kHz. This gap was between the two halves of the pot core, giving a total air gap of 0.2mm.

Due to the high reflected capacitance, the waveform at the collector of Q2 was a near-sinusoid. Because of this, the usual suppression components around the power transistor were not required.

Resistor R1 reduces the effect of this capacitance on Q1.

John Vincent
Caterham
Surrey
G9

£50 winner

Frugal pilot light - three-component voltage step up

This circuit uses the negative resistance effect from a pair of JFETs to voltage double a 1.5V supply in order to light a LED. Output voltage is 2.9V given a 1.5V supply.

The unusual feature of this oscillator is its extremely low power consumption. I measured this at 250μA. If the LED is removed the circuit draws 60μA.

If a pass transistor is added across L1, it will produce a noise dependent on the series-resonant frequency of the inductor used.

However, L1 should be as large a value as possible to get a low frequency output.

Note that this circuit will also detect shorted turns in an inductor as it will not work if one is present.

One possible use of this circuit is a fishing float light for night fishing.

André de Guerin
Vale
Guernsey
G61

£50 winner
The magazine ad is too small and blurry to read clearly. It appears to be an advertisement for various products and offers, but the text is not legible.
**NEWPRODUCTS**

Please quote **Electronics World** when seeking further information.

7656e: The MAX3436 fixed-gain ADSL driver is available in 8-pin microMAX and SO packages. The MAX3436 externally set gain ADSL driver with shutdown is available in 10-pin microMAX and 14-pin SO packages. The MAX3436S ADSL driver/receiver is available in 20-pin TSSOP and SOP packages. Maxim, Tel: 0080 585048, www.maxim-ic.com

16-bit flash micro lowering costs of debugging

Hitachi's latest flash microcontroller offers 128byte flash and 4kbyte RAM and features an on-chip debug interface that the company claims will enable low-cost debugging in a target system. There is also a low cost B107 emulation option. The HS080BF2 is based on the HS000 core with an 80 minimum instruction cycle at 16MHz. It features an integrated timer unit (ITU) for motor control and a well-balanced peripheral set. The ITU connects to the chip's external interface cortex and is available in a PCl or PCMCIA version. The emulator's features include hardware breakpoints on address and data, software trace, single stepping at a card assembly level, and the ability to download applications and program on-chip flash.

The HS080BF2 is available in a 100-pin QFP/QFPQ (Flat Quad Flap) package. The HS080BF4, E107, F107-3025 evaluation board and 163052 emulator support are all available. Hitachi, www.hitachi-eu.com

In-system programmer for STAPL diet

Actel has teamed up with First Silicon Solutions to offer a programmers for in-system programming of its flash-based ProASIC field-programmable gate arrays (FPGAs), including the recently announced ProASIC Plus family.

The in-system programmability feature uses the IEEE standard 1149.1 TAP (Test Access Port) interface, which permits devices to be programmed after they are mounted on the PCB. Called FlashPro the programming system also supports the Standard Test and Programming Language (STAPL), which makes the programmer independent of any specific programming algorithms. According to the firm, it will also support new devices immediately upon release with a new SO file. The portable programmer is currently available for use with Actel's flash-based ProASIC 50k and ProASIC Plus families. Actel, Tel: 01276 401462.

**Eurostep terminal block is highly sprouting**

The Europlug terminal block from Molex incorporates a spring clamp which means it can be unplugged without wireing for replacement of faulty or damaged electronics.

Applications include automation, motion and process controls as well as telecommunications equipment, HVAC systems and power supplies.

A pre-loaded stainless steel spring clamp enables installers to secure terminations reliably and securely. With horizontal and perpendicular spring actuation slots, termination may be accomplished for many orientations.

Available in two to 24 circuits, these terminal blocks have 5.08mm (0.200inch) pitch and use 14 or 24 AWG. Field service rated at 300V for 10A with 14AWG wire, operating temperatures are -40°C to 140°C. The system uses phosphor bronze contacts and hot dip plating (also available in gold). The insulator is also surface mount compatible (SMD), made of high temperature polyamide resin with a 94 V-O flame rating, eliminating wave soldering.

Molex, Tel: 01922 720751, www.molex.com

**Single-chip modem with caller ID**

TDK Semiconductor has introduced a 3.3V single chip modem that combines all the control (DTE) and data functions necessary to implement a V.22bis data terminal. The TMD320CL includes functions like caller ID, blacklisting, parallel phone line, detect (Line-In-Use and Parallel Pick-Up-Line-Sensitive), long space disconnect, inactivity timeout and programmable call progress. The device is housed on an 802 microcontroller core with a proprietary multipliy and accumulate (MAC) co-processor, analogue from end, Sigma Delta A/D and D/A. The ROM and RAM necessary to operate the modem are contained on the device. It is capable of data transmission and reception at 2400bps and power consumption is 9.5mA.

The modem is available in a 32-pin PLCC, 32-pin TQFP or a 44-pin LQFP package. TDK Semiconductor, Tel: 011 714 508 9881, www.tdksemdx.com

**Current switch has 1.75A limit for cards**

Maxim has introduced the MAX7922 high-side MOSFET current-restricted-limited 750mA power switch with built-in fault build-in protection. It has a 1.75A current limit (±20% per cent) maximum over the operating temperature range, which protects power distribution systems in PC cards, 150s and other hot-swap plug-in applications. The narrow current limits lead to better control of the lower cost-power-supply components that can be accommodated in power over current fault conditions. Input voltage ranges from 2.7 to 5.5V. The device comes in an eight-pin SO package. Maxim, observe.maxim.com

**CAN transceiver survives loss of ground**

Linear Technology has introduced the LT1796, a transceiver for controller-area network (CAN) bus applications, designed to withstand ±15kV ESD strikes and faults up to 10kV in automotive applications. In these applications, the loss of ground connection or cross-wiring faults can force DC voltages in excess of 24V in either polarity onto the bus pins. The device is designed

**Dual-View dual-LAN board for industrial applications**

A feature-rich single-board computer (SBC), able to support two independent displays in various combinations of CRT, LCD and TV, is now available from Andes Electronics. Supporting Intel Socket 370, Coppermine Pentium III and Celeron CPUs, the 5.25in board is ideal for a wide range of industrial applications. Featuring single and optionally dual-LAN (10/100) as well as dual-view capability, the NC-640 offers a highly flexible display configuration, supporting simultaneous images and refresh rates on LCD/CRT, LCD/LCD and CRT/TIV. The product will drive 128-bit 3D CRT/LCDs with 800x600 video modes and CRTs to 1200 x 1000 true colour and TFTP/DSTN LCD panels up to 1280 x 1024 resolution. It also includes an integrated single-channel 110MHz LVDS transmitter, allowing connection to displays up to 10 metres away or to displays with an integral LVDS interface. Incorporating TV-out with Macintosh, CGA-A and VSS for DVD copy protection, the NC-640 also offers MPEG 2 video textures and motion compensation for full-speed DVD playback. The product has advanced 3D audio capability and a wide range of connectivity options, including on-board USB 2.0 and I/O interfaces, COM ports, RS-232/422/485 (5V and 12V), PCI, PCI/104, IDE and a bidirectional parallel port. GPS and touch-panel interfaces are available as options. Andes Electronics, Tel: 020 7988 7117, www.andes.co.uk

**High-current bench power supplies**

The newly upgraded TSSX range of bench DC power supply units from TTI offers very high performance at significantly lower costs than other PSUs of comparable performance.

Models currently available include 35V, 10A and 60V units in both standard and programmable versions. The standard versions incorporate conventional analogue controls, while the programmable versions offer keyboard control along with RS-232 and IEEE-488 interfaces. The heart of the TSSX series PSUs is an advanced regulator design which combines switch-mode pre-regulation with a post-regulation. The pre-regulator uses specially developed techniques to dramatically reduce the capacitance between input and output, thus eliminating the high levels of common-mode noise normally associated with switch mode PSU. The linear post-regulator combines very low levels of output noise with excellent load regulation and transient response, resulting in performance comparable with that of a pure linear design. The hybrid regulator design provides a PSU which is both smaller and lighter than traditional designs. The high thermal efficiency also means that the PSUs are silent in operation, thus fan cooling is unnecessary. All TSSX series PSUs can operate in both constant-voltage and constant-current modes, with automatic crossover and automatic mode indication. They incorporate high-resolution digital meters for both voltage and current. Voltage and current limits can be set to high accuracy prior to connection to the load, and the limit settings can be checked at any time. Thurlby Thandar Instruments, Tel: 01480 412451, www.th-test.com
NEWPRODUCTS

Please quote Electronics World when seeking further information

to survive these faults without the need for external protection circuitry, said the company. The device maintains the industry standard footprint in the SO-8 package including a standard slow rate/standby pin. In standby, the supply current is reduced to 80uA. The slow rate control allows a maximum data rate of 500Kbps or can be programmed for slower rates to minimise EMI and reduce reflections due to long cables or improper termination. It is offered in the 8-pin SO and PDIP screened for both the commercial and industrial temperature ranges.

Linear Technology Tel 01276 776776 www.linear-tech.com

LCR meter is one touch for strains
Available from Yarn Draper, the RLC100 is a microprocessor controlled LCR meter capable of making four four measurements of L, C, Q, QL, DC and d using series or parallel connection. The unit can display deviations of measured values from reference components either absolutely or relatively in terms of percentage. Also included is a diagnostic software and one-touch strain resistance compensation. The design of the instrument has reduced the number of front panel controls to four, plus a mains on/off, which enables the instrument to be set or operated with little adjustment. A group of LEDs indicates control selection and a 16 x 1 alphanumeric backlit LCD provides measurements and a readout of the measured values. Yarn Draper Tel 01634 794706 www.yarndraper.co.uk

Precision resistors on a budget
The RE-0207 and RE-0204 from VTM are two ranges of precision metal film resistors in 0207 and 0204 (0.25 and 0.25Ω) body sizes. According to the supplier, they are intended as a lower cost alternative to traditional precision resistors. The RE-0207 is available in a resistance range of 10Ω to 2MΩ, while the RE-0204 is available between 10Ω and 1MΩ, both with a standard tolerance of ±0.1% and a temperature coefficient of resistance of ±10ppm/°C. Although other tolerances and TCRs are available. The resistance element in these resistors is a precisely controlled thin film of metal alloy deposited on a high quality alumina substrate. Parallel caps are force-fit before the assembly is trimmed using laser techniques.

VTM Tel 01444 796008 www.vtm.co.uk

Miniature joystick for movement in five directions
A five-direction miniature joystick from Tyco Electronics measures 10.4 x 12.0 x 5.9mm. A single pole, five throw configuration, the switch is rated at 1 to 50mA at 24V DC. It also provides a select function and scanning functions.

Up/Down/Left/Right Contact resistance is 200mΩ maximum and insulation resistance is a minimum of 1000MΩ at 100V DC. Travel is 0.25 ±0.15mm for the select function with an operating force of 30g ±5g, and a minimum release force of 10g.

Tyco Electronics Tel 020 8954 2500 www.tycoelectronics.com

Capacitor array in 0612 package
The GNJ34 capacitor array from Murata contains four individual capacitors, all of the same dielectric material, tolerance, capacitance value and voltage rating, in a single 0612 package. It includes temperature compensated arrays available from 10pF to 360pF, dielectric constant types from 220f to 1000pF (X7R) and 2.2nF to 150nF (Y5V). Rated voltages are from 10 to 16V.

Murata Tel 01252 818866 www.murata.co.uk

Polarity controller for EMC antennas
Hurstley EMC Services has introduced a new polarity controller for EMC testing in automated anechoic chambers. The controller is GPIB and RS232 interfaces with a manual override facility. The MC4090 motor controller is suitable for all pneumatic mast, said the supplier. And at £45,000 + VAT

Fast LVDS for 3G backplanes
National Semiconductor has announced a 10-bit bus low voltage differential signalling (LVDS) serializer/deserializer chip set for high-speed data transfer over a single differential pair. The SCANN21025 and SCANN21226 are designed to meet the high-speed data transfer rates of third-generation wireless base station, video, and medical instrumentation markets, said the company. The chip sets were developed to address clock speeds over 66MHz, specifically 78.8MHz for television and 74.25MHz for video applications. The serializer input accepts as many as 10 parallel bins with the associated transmi clock to latch the parallel bins into the device. It serialises them and embeds the clock for serial transport. The deserialiser accepts the serial stream, recovers the clock and data, and delivers both to the receiver parallel interface. The company has also introduced the SCANN21025UB, which incorporates six 1:10 deserialisers with IEEE 1149.1 test capability and built-in self-test mode that supports data rates up to 106.25 MHz. The 10:1 TTL to LVDS serialiser has a frequency operation of 30MHz to 80MHz. The deserialiser has a random lock and frequency operation also of 30MHz to 80MHz.

National Semiconductor Tel 0970 2402171 www.national.com

Validated Input Output Module
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can provide a relatively inexpensive method of upgrading manual BMC test chambers, and the company.

Murry EMC Services
Tel: 023 8027 1111

Switch probes for automotive testing
The P200 GI from Peak Test Services is a range of switch probes for use in test modules for checking wiring harnesses in the automotive industry. According to the supplier, unlike traditional techniques that require the complete module to be removed, the probes and receptacle are fixed with a pin and a socket inside the receptacle. The wire is soldered directly on the connector pin of the receptacle, leaving the switch probe replaced without re-wiring. The devices come in various tip styles, and have a working voltage of 4mm and switch travel of 1.7mm. They can handle up to 5A.

Peak Test Services
Tel: 0191 387 1923

Precision resistors up to 20Ω
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CTL Components

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www.computer-solutions.co.uk

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In this second article on programmable logic, Andrew Malcolm looks at the standard language used for defining programmable devices.

Designing with VHDL

In my last article I looked at the history of programmable logic devices, from their first, simple forms to the multi-million gate forms of today.

In those early days, programming these devices was more or less manual, using modified PROM programmers to write directly to the device's fuse-map. Device complexity increased and software support for other parts of the design cycle became available, including schematic capture and CAD layout programs. As a result, the tools available to programmable logic designers became more sophisticated.

Inevitably, device vendors implemented their own software to support their own devices. Soon there was a variety of incompatible packages, each with their own standard. Moving a design from one vendor's device to another often meant a complete redesign, and so designers became locked in to a particular vendor.

At the same time, the chip design industry was struggling with the growing complexity of fixed-logic devices, from microprocessors to LAN chips. A software industry grew up to support these design activities. Again, many proprietary languages and techniques came into being.

In the early 1980s, the IEEE - America's equivalent to our IEE - realised that standardisation across the industry would bring benefits by allowing all logic design concepts to be expressed in a common language. As part of the 'Very High Speed Integrated Circuit', or VHIC/IC, initiative, VHDL was born.

VHDL - an acronym for VHSC Hardware Definition Language - is used for many purposes today. These range from specification to simulation, on device architectures from simple PAL devices to multi-million gate FPGAs. The key to VHDL's success here is its ability to express designs at many different levels of abstraction, and its modular approach to design.

Many vendors, both device vendors and independent design-tool companies, provide VHDL compilers and filters. They also provide tools that generate device constants from schematics. These use VHDL internally. Some tools are prohibitively expensive, and can be dauntingly complex to set up and use.

There are simpler tools available however, and some of them can be downloaded from the Internet for limited-time use. A list of starting points is presented in a separate panel article.

Intellectual property

VHDL and its associated software tools have enabled a whole new industry: that of intellectual property.

Companies can write and sell device definitions from simple libraries that mimic TTL libraries and other MSI devices up to complete protocore cores, complex peripherals and specialist memory arrays. OEAs can use this "IP" to quickly assemble a product, using CPLDs and FPGAs as the target devices.

Alternatively, they can pass on their design to a silicon foundry for ASIC production. In this way, companies can take advantage of the high level of integration offered by FPGAs and ASIC technology, without having to design from scratch. They don't need to have the specialist knowledge required to produce the IP for some types of design either.

A good example might be a JPEG codec (encoder/decoder). A digital camera manufacturer may not have the mathematical expertise to implement a codec in hardware. However, the manufacturer could buy the IP as a "black box", and would have the expertise to exploit it.

Elements of the language-combinatorial logic

Let's take a look at a simple example: describing an AND gate, Fig. 1, in VHDL.

library ieee;
use ieee.STD_LOGIC_1164.ALL;

entity and_gate is
port (a, b : in STD_LOGIC;
c : out STD_LOGIC;
end entity;

architecture arch of and_gate is
begin

end architecture;

An AND gate is described in the above VHDL extract. Taking the file line by line, I'll explain the language features shown here. The first two lines declare a reference to an external library. In the next line, a library declaration is made. In this example, only one library is needed.

Entity

The entity declaration introduces the symbol for the module, in this case an AND gate. It is followed by the interface: input and output signals.

Architecture

An architecture is a design description, specifying how the signals will be connected. This example is simple, using personal style to introduce the details of the architecture.

The gate is specified as a basic gate consisting of two inputs and one output. The gate is a combinational logic device. The next section will look at sequential devices.

The AND gate is connected to the 'and_gate' symbol defined in the library.

End entity

This line completes the description of the gate.

End architecture

This line concludes the entire description of the gate.
This case, it’s a standard type library defined by the IEEE. The types it defines are the std_logic types, which I’ll be discussing later.

The next four lines declare the entity. This is analogous to a schematic symbol, as it defines the inputs and outputs to a unit of functionality. Note that these inputs and outputs may or may not correspond to physical pins on a device. This entity may be part of a larger hierarchy, such as a block diagram, much in the way a TTL IC might form part of a larger board performing a more complex function.

In this case, the entity has only two outputs, a and b. The entity has a single output, c. The entity is named and_gate, and this name is used to refer to the entity later as if it were incorporated into a larger design. The remainder of the file describes the architecture of the entity. This is in effect, its desired functionality. In this case, the AND gate is fully described in terms of simple Boolean algebra, and so the single line `c := a and b' expresses the required functionality.

Port declarations

Returning to the entity description, let’s look at the port declarations. Both input and output are declared as std_logic. This is an IEEE defined type from the IEEE library. The type defines the legal states of the port. Although we think of logic pins as having only two states, 0 or 1, the reality is somewhat different: what about three-state or open-collector outputs?

The std_logic type defines all the legal states of a port, and comes into play when entities are placed on a bus. It is also useful in describing unknown initialisation states in entities with bistable devices. These extra states make it possible for synthesis and simulation tools to detect conditions such as bus conflicts – i.e. two drivers driving a common line simultaneously – and floating, undefined inputs. From the above example, and a few extra keywords such as nor and nand, you should now be able to write entities describing most of the standard TTL combinational functions. For example, by simply adding extra input ports and extending the architecture like this: `c := a and b and c and d, etc', an N-input AND gate is easily described.

It is possible for an entity to have internal signals, those that are not visible from the entity declaration. In this way, the architecture may describe an internally complex logic function of N inputs:

```vhdl
library ieee;
use IEEE.STD_LOGIC_1164.ALL;

entity and_or_func is
d port (a,b,c : in std_logic;
        d : out std_logic);
end entity;

architecture arch of and_or_func is
begin
    output = a and b and c and d;
end architecture;
```

Elements of the language-sequential logic

In the last section I showed that it is possible to describe arbitrary combinational functions and package them within an entity. Later I will describe how it is possible to combine those entities into a larger, system in much the same way that you might build a system from TTL gates. Combinational systems alone are of limited use. The TTL designer is soon reaching for bistable devices and registers to create systems that have state, that is to remember the value of their inputs over time.

VHDL has constructs that allow the designer to describe sequential logic:

```vhdl
library ieee;
use IEEE.STD_LOGIC_1164.ALL;

entity d_type is
port (clk : in std_logic;
      q : out std_logic);
end entity;

architecture arch of d_type is
begin
    process(clk, rst)
        variable q : std_logic := 0;
    begin
        if rst = '1' then
            q := '0';
        elsif rising_edge(clk) then
            q := d;
        end if;
    end process;
end architecture;
```

The architecture block itself consists of port, map statements, one per functional block. These, as their name suggests, map the ports of the contained entity to the ports of the containing entity. Each element within brackets maps a single port from the component to a port on the entity. From left to right, these ports correspond with ports from first to last in the component declaration.

The functional blocks are given a reference, in the same way as on a circuit diagram – IC1, IC2 – and the required block name follows that. So in this case the `clk' and `q' of the output entity are mapped (connected) to an and_gate block's inputs a and b respectively. Similarly, IC2.a_d_type is connected to `a' and output `q'.

Internally, the connection between the output of the AND gate and the d input of the bistable device is achieved via the signal `p' as it appears in the port_map statement for the and_gate and the port_map statement for the d_type.

Glossary

- FPGA: field-programmable gate array
- CPLD: complex programmable logic device
- PAL: programmable array logic
- VHDL: VHDL hardware description language
- VHSC: very high speed integrated circuit
- IEEE: Institution of Electrical Engineers (UK)
- IC: programmable read-only memory
- CPU: central processing unit
- PROM: printed circuit board
- RAM: random access memory
- PCI: personal computer interconnect
- LED: light emitting diode

Internet resources

Major vendor directories:

- [https://www.latticesemi.com](https://www.latticesemi.com)
- [http://www.xilinx.com](http://www.xilinx.com)
- [http://www.altera.com](http://www.altera.com)

These sites are amongst the largest and most versatile FPGA sites.

Digital design vocabulary:

- 48: DIGITAL DESIGN
**PCBs for Class G**

Circuit boards for Doug Self’s Class-G amplifier, detailed in the December 2001 and January 2002 issues, are available. These PCBs are double-sided with full solder masks and roller-finishing. Full component identifications are also included. Their size is approximately 190mm by 175mm each.

To order a pair of these boards, send a cheque or postal order for £43.50 to Jackie Lowe, Class-G PCBs, Anne Boley House, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ. E-mail electronics.world@ntlworld.com for details of overseas postage. You can also fax your credit-card details - name and address of card holder and card type, number and expiry date - on 01782 878233 (+44 1782 878233). Please make cheques payable to ELECTRONICS WORLD.

**About the author**

Andrew Malcolm is a Chartered Engineer with more than 20 years experience in the electronics, industrial control and software industries. He runs his own consultancy company, Synchronous Designs Ltd. www.synchronousdesigns.co.uk

He may be contacted at info@synchronousdesigns.co.uk

Now you have a 32-bit register — without changing the architecture. As the clk signal was not declared as a vector, it will be used to clock all the registers — 32 of them — generated by the process block. This technique could equally be applied to our d_type_ful1 block, giving a 32-bit register with reset, clock enable and q-bar signals.

Using a further technique, known as generics, it is also possible to parameterise the bus width in order to produce a register whose width may be determined by the user. Of course, when you compile this code in order to program a device, this register will take up precisely 32-bit bistable device cells. As a result, it must be borne in mind that large structures will take up correspondingly large parts of the target device. This is a shorthand, like the schematic bus, but it doesn’t magically save device space.

Once designed using this technique, bus-based subsystems like this can be connected with structural VHDL as before. Again, the vector syntax means a single posng map... statement can deal with many signals at once.

**What next?**

In the next article on this topic, I will show how to apply the VHDL presented here to a practical application. This application is a high-speed frequency counter with LED display. I will also introduce a few more language constructs.

On the practical side, I will be looking at one vendor’s tool set and at mapping a design into a particular device, along with programming tools and techniques.

Further reading

VHDL for Designers: Systems and Labs, Prentice Hall, 1997 ISBN 0134734149. This is an excellent book for newcomers and experienced users alike. It is very easy to read, covering all the topics touched on here in much greater depth.

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---

**Track**

2. Good Old Summertime, The American Quartet 1904
3. Marriage Bells, Bells & xylophone duet, Burkhardt & Daab with orchestra, 1913
4. The Volunteer Organist, Peter Dawson, 1913
5. Dialogue For Three, Flute, Oboe and Clarinet, 1913
6. The Toymaker’s Dream, Fox trot, vocal, B.A. Rolfe and his orchestra, 1929
7. As I Sat Upon My Dear Old Mother’s Knee, Will Oakland, 1913
8. Light As A Feather, Bells solo, Charles Daab with orchestra, 1912
9. On Her Pic-Nic Piccolo, Billy Williams, 1913
10. Poka Des English’s, Artist unknown, 1900
11. Somebody’s Coming To My House, Walter Van Brunt, 1913
12. Bonny Scotland Medley, Xylophone solo, Charles Daab with orchestra, 1914
13. Don’t the Raccoon, Billy Murray, 1929
14. Luce Muff Francesco Daddi, 1913
15. The Clio Minstrel, 2nd part, 1913
16. Peg & My Heart, Walter Van Brunt, 1913
17. Auf Dem Mississippi, Johann Strauss orchestra, 1913
18. I’m Looking For A Sweetheart And I Think You’ll Do, Ada Jones & Billy Murray, 1913
19. Intermezzo, Violin solo, Stroud Massan, 1910
20. A Juanita, Abrego and Picazo, 1913
21. All Alone, Ada Jones, 1911

Total playing time 72.09 min.

---

21 tracks — 72 minutes of music Published by Electronics World. All recordings re-recorded by Joe Pengelly.
of the great attractions of Electro-ics World is the number and variety of desirable electronic circuits it publishes. Perhaps like me you have frequently said, "I would like to build this, if only a circuit board was available". Many articles do include details and drawings of the printed circuit board used to build the prototype design. Because of the tooling and minimum order costs involved though, commercially produced circuit boards may simply not be viable. Yet for little equipment cost it is feasible to etch and drill your own PCB.

This article is not intended as a council of perfection. Instead it recounts various methods I have found to work - or not - for producing prototype PCBs. A minimal-cost DIY approach

When a PCB is to be built on a solid resin and component legended printed circuit board, it is not essential. Reduced to the minimum, it is only necessary to etch the tracks, drill the holes and trim the board outline to size. I produced my very first home-made PCB almost forty years ago. It was designed for the pulse counting PM counter, then published in Wavetrain World. In those days photo-sensitive PCB materials were not readily available. Using carbon paper, adhesive tapes and etch-resistant strips or etch resist pens, the artwork was often prepared directly on the copper surface.

Commercial methods

The actions needed to provide commercially produced PCBs can be broken down into:

- Artwork design
- Preparation of suitable Gerber and NC drill files
- Photoplotting
- Board etching and drilling
- Solid resist and legend applications
- Saving or routing to size
- Inspection and test

Of these stages, the board designer is responsible for the artwork design, Gerber and drill file preparation and accuracy. Checking the accuracy of artwork design is relatively easy. Validating the Gerber and drill files can prove extremely difficult. Most low-cost PCB design software systems can output the required files, but do not provide any means to 'read back' for verification, prior to committing to production costs. Gerber files are used to photoplot the masters used to etch circuit tracks. They are also used to produce the solder resist patterns and component legends. They must be in a format accepted by the photoplotter and error free. Particular care is needed to avoid including extraneous, duplicated or broken lines or tracks. Some photoplotters do not recognise a track as such, but are simply triggered "on" when crossing one light dark transition and "off" when crossing the next. Some of the smaller commercial PCB suppliers will agree to pre-etch these files for you before your costs escalate. For this they need your full drawing set, the same software package you used and copies of your design files.

I well remember being extremely nervous about the quality of the Gerber files for my tan meter boards. Fortunately my supplier had a copy of my software and would check my Gerber files. In the event, while they did query one intentionally unterminated guerd track, the first-off boards had one essential track missing. My boards had to be re-traced and re-made, doubling costs. Tooling charges vary, but typically each photoplot and drill file will cost some $15. Expect to pay $60 plus to produce tool a single sided board, doubling these costs for two-sided boards. Board manufacture and delivery costs are additional. All charges escalate rapidly if narrow track widths and spacings are used, so do check first before committing.

duplicate boards were needed they were screen printed, using artwork made from Reeves two part 'Profilem' stencil paper, affixed onto a silk screen using a hot iron. Covering a board-sized polyesterene tile with 1m graph paper facilitated layout. The required components were easily pressed into position. With components positioned, the tracks were drawn on a duplicate piece of paper. Affix or Seoul pre-printed, rub-down, etch resistant resists for most ICs and components paths can still be bought for a few pounds. Self-adhesive, flexible, black cross track tape is available in small rolls. Two or three rolls provide sufficient choice of track widths for most circuits. Some designs were printed to scale in magazines' others had clearly identified board dimensions. For these I used overhead projector transparency foils in a dry room. Photoplotter to make a true-size foil. Any track that lacked density was easily overlaid using transfers or tape. Needing no special equipment, the Sense 'etch in a bag' method provides a clean, economical and safe method of etching a few boards. The supplied neutralizer converts exhausted etchant into an easily disposed of solid mass. Etching, washing and drying a PCB can be completed in less than thirty minutes. Use plastic containers for developers and etchants. While glass is also suitable, accidental breakage presents an unnecessary hazard. Do not use metal tools or containers.

These low-cost method cost are still valid today. However many alternatives have since been developed, most of which I have used at one time or another.

Other artwork options and methods

Assuming you have a laser printer available, you may find that it gives an adequate image on laser transparency film using just one print pass. However you may produce better images using Laserans film, specially developed for printing PCB artwork. Laserans 100062 film is available direct from Mega in packs of 10 A4 sheets for about £6. Suitable for any laser printer it produces a good dense image. This film is also usable in many dry toner copiers, allowing artwork production in many offices. Some copiers have reported great success using the press-n-peel transfer system. This film is printable using a laser printer or suitable photocopier. The resulting image is transferred to your PCB laminate using heat from a domestic 'iron'. However I find it an unsuitable art work so this is one method I have not tried for myself.

The very best artwork is produced using a photoplotter and Lith photographic film. This is the method most used professionally even for small production runs. Provided you can output the appropriate Gerber file, an artwork photoplot can be received in three or four working days, for around £20. This may prove too expensive however when only a single PCB is required.

There's an even simpler method using the same Gerber and matching NC drill file. A number of PCB makers will provide a complete one-off prototype single-sided PCB complete with component legends and solder side resist for some £65. Of course for these last two routes, you must accept responsibility for any errors your files contribute.

The safest route for one-off PCBs is to purchase a suitable flat-bed pen plotter, with pens and ink to match your film. This can provide excellent quality and low-cost artwork, but don't forget to clean your plotter pens properly when their work is finished.

Using an etch resist ink, a flat-bed plotter can be used to plot direct onto the copper laminate, completely bypassing the artwork film, UV exposure and developing stages.

While I print most of my artwork, occasionally for test jigs or PC test line circuits I find the quickest method is to use stripping film and UV-proof red Solaset. This method was used extensively 30 years ago to produce times ten master artwork. The large artwork was reduced to size with a camera and used to manufacture precision thick-film circuits. Called Autographic Ruby Automatic film, this film comprises a transparent red UV proof film, laminated to a clear base film. A sharp model knife cuts through this red film around any unwanted area. Unwanted red film was then easily peeled away. I still use this method to quickly produce artwork for jigs or ground planes. Being UV and etch resistant, the red Solaset can be used for artwork as well for direct etching.

In my pre-computer years - especially when a printed drawing had to be re-scaled - I cut short lengths from black and white high contrast 35mm document film. Loaded with five or six exposures, my 35mm camera produced excellent quality negatives. A correct sized positive enlargement onto Lith' cut film was then used as the final artwork. Document and Lith films are orthochromatic or insensitive to red light. They are easily handled using a bright red safe-light. Development can be by time and temperature, or more usually by inspection in a dark, as used to develop a black and white photographic print. This method is valid today and is still used commercially. 'Lith' film is a very high contrast material that produces a sharp and extremely dense, archival quality image. I have some films I made more than twenty years ago that are still usable. All materials can be obtained mail order from the Silverprint Company.
Once your PCB design has been completed the copper layer should be printed onto UV transparent film. This master will be used to expose the photosensitive coated PCB material.

I hand write in capitals 'Copper Side' as appropriate, on the artwork film, ensuring it can be easily seen when registering PCB and artwork, for the exposure. For many years, I used a Hewlett Packard DeskJet 500C ink jet printer with overhead projector transparency foils. Using "JM CG3406" transparencies with this printer produces a very good image, provided the foil was overprinted three times, Fig. 2.

I have seen artwork produced using an unknown Epson ink jet printer and Epson film that looked sufficiently dense with a single printing. However many, like me, who need a PCL capable printer, will use HP ink jet printers. In this case, my methods may prove useful.

When I first started using surface-mount components, I evaluated a number of film/ink combinations. I changed to Hewlett Packard transparency film CB32JA, used with re-manufactured ink cartridges. I bought these from "System Insight". This combination worked better, usually providing sufficient density after two print passes.

Both the JM and HP foils include a white end label, clearly indicating the print side. This is essential when multiple print passes are needed.

Most recently I tried some Jetstar ink jet film, intended for Epson printers and bought from Mega Electronics. This lacked any indication at all as to which side should be printed. However as with many photographic print papers, the print or emulsion face of a mounted sheet is applied to one corner.

Once identified I lay away a small portion of the film/ink combination while the film was placed correctly in the printer to indicate how re-insert the film. Provided it is kept dry and in a warm location, this film with my ink prints excellent and dense images, using just one or at most two passes.

Double/triple printing

To accept ink from an ink jet printer, the overhead-projector transparency film has to be pre-treated on one side in manufacture. Some makers clearly indicate which side is supposed to take ink. If not, usually this side will exhibit either a slightly finish which 'drags' a moistened finger. Alternately, one surface will feel much rougher to the touch.

Most films print with adequate density for text, but PCB designs require dense coverage of larger areas. When fully dried and held close to a light for inspection, variations in print density may be seen, requiring another print pass to become acceptable.

The UV light used to expose photosensitive resists readily penetrates any location not covered by visible opaque ink. Such locations are most noticeable at the peaks of a roughened film surface. At best this results in many tiny-probules in the etched copper tracks.

Provided you are consistent when inserting your film into the printer you will find most ink jet printers are remarkably repeatable. While great care is needed in registering the film is needed; provided the film is fully dried, three print passes can be used with negligible blurring of the final artwork. Fig. 2.

Your printer needs some paper handling. It has a spring-loaded sideways locating guide bar for the left top third of the film only. However a judiciously added spring clip, to control the left bottom third of the film, proves sufficient to triple print down to micro-30C size parts.

To fully dry the ink, I suspend the printed film over the warm air emerging from my monitor for at least 15 minutes before re-printing.

In the winter months, to avoid film shrinkage when driving the ink for a second pass, the pass of unpinned film is stored overnight in a warm location. If the film is not properly pre-dried, you can find errors, negligible at the top but increasing towards the bottom of the page. These are sufficient to spoil the artwork when double or triple printing.

Photosensitive resist

Most component distributors supply ultra-violet-exposure units, with prices starting from £90. Essentially these are just a small box containing two or more UV tubes, a timer, a glass window and padded lid. With these, the artwork is pre-exposed over the photosensitive PCB material then both are placed together, artwork down onto the glass window. The closed lid retains the position and constrains the UV light. More expensive UV units reverse this arrangement by having their tubes in the lid and a padded base. This makes for easier alignment of PCB material and artwork. These types usually provide a larger working area and prices start around £400.

More elaborate models are also available. These use a vacuum held down method for artwork and PCB, which enables very narrow tracks to be printed. Some versions provide simultaneous exposure for double-sided boards.

Assuming a suitable light source that produces UV-A is available and you only occasionally make a PCB, a variation of the contact printing method is possible. This method has long been used for photographic prints. The lamp is mounted downwards facing, above your work, in a desk stand. The artwork and photosensitive PCB are maintained in close contact, in a photographic contact print frame. I prefer this method to using a conventional light box. It allows flexible working - especially when exposing two sided boards and test strips.

Most easily-obtained glass attenuates ultra violet light, but some plastics, e.g. UV transmitting Acrylic or Perspex attenuates much less. But take care, most easily-obtained Acrylic plastic sheets incorporate UV stabilisers. These attenuate UV even more than does window glass, extending your exposure time.

If you have a suitable UV light source, this method costs almost nothing to arrange, but do take proper care. Because the light source emits strong UV at around 400 nanometre, appropriate safety precautions are essential. I always vacate the room when my light is on.

If you do not already have a lamp, obtaining a suitable light source may prove more difficult. Problems resulting from using the original halogen "white-light" desk lamps resulted in legislation prohibiting almost all lamps from emitting UV light. You will find most lamps are now marked as "UV Blocked". For a one-off trial, even simpler methods can be used. Some years ago, when no UV source was available and the work could not wait, I recall making a satisfactory exposure using sunlight. The sensitised PCB and artwork were simply left under a piece of glass for a few minutes outdoors on a sunny day.

Test exposures

Whatever method is used to expose your artwork, the exposure used should be determined experimentally. Compared to photographic materials, photo-resist has a wide latitude. Because developing can be done in normal room lighting, under or overexposure is easily compensated by increasing or decreasing developing time. Remove the board when visibly fully developed.

This is not difficult. Once a full-pack exposure has been decided for a batch of PCB materials, that exposure can be used with little change for that batch. Although warnings are printed on each pack about storage and shelf life, I have used similar exposures on a batch of material after a year in storage.

When making a trial exposure for a new delivery it is important to use your 'standard' conditions for the UV light source and development. Standard time for many developers is two minutes at 20°C, but some need less time.

Depending on your UV unit and the glass window used, typical exposure times will range from some four to twelve minutes. For a new delivery of Photoboard from Mega, I made a test strip using four, eight and twelve minutes, Fig. 3.

Using spare material cut from one board, I removed the protective film and exposed for four minutes using scrap artwork. After four minutes one third of this material was covered by a piece of thin black card and the remainder exposed for a second four minutes. The card was moved to now cover two thirds and exposed for the final four minutes.
Developed for exactly two minutes at 20°C then washed under cold running water, the board was dried and examined.

If it is underexposed, an image may be seen but the copper will remain coated with a thin layer of resist. If overexposed too much resist will have been removed so the image will appear thin and washed out. Correctly exposed, the image should show good contrast, with a visibly dense resist covering the unwanted tracks, but no resist remaining elsewhere.

With all copper still covered by a thin layer of resist, the four minutes exposure clearly was not sufficient. Eight minutes looked perfect and the twelve-minute exposure was not too long. This batch of boards was then exposed for eight minutes.

Developing the board

PCB development is extremely simple. The material has a wide latitude both for time and temperature. Because development can be done safely by inspection under normal room lighting, slightly longer or shorter time can be used to compensate for exposure time and developer temperature.

For occasional use, Seno supplies a universal PCB developer, SN101, contained in an applicator. The applicator sponge is simply wiped across the surface of your PCB. This combines a safe working method and a two-year shelf life.

Most materials and developers have standardised on two minutes and 20°C. Recently though, some much quicker developing PCB resists have been supplied. For this, the company Mega recommends diluting its developer with an equal volume of water.

Do not use metal containers. To develop a board I use a small A5 size plastic photographic developer tray. This floats in a larger tray containing water, as a water bath. This water bath can be used to raise developer temperature in the water or lower its temperature in the summer, as required.

As part of my standard routines, I apply gentle developer agitation by rocking the developer tray in its water bath. This agitation ensures a constant supply of fresh developer to the work, minimising uneven development of any large exposed areas.

Some commercial developers are based on a weak solution of caustic soda. Regardless of make, for safety, wear protective gloves and use plastic tongs to immerse and remove your board from the developer tray.

A PCB developer works by dissolving or removing the exposed, unwanted areas. If no agitation is used these areas become covered in scale developer, prolonging the required developing time.

With some PCB resists/developers, you may find it preferable to remove the board for a pre-wash under cold running water, when two thirds of the developing time has elapsed. Then return the pre-washed board to complete its development.

Etching

Etching is perhaps the simplest process for the amateur board maker. The etchant used is corrosive, can stain your hands or your clothes. Wear plastic gloves, handle with care and follow your supplier's precautions.

The most easily available etchant is a solution of ferric chloride in water. This produces an acid solution. When supplied full strength at 45 Baumé or a specific gravity around 1.43, it should be diluted by adding 30% water, before use.

Ferric-hydroxide liquid is initially a red brown and its etching efficiency improves after initial use. The etchant then changes to a muddy brown mixture of ferric and ferrous hydroxide.

When completely, exhausted it changes to a dark green solution with a black precipitate at the bottom. Before disposal, any remaining acid can be neutralised by slowly adding household washing soda crystals. When effervescence ceases, the etchant has been neutralised.

For best results, most etchant should be used at 40°C. With minimal agitation, etching then takes some twelve to fifteen minutes.

The Sn60 'etch in a bag' provides all needed equipment and instructions for safe usage. Other methods will need more care.

Proprietary 'bubble in etch' tanks are designed to provide safe handling and economic etching. Injecting air into the etchant provides both agitation and the free oxygen needed to etch copper. These bubble tanks work well but may be too expensive for occasional use.

A minimal cost method – one that I have used for many years – involves a high-density plastic breakfast cereal storage container from a supermarket. Its securely fitting lid ensures freedom from handling splashes and safe storage of etchant.

Two ex-ice-cream containers, one inside the other, provide an insulated water bath in which to use and store the cereal container of etchant.

I find my cereal container holds etchant sufficient for boards up to 100 by 120mm, with the board suspended vertically in the solution. I drill a 3mm hole along one longer side and use a short length of 2mm enamelled-copper wire as a hook.

To ensure initial 'wetting' of the board surface, I raise and lower the board a few times. This agitates and drains air into the etchant.

Use only plastic containers and tools when using or storing etchant. For safety avoid using metal or glass. The only exception is my enamelled copper wire PCB supporting hook.

Suspension the board vertically in the etchant provides good etching with acceptable undercut except when using very fine track widths. Bubble agitation would be underused, but tracks down to 0.5mm do not need bubbles.

If bubbles are desired, a small fish tank pump with plastic piping connecting to an air diffusing stone submerged in the etchant, could be used.

With the etchant container in position I fill the water bath with hot but not boiling water. This heats the etchant and maintains working temperature sufficient to etch a few boards.

Washing

When the board is fully etched, I hold it by its copper wire hook then pre-wash it by dipping it in another ex-ice-cream container, half filled with clean cold water. This removes sufficient etchant to permit a visual inspection, followed by a final wash in cold running water.

When dry the board is ready to be drilled and trimmed to size.

Trimming a board to size

Almost any convenient back saw and file will suffice. All edges can be finished by hand finishing the board on a 100 grit abrasive-paper covered flat surface.

Drilling your PCB

Most component holes are best drilled 0.8mm. In principle any drilling method can be used but small drills are easily broken using a power drill or stand-drilling machine.

High-speed steel drills blunt extremely quickly when drilling FR4 fibreglass PCBs. The more expensive – and more easily broken – tungsten carbide drills seem to stay sharp forever*. To reduce drill breakage, your PCB should be supported on a scrap of plywood or PCB material. Small hand-held drill motors are much easier to use than in a large power drill. For many years I regularly used a low cost 12V 'Reliant' drill, powered from 8V to reduce its speed. This allows time for the drill to almost self-centre itself in the etched pad, before drilling the hole.

Resist removal

The resist is best left in place until the board is to be assembled. It does not have to be removed. Left in place it helps to 'lash' the copper, Fig. 5.

However I prefer to remove this resist, to facilitate board inspection. Commercial resist removers can be used, but I use methylated spirits applied with a rag. The board is then finally cleaned and polished using water with a dab of household abrasive pumice cleaning powder, thoroughly washed and left to dry.

Double sided boards

This article has deliberately avoided discussing two sided PCBs. These – together with a much improved, very low cost, drilling method – will be covered in my next article. ■

References

1. Electronica, http://www.electronica.co.uk
2. System Insight, http://www.systemmgmt.co.uk
5. Silverprint Company, http://www.silverprint.co.uk

*They do seem to go on forever, but I find that after about 50 holes, although not blunt, tungsten carbide drills start to push the copper slightly around the edges of the hole. There's a special green whet stone for carbide drills. Normally, the rake of a drill is curved, but such small drills work effectively with a flat rake. Just make sure that you keep the sharp in the middle, i.e. make the two flats identical. Ed.
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