

External recirculating diodes

Some of New JRC's stepper motor drivers use external recirculating diodes. It is not possible to choose any power diode which can handle the current. Other parameters have to be considered. This note will provide some background and theory on how to choose these diodes.

In a bipolar constant current chopping stepper motor driver application the energy is fed through the motor winding in small portions by switching the current from the supply on and off. The motor winding will continue to force current even if the driving transistors are switched off. This can result in very high voltages across the circuit. Therefore the recirculating diodes are necessary in order to allow the current to flow and to keep the voltage at the safe level.

In a bipolar chopper drive there are essentially three current paths, for each phase (i. e. each current direction in the motor winding). Figure 1 shows these paths. In this example transistors T2 and T3 are shut off due to the selected phase.

Path 1 shows the normal "on" current path. In this case transistors T1 and T4 are both turned on.

Path 2 shows the current path during the constant current switching "off" mode. In this case transistor T4 is on and transistor T1 is off. The current forward biases the D3 diode. The result is slow current decay because the recirculating current is only opposed by a low voltage (one V_d).

Path 3 shows the current path during a phase shift. The result is fast current decay since the recirculating current is opposed by a high voltage (the motor supply voltage).

The voltage at the N1 node alters between near ground and $V_{MM} + V_d$ when transistor T1 is switching on/off during constant current chopping. (For more information see the Drive Circuit Basics section in the data book).

This drive mode places a very high demand for "fast recovery" of the upper recirculating diodes D3 and D4 when switching from forward to reversed direction. The measure of a diodes ability to do this is given by the recovery time (t_{rr}) parameter (see theory below). In practice the t_{rr} parameter sets the time current will flow in the reverse direction through the diode, immediately after it has been switched from conducting in the forward direction. The result is that the current will flow, through the diode D3 in the reverse direction and through T1, for a short period of time after the T1 turn-on. (Path 4 in figure 1). A current transient is generated every time T1 is turned on. (See figure 2). The reverse recovery of diode D3 is not the only cause of this transient, but it is the main one. The capacitance in diode D1 and other stray capacitances will also affect this, but to a lesser extent.

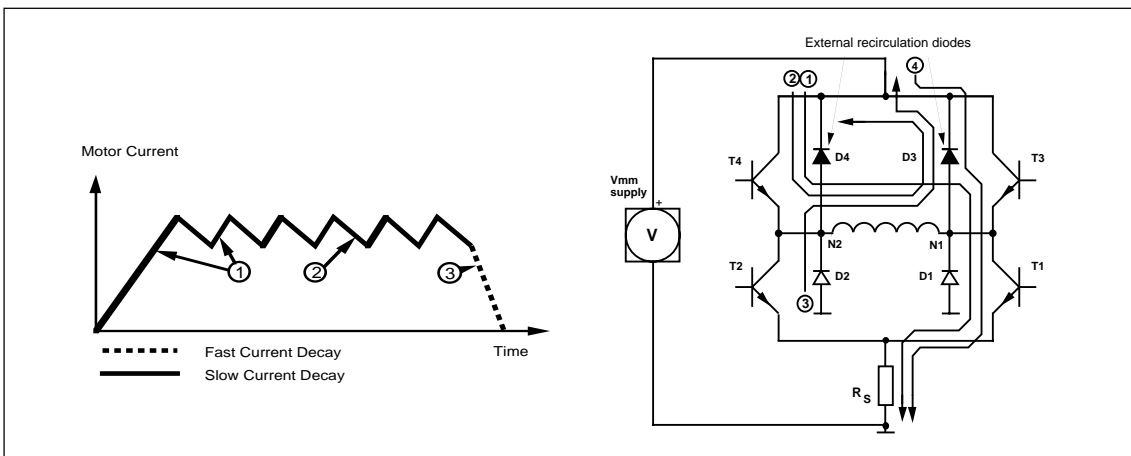


Figure 1. Output stage with current paths for fast and slow current decay.

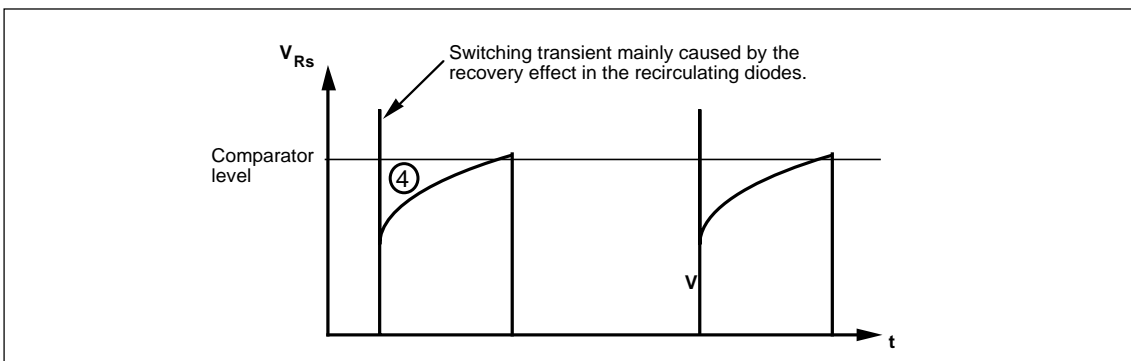


Figure 2. Voltage across the sense resistor R_s during constant current switching.

If t_{rr} is too long this current transient can reach a very high level (several amperes) and may cause the transistors to break down. This does not necessarily happen immediately but can occur after some time in operation. If t_{rr} is less than 100 nS the current transient will never reach dangerous levels since there is a max rise time related to the T1 transistor at turn-on which compensate for the diode recovery time.

Power diode characteristics at turn-on and turn-off.

The diagram shows the voltage and current wave forms for a power diode driven by currents with a specified rate of rise during turn-on and a specified rate of fall during turn-off.

During turn-on and turn-off specific physical processes occur in sequence. (See figure 3)

During turn-on.

t1: During t1 the space charge stored in the depletion region is, because of the large bias voltage, removed by the growth of the forward current.

t2: During this phase, the excess carriers distribution in the drift region grows towards the steady state value that can be supported by the forward current.

During turn-off.

t3: The excess carriers stored in the drift region must be removed before the metallurgical junctions can become reverse biased.

t4: The depletion layer acquires a substantial amount of space charge from the reverse bias voltage.

As long as there are excess carriers at the ends of the drift region the junction must be forward biased.

When the current goes negative and the carrier sweep-out has proceeded for a sufficient amount of time to reduce the excess carrier density at one or both of the junctions to zero, the junction or junctions become reverse biased.

t5: The diode voltage goes negative and the depletion regions from the two junctions expand towards each other into the drift region.

At this time the negative diode current demanded by the stray inductance of the external circuit cannot be supported by the excess carriers. The diode current ceases its growth in the negative direction and quickly falls and becomes zero.

The parameter t_{rr} is defined as the sum of t4 and t5. The amount of charge that has to be removed before the diode can be reverse biased is defined by $Q_{rr} = I_{rr} t_{rr} / 2$.

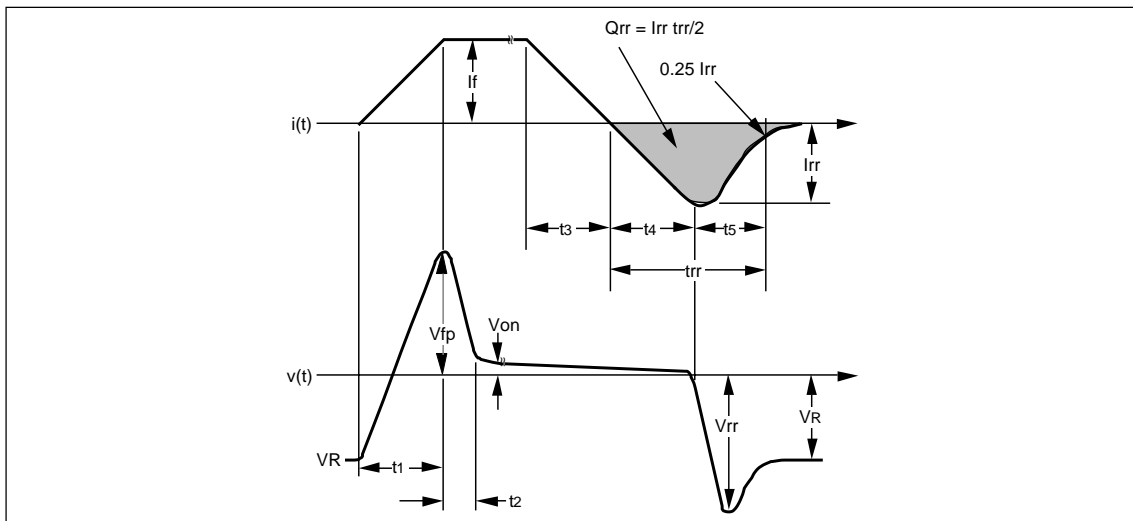


Figure 3. Voltage and current waveforms for a power diode driven by a current with a specified rate of rise and fall during turn-on and turn-off.

Diode selection guide

Diode	Manufacturer	t_{rr}
UF-4001	General instruments	<50 nS
BYW-22	Tomson-CSF	35 nS
BYW-98	Tomson-CSF	20 nS
BYV-27	Telefunken	25 nS
1GU 42	Toshiba	100 nS
1R5GU 41	Toshiba	100 nS
BYV 26A	Philips	30 nS

Exempel.