Project 18:

A 'Knightrider' Scanner

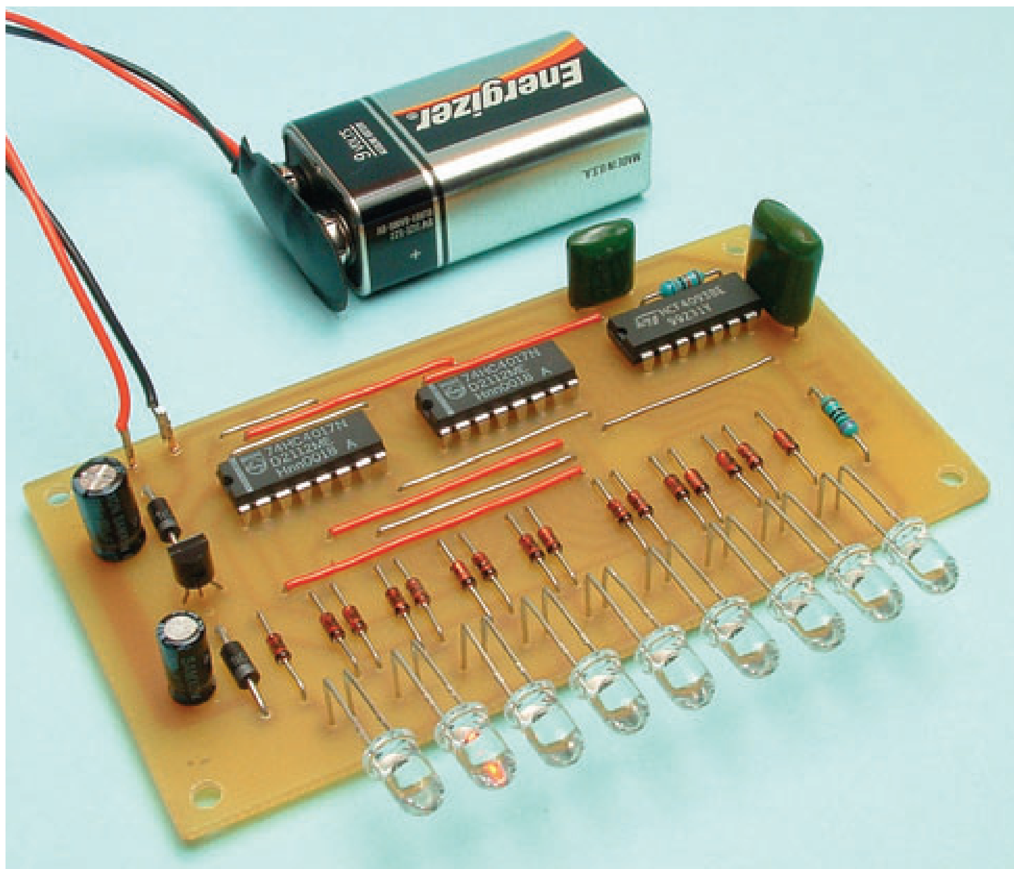
Here's another novelty project: a simple circuit that makes a row of LEDs glow in sequence back and forth, like the lights on the front of the computerised car in the old TV series *Knightrider* when it was 'scanning'. It's eye catching, it's easy to build, and you can vary the scanning speed if you wish.

What does it do?

Back in the dim dark ages of TV, there was a series about a computerised car called Knight 2000 or 'Kitt'. This had a row of red lights along the front, which glowed in sequence back and forth when the car was supposedly 'scanning' where it was going. A load of nonsense, of course, but the glowing light scanning from left to right and then back again was certainly eye catching. The same effect was used to represent the 'eyes' of robots in sci-fi movies, as they supposedly watched out for enemies.

The little Knightrider Scanner we describe here produces the same effect, in a row of nine bright red LEDs (light emitting diodes). The LEDs glow in sequence from left to right and then back again, and they keep doing this as long as the project is connected to the 9V battery.

The scanning takes about one second for each back-and-forth cycle, but this can be varied quite easily if you wish. We explain how to do this later, in the What To Do Next section.



Putting it together

All of the parts used in the Knightrider Scanner are mounted on a small PC board, apart from the 9V battery which provides it with power. The board is coded SHRTC218 and measures 102 x 55mm.

Before you start assembling the project, though, it's a good idea to open up the kit and lay out all the parts so you can make sure you have everything. You can do this by checking them off against the parts list. While you're at it, give the PC board a careful inspection (especially on the copper side) just to make sure that there are no etching 'glitches' or undrilled holes.

If everything seems to be in order, you can begin assembling the project by fitting the two PC board terminal pins. As you can see from the wiring diagram these go at the back of the board on the left, for connecting the battery clip lead wires.

Next fit the wire links. There are quite a few of these in this project — nine of them, to be exact. They can all be made from lengths of insulated hookup wire if you wish, although some of them can easily be made

The parts you'll need for this project:

1 PC board, code SHRTC218, 102 x 55mm
1 9V battery, 216 type
1 Battery clip lead to suit
2 PCB terminal pins, 1mm dia.
2 Short lengths of tinned and insulated hookup wire for links
1 Small pack of resin-cored solder

Semiconductors

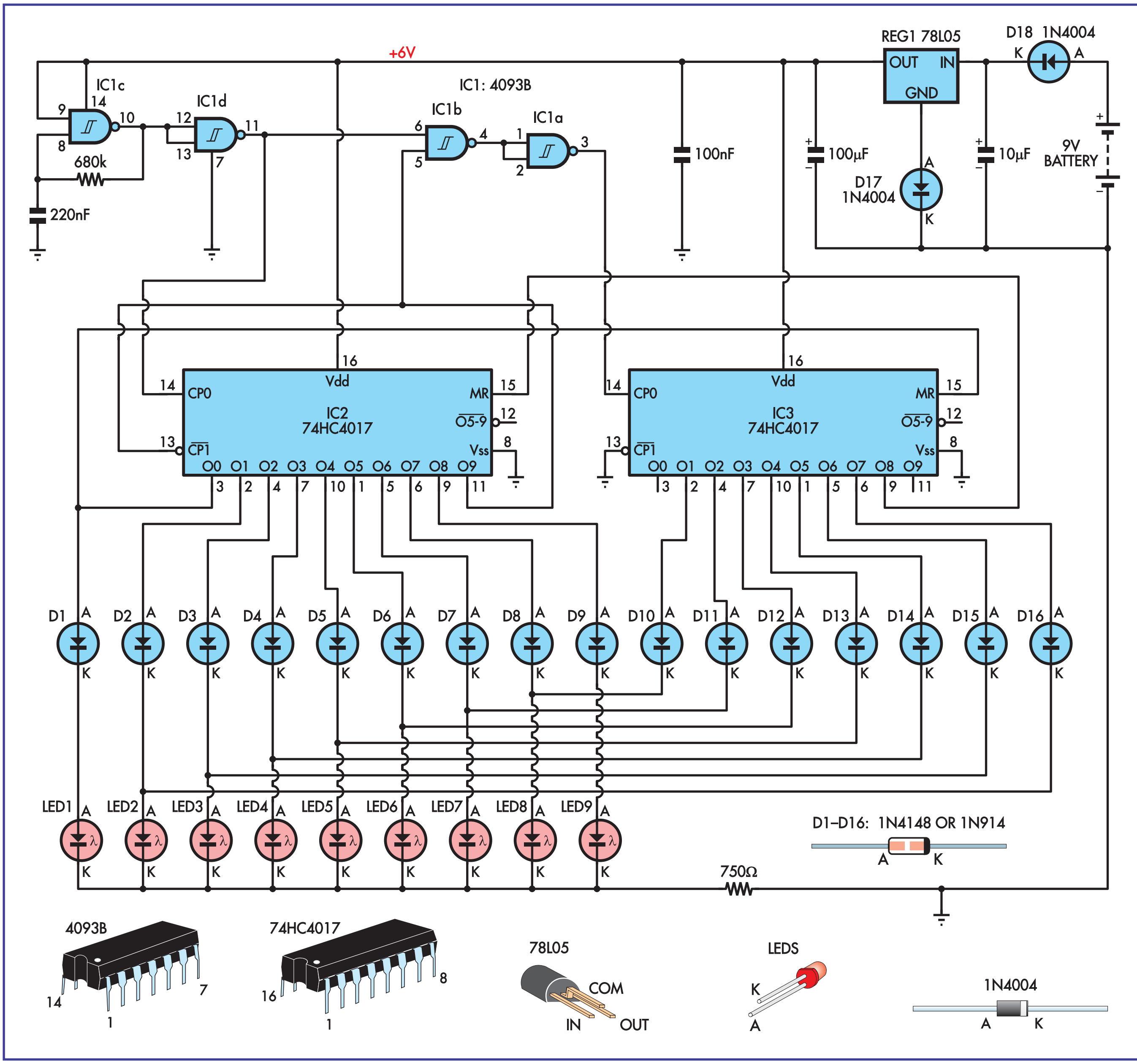
1 4093B quad Schmitt NAND (IC1)
2 74HC4017 HCMOS counters (IC2,IC3)
1 78L05 +5V regulator (REG1)
9 5mm clear bright LEDs (LED1-9)
16 1N4148/1N914 silicon diodes (D1-D16)
2 1N4004 silicon diode (D17,D18)

Capacitors

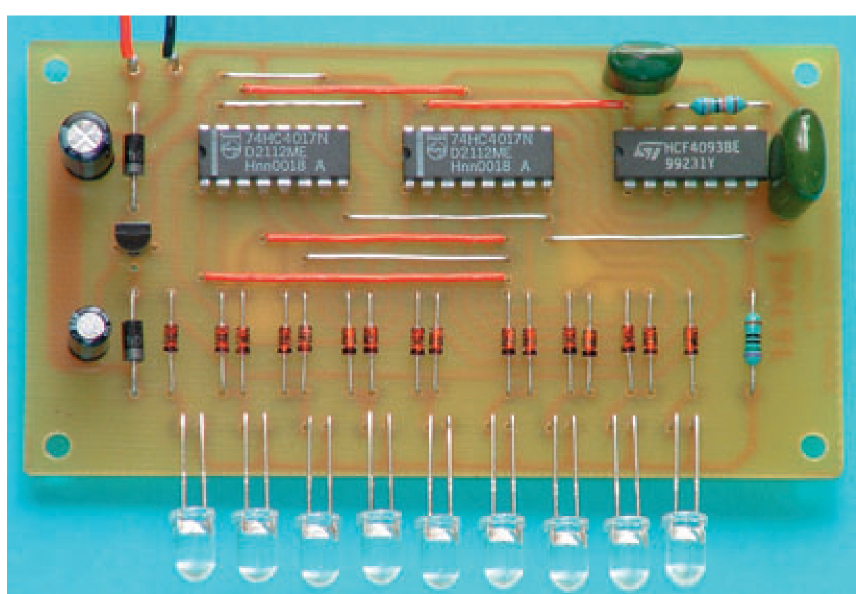
1 100µF 10V RB electrolytic
1 10µF 16V RB electrolytic
1 220nF greencap
1 100nF greencap

Resistors (0.25W 1%)

1 680k
1 750Ω



Here's the circuit diagram (above) for the Knightrider Scanner, plus a closeup photo of the top of the PC board assembly (right). Use both of them, along with the photo opposite and the wiring diagram overleaf, as a guide when you're building up your own Scanner.



using lengths of tinned copper wire instead as you can see from the photos. The main thing is to use insulated wire for every alternate link where a number of them run in parallel and fairly close to each other. This should be enough to prevent them ever touching one another and causing trouble.

When the links are all fitted and their ends soldered to their pads, you can fit the resistors. There are only two of these in the project, one with a value of 680k which goes at back right, and the other of 750Ω which goes at front right. Be careful not to swap them, because this will stop

Tech Talk: How does it work?

The circuit of the Knightrider Scanner probably looks a bit complicated, but its operation isn't hard to understand if you break it down into sections.

First, as you've probably guessed, there has to be an oscillator somewhere to produce a stream of 'clock' pulses which set the Scanner's scanning speed. This oscillator is up at the top left corner of the circuit diagram, using gate IC1c. As you can see this is a standard **astable** or free-running oscillator circuit with a 680k feedback resistor and a 220nF capacitor from input pin 8 to ground.

The pulses produced by IC1c are then passed through gate IC1d, connected here just as an inverter and buffer. They are then fed directly to the clock input of IC2 (pin 14), and also to the same input of IC3 via gate IC1b and gate/inverter IC1a. IC2 and IC3 are 74HC4017 counters.

The reason for feeding the pulses to both IC2 and IC3 is that they are connected together to form a **modulo-16 counter** — that is, a counter which counts up to 16 and then drops back to 1 to count over again. (IC2 and IC3 are basically modulo-10 counters, but they can be made to work together as a modulo-16 counter by connecting them as we've done here, using gate IC1b and inverter IC1a.)

So the part of the circuit we've talked about so far produces a stream of clock pulses, and then feeds them to a modulo-16 counter. As the counter counts the pulses, its 16 outputs (O0-O9 of IC2, O1-O8 of IC3) therefore go high (+9V) one at a time in sequence, and then the process repeats itself.

We use diodes D1-D16 to change this repeated counting up to 16 sequence into an up-and-back sequence of glows by the LEDs. This is done simply by connecting the diodes so the LEDs glow in the 'up' direction from the outputs of IC2, but then in the 'down' direction from the outputs of IC3. As you can see diodes D1-D9 provide the 'up' drive currents for LED1-LED9, while D10-D16 provide the 'down' drive currents for LED8-LED2. (Notice that LED1 and LED9 only glow once in each up-down cycle, while the others glow twice.)

Because only one LED conducts current and glows at any instant, we can use a single resistor to limit the current in them all. This is the 750Ω resistor connected between their common cathodes and ground (the negative line).

Since the LEDs are being driven directly from the outputs of IC2 and IC3, via diodes D1-D16, we need to run the two counter ICs from a reasonably high voltage so the LEDs glow brightly. However the maximum supply voltage that can be used for the 74HC4017 devices is 6V, so they can't be run directly from the 9V battery. Instead we use REG1, a 78L05 5V voltage regulator, with diode D17 connected in series with its GND lead. This boosts the regulator's output to very nearly +6V, so IC2 and IC3 are happy while the LEDs glow quite brightly.

the Scanner's LEDs from glowing at all.

Next after the resistors, fit the greencap capacitors. Again there are only two of these, and they both go on the right near the back of the board. The larger 220nF greencap goes on the far right, while the smaller 100nF greencap goes about 20mm to the left and at the very back.

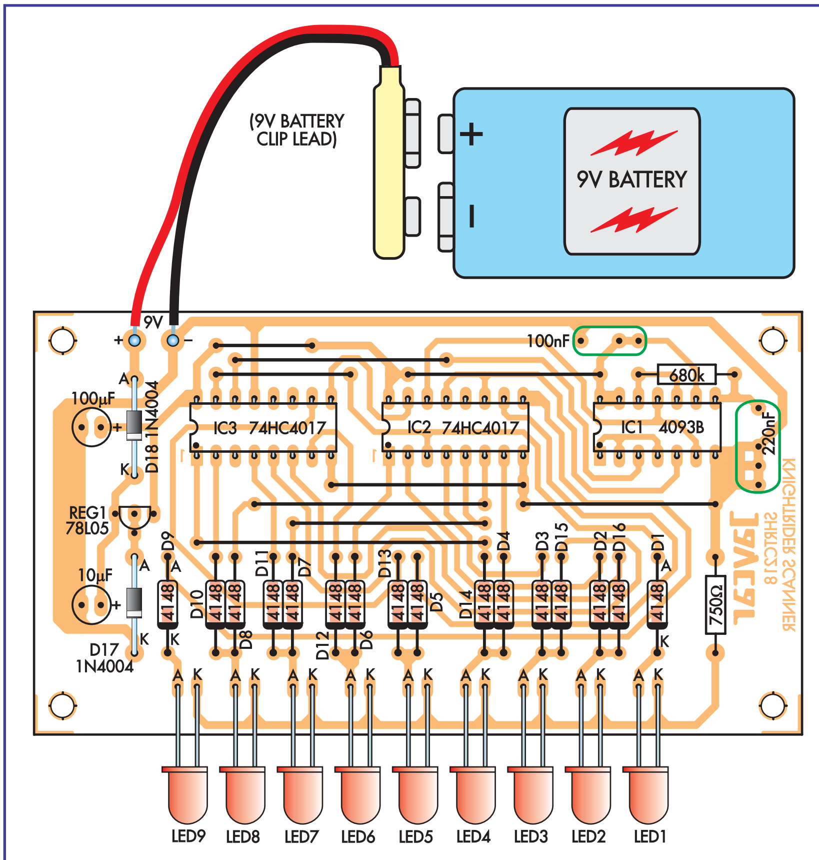
Now fit the electrolytic caps, and there's again only two of these. They're polarised, of course, and they both fit at the left-hand end of the board with their negative 'stripe' sides towards the left and their positive leads on the right. The larger 100µF electro goes towards the back, while the smaller 10µF electro goes down near the front.

Next fit the two 1N4004 power diodes, which are in plastic packages and become D17 and D18. As you can see from the wiring diagram these fit just to the right of the two electros, with their cathode 'band' ends both towards the front. Make sure you don't fit either of these the wrong way around, because this can make the Scanner either not work at all, or damage the ICs.

Next you can fit the sixteen 1N4148 signal diodes, which are in a smaller glass package. These diodes become D1-D16, which are all in a row near the front of the board — between D17 and the 750Ω resistor. Notice that they should all be fitted with their cathode band end towards the front, just like diodes D17 and D18.

Next fit the 78L05 regulator REG1, which comes in a small TO-92 plastic package just like a transistor. This fits on the left-hand end of the board in the centre, between D17 and D18. Make sure you fit it with its flat side towards the rear, as shown in the wiring diagram. You'll probably have to crank its two outer leads away from the centre lead, so they'll all go through the board holes without strain.

Now you can fit the three ICs, which all go in a row near the back of the board. They're all orientated with their notch/dimple ends towards the left, to make things easier. The 4093B device goes on the right and becomes IC1, while the two 74HC4017 devices go in the centre and on the left and become IC2 and IC3.



Here's the complete wiring diagram for the Knightrider Scanner.

You will probably need to bend the rows of pins on each IC carefully inwards towards each other, so they'll all pass through the board holes without strain. But remember that all three ICs are CMOS devices, and susceptible to damage from electrostatic charge. So discharge yourself by touching some earthed metalwork before handling the ICs, and of course solder their pins to the board pads using an earthed soldering iron. Also try to solder their supply pins first (pins 7 and 14 of the 4093B, pins 8 and 16 of the 74HC4017's), so their internal protection circuitry can begin working as soon as possible.

The last components to fit are the nine high-brightness LEDs which, as you can see, go in a row along the front of the board. They are all orientated with their flat side and shorter cathode (K) leads towards the right.

So that the LEDs all emit their light towards the front of the board, their leads are all bent down by 90° about 14mm away from the LED's body. It's easier to do this neatly if you bend the leads before you fit the LEDs to the board; then all you have to do is solder each one's leads to the pads underneath while holding the LED and the horizontal sections of the leads about 8mm above the top of the board. When you finish, all nine LEDs should be neatly in line.

All that should be left now to finish building the Scanner, is to solder the ends of the battery clip lead wires to the terminal pins at the back of the board. Make sure you solder the red wire to the pin on the left, and the black wire to the other pin.

Just before you congratulate yourself on finishing the project, though, give it a careful inspection to make sure you've fitted all of the components in the correct positions and with the right orientation. You might want to check the copper side of the board too, to make sure you haven't forgotten to solder any of the component leads — or left a dry joint, or even a bridge of solder shorting between two pads or tracks.

Trying it out

If everything seems OK, connect up a 9V battery to the clip lead. You should immediately be rewarded by seeing LED1 glow, and then LED2, LED3 and so on. When the 'glow' reaches LED9 it should reverse and swing back again towards LED1. Once it returns to LED1 it should reverse again and move back towards LED9, repeating this back-and-forth scanning over and over as long as the battery is connected.

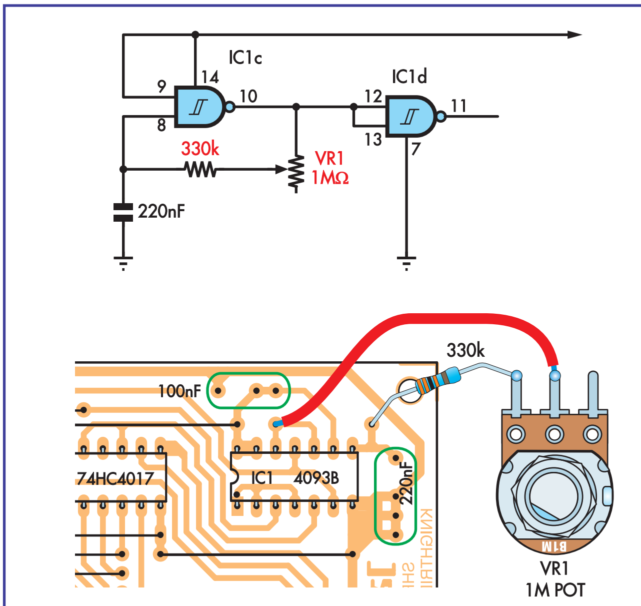
That's all there is to it — so if this is what happens with your scanner, it's working just as it should.

OK, but what do you do if *your* scanner doesn't, and just sits there as dead as a dodo with no LEDs glowing at all? You can probably guess what this means: yes, that's right, you must have made some kind of mistake in wiring it up.

Perhaps you've accidentally connected the battery clip lead wires the wrong way around, or fitted diode D18 backwards. Or forgotten to solder one of the leads of D18, or of REG1. Or perhaps you've made a dry joint on one of these leads, so they're really not making a good connection.

If LED1 just glows steadily, without any attempt to 'pass' the glow along to any of the other LEDs, you may have made a dry joint on one of the pins of IC1, or the leads of the 680k resistor or 220nF capacitor. On the other hand if most of the LEDs seem to be 'passing the glow' correctly except one or two, the odds are that you've connected those LEDs in backwards — or some of the 1N4148 diodes in back to front...

Depending on your Scanner's symptoms, then, the idea is to disconnect the battery and track down the fault by checking each of these possible mistakes in turn. Then when you do find the problem and fix it, your Scanner should spring into life as soon as you connect the battery again.



Here's how to replace the 680k resistor in the Scanner with a 330k resistor and a 1M pot, so you can vary the scanning rate over a fairly wide range.

What to do next

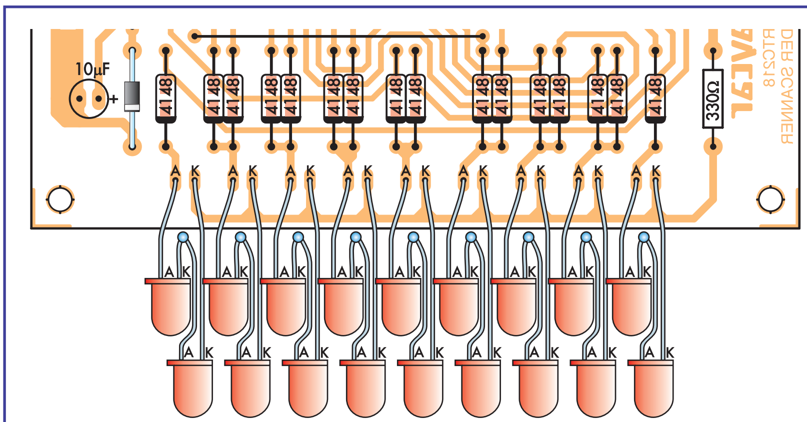
If you'd like the Knightrider Scanner's LEDs to pass the glow back and forth faster or more slowly than the speed they do, this is easy to change. All that's needed is to replace the 680k resistor with one of a different value.

For example, to make the scanning faster, you can replace the resistor with one with a value of say 470k, 390k or even 330k. On the other hand replacing it with a higher value resistor like 820k or 1M will slow down the scanning.

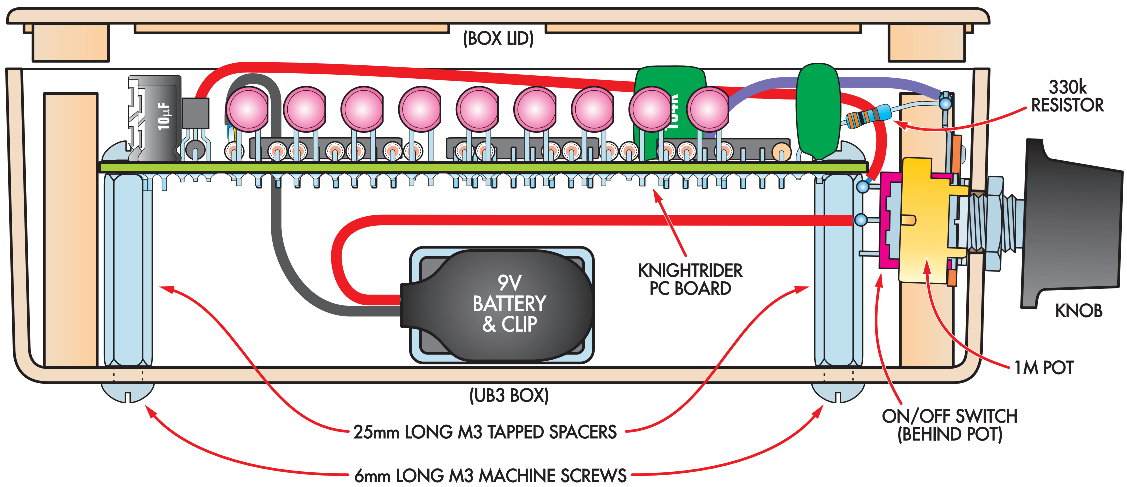
If you'd like to be able to adjust the scanning rate easily at any time, you can remove the 680k resistor from the board and run some wires out to a 1M pot and a 330k resistor connected in series, as shown in the small diagram. Then you can vary the scanning rate over a wide range simply by adjusting the pot.

The 1M pot you use for this can be of either the 16mm or 24mm size, like the Jaycar RP-7524 or the RP-3624. The series 330k resistor can be a standard 0.25W metal film type like the Jaycar RR-0632.

If you'd like the Scanner to produce more light output, this can be done fairly easily by



Like more light from the Scanner? An easy way to do this is by adding another set of LEDs in series with the existing LEDs, like this. But you also need to replace the 750W resistor with a 330W resistor, as shown.



Here's how to build the Scanner into a low-cost UB3 size jiffy box, along with a 1M rate pot and an On/Off switch.

connecting another set of LEDs in series with the original LEDs — in other words, replace each LED with two connected in series. The additional LEDs should be of either the same type as we provide in the kit (Jaycar type ZD-1796) or else the even brighter ZD-1777.

If you do connect a second set of LEDs in series, make sure that the new LEDs are connected with the same polarity. This means that the junction of the two LEDs in each position should be cathode (K) to anode (A), as shown in the diagram. Note too that when you add the additional LEDs, the 750Ω series resistor needs to be replaced with a 330Ω resistor (Jaycar RR-0560) to achieve the same LED current level.

You might also want to build your Knightrider Scanner into a plastic box, especially if you add an off-board pot to vary the scanning rate. Building it into a box will make it much neater, and at the same time protect the components from damage.

It's quite easy to build the scanner into a standard UB3 size jiffy box, so the logical box to use would be one like the Jaycar HB-6023 (grey) or HB-6013 (black). Choose the colour you want.

The way to build the Scanner into a UB3 box is shown in the diagram above. As you can see the PC board assembly is supported inside the bottom of the box on four 25mm long spacers tapped with M3 threads. This allows the spacers to be fixed inside the box using four 6mm long M3 machine screws, with another four of the same screws used to attach the board to the tops of the spacers.

There's room for the 9V battery under the board, and also room for a 16mm 1M pot to be mounted in the right-hand end of the box so you can adjust the scanning rate without having to open it up. In fact there's room as well to fit a small toggle switch (like the Jaycar ST-0335) at the same end of the box next to the pot, so you can switch the scanner on and off just as easily.

Needless to say the long side of the box (not shown in the diagram) needs to have a row of nine 5.5mm diameter holes for the LEDs to protrude through and be visible.

Meet the Pioneers of Electronics:

Edwin Howard Armstrong

Born in New York in 1890, Edwin Armstrong obtained a degree in electrical engineering at Columbia University and put his knowledge to work in World War 1, when he was a captain in the Signal Corps stationed in France. He developed the regenerative radio receiver in 1912, and then conceived and built the first **superheterodyne** radio receiver in December 1918, receiving a patent for this in 1920. His 'superhet' principle, involving the beating or heterodyning of signals down to a lower frequency so they could be better amplified, has been the basis of all high performance radio receivers since then.

In 1920 Armstrong also conceived and built the first **super-regenerative** radio receiver, which became used in early VHF and UHF radio receivers. But his next really outstanding contribution to radio and electronics came in 1935, when he announced the development of FM (frequency modulation) radio broadcasting – offering higher fidelity and a much lower noise level than AM (amplitude modulated) broadcasting.

Armstrong spent more than US$1 million developing high quality equipment suitable for FM, and in 1939 his first FM broadcasting station went on the air in the VHF spectrum. The public were so delighted with FM that by November of the same year, 19 more FM stations were operating in the USA. FM broadcasting grew rapidly in many countries, although it only began in Australia in 1974.

Depressed following a court case in 1954, Armstrong committed suicide by jumping from the window of his New York apartment.