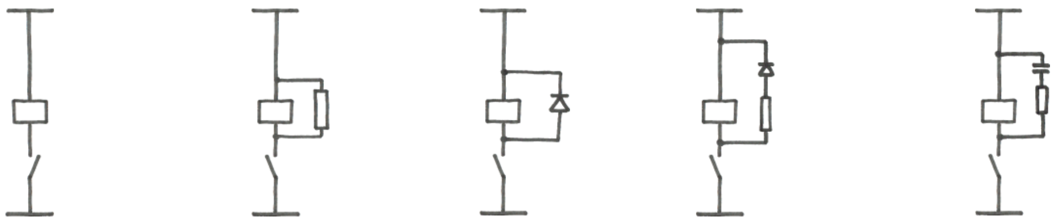
Relay delay okey

When it comes to the standard simple relay, there are widely differing levels of understanding and misunderstanding. Most people don't care – and some care too much. Let's see what a simple question in one of the engineering fora on the web led to. The question (V_{CE} is the maximum recommended transistor voltage):

'a single Zener diode across the Collector and Emitter of a common-emitter BJT (which drives the low side of the relay coil), should be adequate to suppress the coil's voltage spike to the Zener voltage. And using a Vz = 2 x V_{CE}'
The resulting answers and the original poster's answers and objections made me wonder if I had missed something and, if so, what?

The standard solutions
The standard Free-wheeling diode could not be used because it would cause a slower contact opening (according to the OP) and that slow opening would make contact wear excessive. The delay that a FW diode causes was of no concern – only the contact wear. Now, what options are there? And is the slow contact opening a problem? Does it at all exist? I set out to do some experiments. First – the different options (the illustrations are more or less photographed from the White-board, that's why they look 'Hand-made' – which they are):



No snubber   Parallel resistor   Diode   Diode with resistor   RC snubber

The *No Snubber* configuration produces high spikes when the contact opens. That was expected and not explored any further.

The parallel resistor does exactly what one can expect – namely produce an inductive kick-back that is equal to coil current times resistor/(resistor + coil resistance) – which is fine if you can accept the extra power losses in the parallel resistor. Which is seldom the case.

The *Diode* keeps kick-back voltage very low – not more than around one volt below zero. It also introduces a time delay because the free-wheeling diode lets coil current circulate (driven by coil inductivity) and thus keeps the magnetic forces alive for around ten milliseconds. That is seldom a problem in ordinary automation or signal switching, so a simple diode is a very common snubber. Some relays have an internal diode built-in.

The *Diode/resistor* combination reduces the delay down to values very close to the "No Snubber" delays and is sometimes used to accelerate the switch-off. But, if the delay is a problem, then one should find better solutions where delays can be taken below 1 millisecond instead of the usual 5+ ms.

The *RC combination* has several advantages. It is fast, it fails safe, it does not only reduce kick-back but it also reduces HF EMI. The resistor can sometimes be eliminated, but is normally needed to reduce peak current in driving circuitry like transistors and switches. The RC combination works equally well with DC coils as with AC.

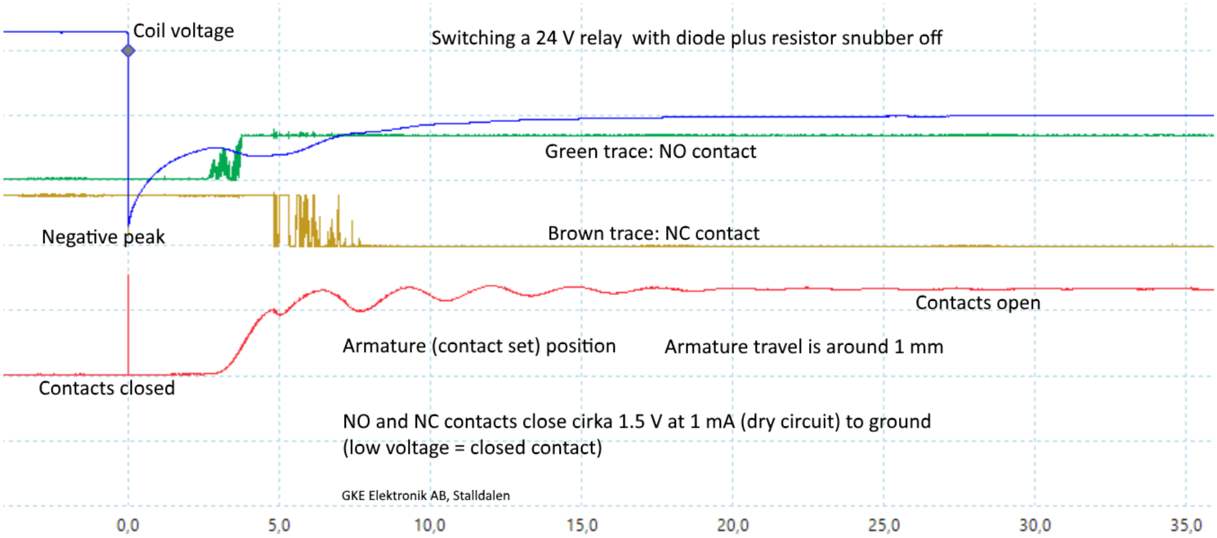
There is a plethora of other devices, like MOV (Varistors), TVS (Transient Voltage Suppressors – Tranzorb etcetera), gas discharge tubes and other more or less exotic devices. They are not treated in this chapter.

The delay – or the delays, actually

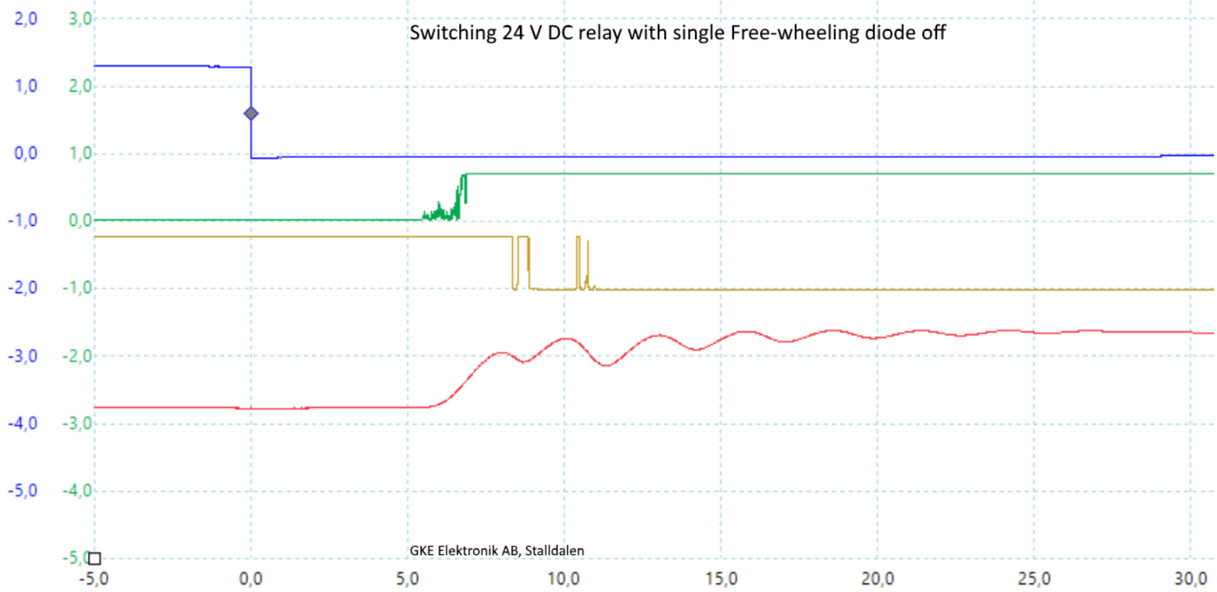
The delay is a little more complicated than the simple delay caused by the L/R time-constant. There are three delays that influence the performance of a simple relay. Or, rather four – if you also count the bounce time. They are:

1. Time constant of the relay coil and external circuitry
2. Time needed to accelerate the relay armature
3. Armature travelling time
4. Contact bounce/chatter time.

The picture below shows all these times when de-energizing an OMRON MY4 relay with a 24 V DC and 600 Ω coil.



The same circuit but without resistor in series with the diode is shown below. Comments in pervious picture:



What has changed? The kick-back is completely gone. And with it the interference seen in the red trace in first picture. The delay is, again as expected, longer.

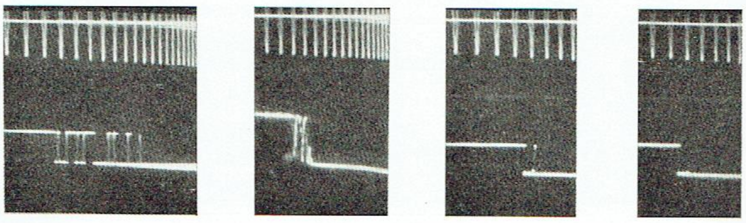
But, the armature moves at the same speed in both cases – shown by the armature position and the time it takes to move from closed to open. The difference between NO open to NC closed is exactly the same in both pictures. Measure distance from stable green trace to first bounce in the brown trace to verify.

But, what about the bounce? It was supposed to be worse with the diode than without it. Is that so?
No – not really. There are two 'Bounce types' and it is only one of them that is bounce. The other type is contact resistance due to low contact force just before the armature starts moving and that is what makes 'Dry Switching' difficult in many cases.

The bounce is shown as square and nice pulses in the brown trace (the closing contact, opening contacts very seldom bounce). The red trace, contact position shows clearly that it is about bounce. The ringing is very often mistaken as an electrical transient. But it is a pure mechanical vibration picked up by the optical reflex detector that was used to do these measurements. The frequency is around 2000 Hz, which is what my musical wife guessed when I played it back from a voice recorder. Such low frequencies do not exist in low capacitance circuits like this one.

There is a whole book on contacts…
Finally, an excerpt from the book Electric Contacts by Ragnar Holm, printed in 1946:

The impact-time and the jump-time are usually very small in relays and must be recorded by means of a cathode-ray oscillograph. Some records are given in Fig. (51.01). They show contact making of various qualities. The relay A makes several jumps before remaining closed. Impact and jump times are of the order 5 to 7×10^{-5} sec. The record B is complicated with two real jumps and some effects of trembling. The contact make finishes with a



A B C D

Fig. (51.01). Current records of bouncing contacts.

Ragnar Holm 'Electrical Contacts' Uppsala 1946

The time seems to be somewhat off – I think that it should be 5 to 7 $\times 10^{-3}$ seconds. But otherwise, not much new has happened for seventy years. Or what do you think?