

Automotive Relay Drivers using the ZVN4206AV

Protection Free Load Interfacing with Avalanche Rated MOSFETs

David Bradbury

Introduction

The ZVN4206AV is considered to be the ideal automotive relay driver. It allows significant simplification and cost reductions to be made when replacing standard drivers such as bipolar Darlington transistors. The following note explains the popularity of relays as high current switches in automobiles, some of the problems to be solved in designing driver circuits, a standard driver circuit and an improved ZVN4206AV based circuit. The excellent performance of the ZVN4206AV is demonstrated and circuit options discussed.

Automotive Relays

Despite advances in intelligent power semiconductors over the past few years, relays are still extensively used to operate high current automotive loads. Their low conduction resistance, low cost and excellent fault tolerance make relays hard to better in harsh automotive environments. Relay coil currents vary considerably with application but the largest class of automotive relays have 150 to 220mA coils. Controlled by standard logic or similar low power circuits, these relays need a medium power driver transistor to interface to them.

Selection of a suitable driver transistor requires many constraints to be evaluated. Automotive power supplies are rarely clean. Normal operating voltages are from 10 to 15V for normal running but if the relay must remain energised during starter operation then the lower limit can fall to 6V or less. Commercial emergency starting equipment can force the battery voltage beyond 24V so automotive systems must be designed to withstand this voltage for up to 3 minutes to meet present automotive regulations. Load dump and other high energy supply voltage transients must also be withstood. Additional transients are also generated by the relay coil as its magnetic field collapses during turn-off. Wide variation in ambient temperatures must also be taken into consideration. Behind the vehicles instrument panel, ambient operating temperatures can vary from -40°C to over 85°C, whilst within the engine compartment, temperatures can be even higher.

Meeting these constraints usually results in specifying an oversized relay driver or one requiring many protection components.

Standard Drivers

Bipolar Darlington transistors are currently the most popular automotive relay drivers as they have the current gain necessary to interface between logic and relay with a single stage circuit. Figure 1 shows a typical Darlington driver with the extra protection components needed to ensure reliability. Diodes provide reverse supply protection and a clamp for the relay's turn-off transient. A power VDR is used to limit positive transients to within the Darlington's breakdown voltage. The saturation voltage of the Darlington (typically over 1V) causes sufficient power dissipation to eliminate the safe use of inexpensive TO92 types (unless they have a 200°C temperature rating - see Note 1 below) so TO126 or TO220 types are often selected. The resulting circuit is expensive, bulky, awkward to assemble and can be subject to mechanical reliability problems.

[Note1:

The Zetex E-Line package allows operation to 200°C, and the product range includes Automotive specific Darlington devices.]

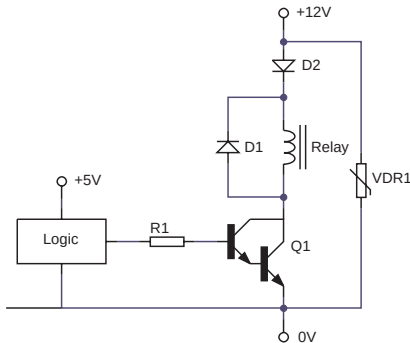


Figure 1
Darlington Driver with Typical Protection Components.

The ZVN4206AV Relay Driver

The introduction of the ZVN4206AV provides a far simpler, if not the simplest possible solution to the problems of relay drivers. It is an avalanche rated 60V 1Ω N-channel MOSFET designed specifically for use with automotive relays. The ZVN4206AV can drive relays with coil currents up to 600mA, and doesn't require a catch-diode to clip the turn-off transient caused as the relay is deactivated. The energy stored in the relay's magnetic field is dissipated harmlessly by avalanche breakdown of the ZVN4206AV's body diode. The same body diode also protects the MOSFET in the event of reverse battery connection. Characterised for 5V gate drive it can be driven directly from standard logic with no interface components.

Figure 2 shows how simple a relay driver circuit can be made by using the ZVN4206AV. The device's MOS gate input requires no DC input current so direct connection to logic is possible without buffers or current setting resistors.

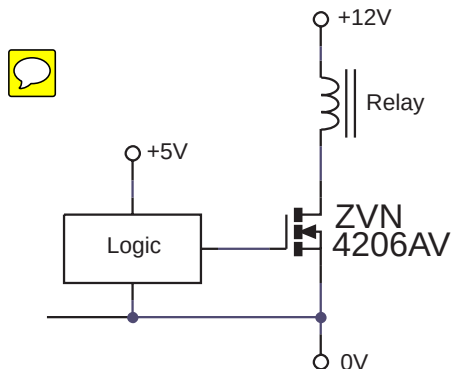


Figure 2
Reduced Component Count Relay Driver using the ZVN4206AV.

When on, the typical relay coil current of 200mA will cause less than 40mW dissipation in the MOSFET at 25°C ambient. Giving an on-voltage drop of only 200mV at this current, the ZVN4206AV will operate the relay with battery voltages 1V lower than can be achieved with Darlington based circuits.

Approximately 2mJ is stored in the magnetic field of the relay whilst energised. When the relay is turned off, the current flowing in the relay's coil causes the drain voltage of the ZVN4206AV to rise rapidly up to the breakdown voltage of the transistor (approximately 80V) and the stored energy is dumped harmlessly into the body diode of the MOSFET. Figure 3 shows the turn-off voltage and current waveforms of a typical relay driver circuit.

If a commercial starting aid is used which doubles the battery voltage, the ZVN4206AV will be forced to pass twice

its normal operating current. For loads of 300mA or less it will stand this indefinitely - more than can be said for the relay.

Reverse connected supplies will cause the body diode of the MOSFET to be forward biased and hence conduct. The current will be restricted by the relay's coil resistance to a safe level though the relay will be energised. With bipolar driver transistors, harm can come to the control logic due to a possible current path from a reverse connected battery through the driver to the logic's output. This cannot occur with the ZVN4206AV.

Figure 4 shows a load dump supply transient, caused by the vehicle's alternator if a battery connection should fail during heavy charging. This transient could occur when the relay is on or off and the stress placed on the driver circuit can therefore be very different. If off, the 65V transient will not reach the breakdown voltage of the ZVN4206AV and so no current will flow.

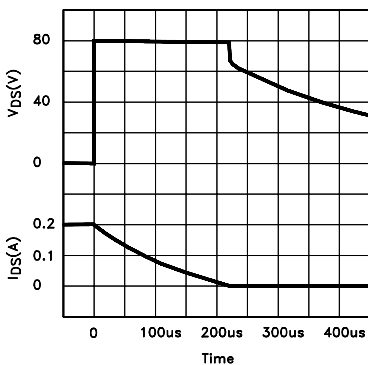


Figure 3
 V_{DS} & I_{DS} of ZVN4206AV During Turn-Off of Relay.

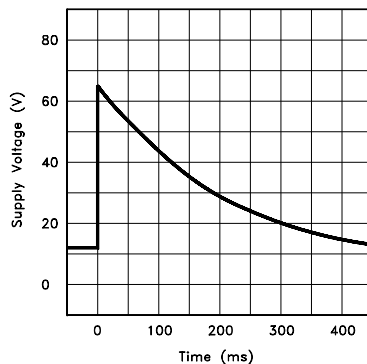


Figure 4
Load Dump Transient Waveform.

Figure 5 shows the current and voltage waveforms that occur should the relay be energised during a load dump transient. By integrating the current-voltage product, it can be calculated that a junction temperature rise of approximately 20°C is caused by the transient but this will quickly decay away. Consequently, infrequent load dump transients cause no problems for the ZVN4206AV relay driver circuit.

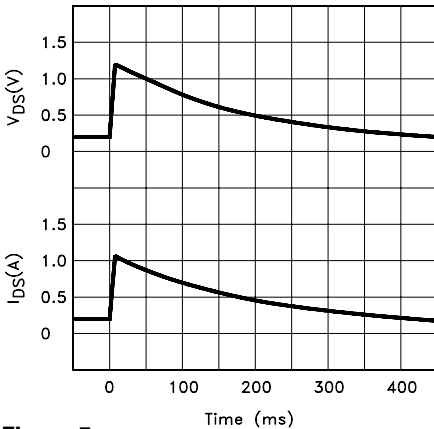


Figure 5
V_{DS} & I_{DS} During a Load Dump Transient.

Figure 6 shows a second transient that is often used to test automotive electrical systems - a 350μs time-constant 10 ohm source impedance inductive discharge transient. The peak voltage used in this test varies from manufacturer to manufacturer over the range 100 to 240V. To give worst-case results a 240V peak transient is used here.

Figure 7 shows the driver circuits response to this transient when the relay is on. The relay coil current rises from its nominal 200mA to a peak of around

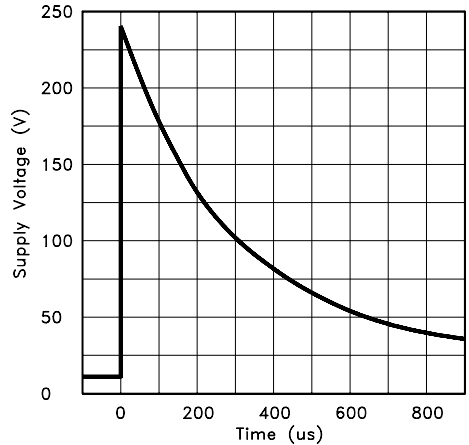


Figure 6
240V Inductive Line Transient Waveform.

900mA and then falls back. The ZVN4206AV maintains a low drain-source voltage for the duration of the transient so the power dissipation caused is negligible.

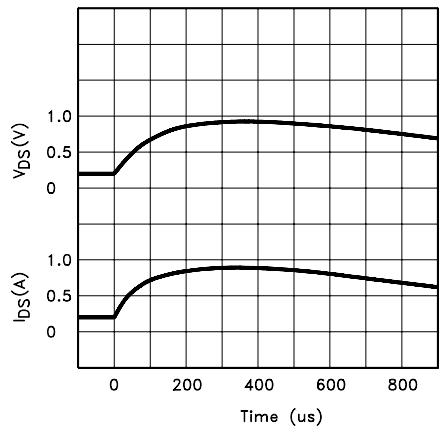


Figure 7
V_{DS} & I_{DS} During a 240V Inductive Line Transient (Device On Before Transient).

Figure 8 shows the circuit's response to the 240V transient when the transistor was off before the transient. For this case, the transient forces the ZVN4206AV into avalanche breakdown. The peak avalanche current that flows is limited by the relay's inductance to around 200mA. The energy dumped into the transistor, calculated by integrating the current-voltage product is approximately 5mJ. These stress levels are well within the avalanche capabilities of the ZVN4206AV.

The effect of temperature on the driver circuit should be considered for automotive applications due to their wide operating range. The on-resistance of the ZVN4206AV increases with temperature by about 0.65%/°C and this does reduce its current rating at high temperatures. However it should be remembered that the resistance of the relay's coil also increases with temperature, reducing the driver transistors load current at the rate of

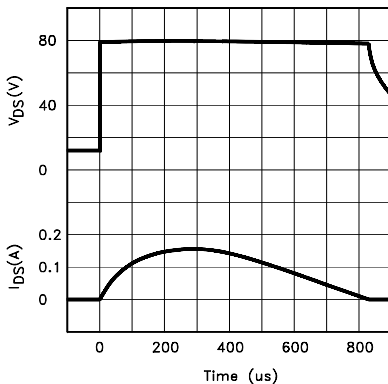


Figure 8
 V_{ds} & I_{ds} During a 240V Inductive Line Transient (Device Off Before Transient).

0.43%/°C. Since the power dissipation of the ZVN4206AV is I^2R related, even though the MOSFET's resistance increases with temperature, its overall power dissipation falls as the I^2 factor is more significant. As a result, a ZVN4206AV driving a 200mA relay will operate within its chip temperature ratings for ambients beyond 140°C.

The use of a ZVN4206AV has given a circuit capable of withstanding all commonly applied automotive transients and conditions of misuse whilst eliminating the need for bulky and expensive driver and protection components. This should not only provide worthwhile cost savings over standard drivers but also lead to improvements in reliability due to reduced power dissipation and component count.

Fault Tolerant Relay Drivers

Many automotive relays are mounted in sockets, remote from their drivers. Attempts to clean socket contacts during servicing or fault finding may lead to intermittent shorts being applied to the relay driver and so sometimes this must be catered for. The circuit in Figure 9 shows a ZVN4206AV relay driver circuit which includes load current sensing. In the event of the load current exceeding 300mA, the ZTX108 is turned on, indicating a fault to the controlling microprocessor. The power dissipated in the ZVN4206AV (12V x 1.5A) - 18W can be withstood safely for around 50ms, plenty of time for the microprocessor to recognise the problem and turn off the driver.

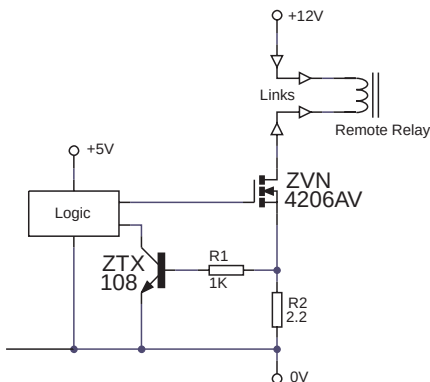


Figure 9
ZVN4206AV Relay Driver Circuit with Overcurrent Protection.

The need for such protection in remote relay systems can be eliminated by putting the driver transistor in the relay module. Figure 10 shows a circuit that

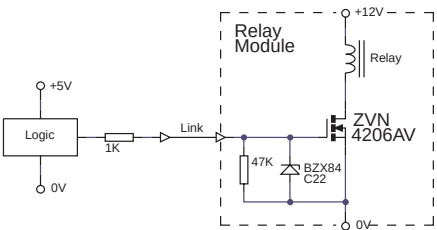


Figure 10
ZVN4206AV Relay Driver Module.

can be used to take advantage of this technique. The output resistor in the logic unit protects it against accidental shorts and the inexpensive resistor/zener circuit included in the relay module with the ZVN4206AV gives ESD and open-circuit drive line protection.

Appendix

Partial Characterisation of the ZVN4206AV. Full characterisation available in the Through Hole Data Book available from your local Zetex agent.

PARAMETER	SYMBOL	MIN.	MAX.	UNIT	CONDITIONS.
Drain-Source Breakdown Voltage	BV_{DSS}	60		V	$I_D=1mA, V_{GS}=0V$
Gate-Source Threshold Voltage	$V_{GS(th)}$	1.3	3	V	$I_D=1mA, V_{DS}=V_{GS}$
Zero Gate Voltage Drain Current	I_{DSS}		10 100	μA μA	$V_{DS}=60V, V_{GS}=0V$ $V_{DS}=48V, V_{GS}=0V, T=125^\circ C(2)$
On-State Drain Current	$I_{D(on)}$	3		A	$V_{DS}=25V, V_{GS}=10V (1)$
Static Drain-Source On-State Resistance	$R_{DS(on)}$		1 1.5	Ω Ω	$V_{GS}=10V, I_D=1.5A$ $V_{GS}=5V, I_D=500mA (1)$
Input Capacitance	C_{iss}		100	pF	(2)
Avalanche Current - Repetitive	I_{AR}		600	mA	
Avalanche Energy - Repetitive	E_{AR}		15	mJ	

(1) Measured under pulsed conditions. Pulse width=300 μs . Duty cycle $\leq 2\%$ (2) Sample test.