

# in practice

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## RELAY SPEED-UP CIRCUIT

*FOLLOWING YOUR item in January 2002 about suppressing voltage spikes when relays are switched off, how can I make a relay pull-in faster? The antenna changeover relay on my linear amplifier is rather slow, and when my transceiver keys it, there is an RF spark. I think this is because the RF power appears before the relay has fully changed over.*

YOU'RE PROBABLY RIGHT. Many modern transceivers provide a delay of 10 - 15ms between key-down - or pressing the PTT or transmit button, or tripping the VOX - and the start of actual transmission. But, since many antenna changeover relays take 20 - 30ms to pull in, you can indeed expect some RF arcing. I will describe a modification that gives you a sporting chance of speeding-up the relay so that it has changed over before the RF arrives.

To make a relay close faster, you need to build up the magnetic field in the solenoid very quickly, but the large inductance of the solenoid fights back against any change in current. There are three ways to overcome this: the classic way, the dirty way and the clever way. The classic way is to operate the relay from a higher voltage than normal, and use a dropping resistor (R1 in Fig 1) to establish the correct steady-state current through the coil. The current through the relay coil ends up at the same value, but it gets there much more quickly if you supply the relay from a higher starting voltage. Fig 1

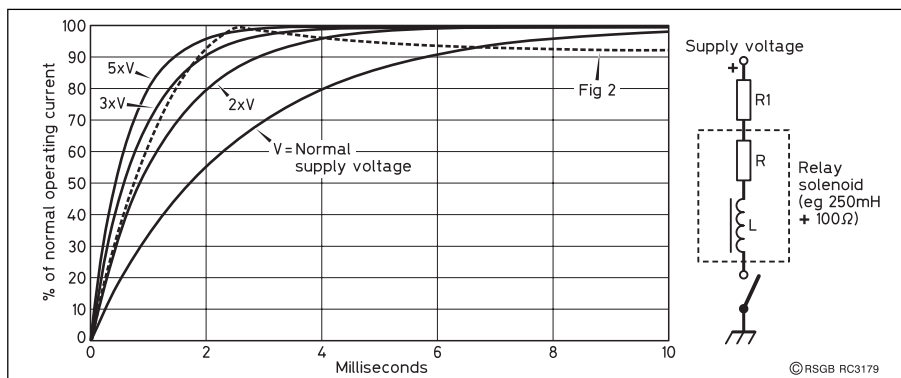


Fig 1: Family of curves showing how the rise-time of current in a relay coil can be speeded-up by supplying the relay from a higher voltage through a dropping resistor. R1 is adjusted so that the final current is the same in all cases.

gives a family of curves showing how the current in a typical relay builds up. The slowest build-up is when the relay is operated from its normal voltage  $V$ , and with R1 short-circuited. The fastest build-up shown is when the same solenoid is operated from a supply voltage of  $5 \times V$ , with R1 equal to four times the solenoid's internal resistance, so that the final current is the same as before. The intermediate curves are for  $2 \times V$  and  $3 \times V$ . If you compare the times taken to reach, say, 90% of the final steady-state value, you find that the speed-up ratio is simply equal to the voltage ratio (and if you know your differential calculus, here's your cue to say "Yes, obviously"). However, this method has certain disadvantages, especially if you wish to modify an existing amplifier - you have to provide a higher-voltage source, often at substantial current, and then throw away a lot of heat in R1 while the relay is energised. Also you have to be prepared to switch this higher voltage, and to handle the switch-off transient as discussed in January.

The dirty way? Oh, simply run the relay from about  $2 \times V$  all the time, and hope the coil doesn't burn out!

Now for the clever way. This one came from K1KP, and it's a way of effectively doubling the relay voltage for the first few milliseconds when it matters, without any of the disadvantages of Fig 1. Fig 2 shows the circuit. Initially the PTT line is un-grounded, and C1 charges up to the full supply voltage  $V$  via the relay solenoid RL1, D1 and D2. TR1 has no forward base bias at this time, and does not conduct. Activating the PTT line grounds the positive terminal of C1, so that the negative terminal of C1 takes the emitter of TR1 down below ground potential, almost to  $-V$ . This causes base current to flow into TR1, which turns fully on so that its collector is also very close to  $-V$ . At this moment the relay RL1 sees  $+V$  on one terminal and  $-V$  on the other, a total of twice the normal voltage, so it pulls-in very smartly. This golden moment doesn't last, of course, because the relay current will discharge C1 within a few milliseconds. D1 and D2 were

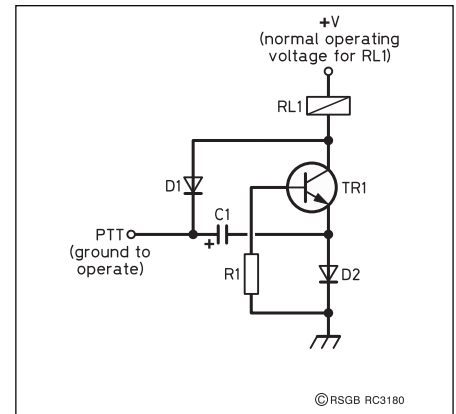
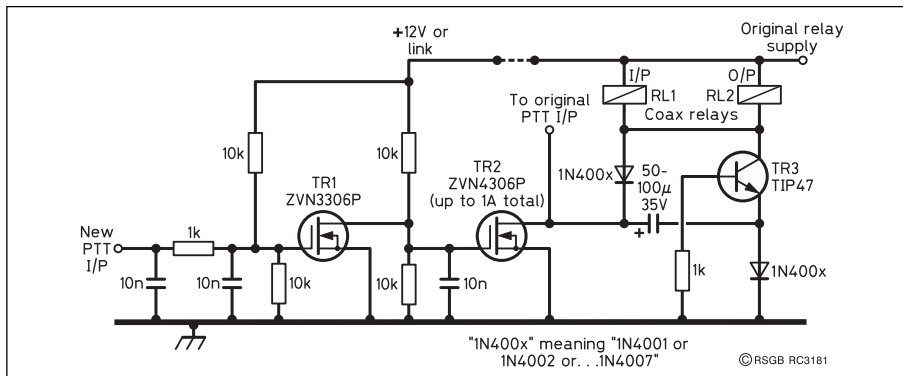


Fig 2: K1KP's relay speed-up circuit will roughly halve the pull-in time, while still using the normal supply rail. This makes it ideal for modifying existing rigs.

both reverse-biased while C1 was pulsing the relay, but when C1 discharges, D1 starts to conduct again and holds the relay in at its normal operating voltage for as long as the PTT line is grounded. Note that R1 is essential to allow the base of TR1 to follow the emitter down towards  $-V$ .  $1k\Omega$  is a suitable value.

The degree of speed-up you can achieve with this circuit depends partly on how quickly it pulses current into the solenoid, and then partly on the mechanical reaction time to move the contacts. Based on detailed simulations of the transient behaviour, the circuit of Fig 2 is equivalent to operating the relay from about three times its normal supply voltage with a series resistor (see dashed line of Fig 1). The speed-up of contact closure seems to be about a factor of two, depending on the mechanical design of the relay.

When the PTT line is released, C1 recharges quickly through RL1, D1 and D2, so the circuit is soon ready for a repeat operation. The unexpected bonus is that when you release the PTT, you don't need to worry about handling the energy stored in the solenoid's magnetic field (see January) because it all goes into recharging C1. This makes the field collapse very quickly, with only a small voltage transient from the back-EMF, so the circuit also shortens the relay's drop-out time. The value of C1 is not very critical. Most antenna relays would need  $50-100\mu F$ , or possibly more if you're driving the input and output relays in parallel. If C1 is too small, the circuit won't pulse all the way down to  $-V$ , and the back-EMF transient on switch-off will increase. If C1 is larger than necessary, it pulses closer to  $-V$  and stays there longer, but the critical rising edge of the current waveform hardly steepens at all. The drop-out time extends by a few milliseconds if the value of C1 is very large, and the recovery time before a repeat operation also increases, although this is not normally a problem. If you want full break-in CW at very high speed, you might then need



**Fig 3:** A more practical version of Fig 2 with an interface for fast, low-current keying from any transceiver. The rating of TR2 depends on the current demand of other keying circuits in the power amplifier.

to optimise C1 more carefully, and spend some time measuring the performance with an oscilloscope.

In order to have the relay contacts closed before the RF arrives, you *must* activate the speedup circuit from the transceiver's fastest PA control output, which is usually an open-collector npn transistor. If you key the PA through another relay inside the transceiver, you're losing valuable milliseconds while that relay changes over first. Every millisecond counts here, because the antenna relay contacts need to have changed over *and also stopped bouncing* before the RF arrives - otherwise you'll get RF arcing as the contacts bounce open again. The difficulty with using the transistor-switched output of many transceivers is that the transistor itself may be quite low-rated in terms of voltage and current. Often this transistor cannot handle the full load of one or two coaxial relays plus whatever else is connected to the power amplifier's PTT line. **Fig 3** is a more practical version of Fig 2, with a simple two-transistor interface that keys the power amplifier without delay, and allows you safely to use the fast PA control output of any transceiver. For the fastest possible response, you should check with a scope that the relay switching is not pulling down the supply rail and, if necessary, reinforce it with an additional reservoir capacitor close to the relays.

I've modified a few relay systems in power amplifiers using this speed-up circuit, and it has greatly reduced the incidence of RF arcing. In particular, it can speed-up the popular CX520 coaxial relays used at VHF/UHF, to bring them inside the typical 15ms deadline. It is still a race against time, so this modification is not guaranteed to work in every case (especially with older transceivers that do not have a deliberate delay before the RF appears). Obviously it isn't as good as a fully-sequenced changeover system that can sense when the relay contacts are fully settled, and also send a hold-off signal back to the trans-

ceiver until the amplifier is completely ready for the RF... but that's a much longer story.

Some relays used for antenna changeover in HF transceivers are really AC/DC power relays, with switching times of 30ms or even more. You may not be able to speed these up enough to prevent RF arcing, particularly because the contacts are very prone to bouncing. You may see arcs from time to time, but not always, which indicates either that the contacts are sometimes bouncing, or that the armature is sometimes sticking on its pivot (most relays are far from being precision mechanisms). The only solution is to replace these relays with something faster. The best solution up to 50MHz is probably to use small ceramic vacuum relays, most of which are very fast because of their special construction [1]. Many vacuum relays have switching times of less than 10ms, and this can be roughly halved by the speed-up circuit. The disadvantage is that most are designed for 24 - 28V operation, so you may require a new relay supply, and may also need to uprate the transistors in Fig 3.

## SHORTENING SCREWS, AGAIN

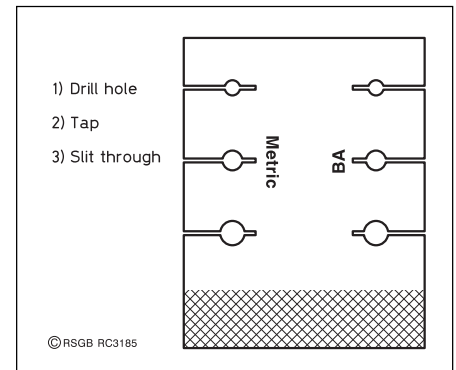
*THE DECEMBER 2001 item about shortening screws brought a number of practical comments and suggestions.*

SEVERAL COMMENTS were about the technique for removing the raised lip that occurs when you run the nut over the sawn-off end to restore the damaged start to the thread. Ideally the aim is to re-create the shape of the original factory-made end... which is somewhere on the floor. You can make a fair effort at this by filing a chamfer all around and then cleaning out the start of the thread where it's squashed down. With a large steel screw, the knife-edged needle file that I suggested may be a bit too fragile for cleaning out the thread - try the edge of a small half-round file instead. If the screw is quite small and made of brass, the needle file is still probably your best bet - just take care, and

don't be too heavy-handed. With small screws the best technique is probably to run the nut back over the cut end, rub off any sharp bits and repeat until the nut starts easily. (It's really much easier to do this than to read about it here.)

If you have a set of taps and suitable drills for common screw sizes such as 2BA, 4BA, 6BA, M5, M4 and M3, G3VTS suggested an alternative to holding the screw in the two nuts. Make a plate out of aluminium or mild steel as shown in **Fig 4**, and make a set of tapped holes in a range of useful sizes. Then slit each hole through the centre and the job is done. The slits make cheap-and-cheerful cutting edges which help to clean up the screw threads more effectively, so there is less filing to do. Although a set of proper split dies in these thread sizes would clean up the threads even better, Colin's idea saves you from the temptation to clamp your good dies in the vice and use them as a sawing guide.

For making the narrow slits as suggested in Fig 4, I'd recommend the X-Acto range of fine saw blades which are available from most model shops. These fit into the handle of an X-Acto knife, which most of the time can hold one of their excellent range of sharp, strong blades.



**Fig 4:** G3VTS suggests this simple idea for cleaning up a wide range of screw threads. Make tapped holes in the screw sizes you commonly use, and then slit them through. The plate is gripped (as shown) in a vice.

## NOTE

[1] Vacuum relays sometimes appear as surplus in this country, particularly the small ITT Jennings RF1E types which are suitable for light HF use. The best source for surplus vacuum relays is probably Allen Bond, whose web pages offer many different types at very reasonable prices, including the popular Jennings RJ1A and Kilovac HC-1 types.

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Allen Bond [www.mgs4u.com/relay.htm](http://www.mgs4u.com/relay.htm)

The 'In Practice' website (see the previous page) contains a cumulative index from 1994-2001, and links to component suppliers, etc. ♦

If you have new questions, or any comments to add to this month's column, I'd be very pleased to hear from you by post or e-mail.

Please remember that I can answer questions through this column only, so they need to be on topics of general interest.