APPLICATION NOTE

HIGH SIDE DRIVERS

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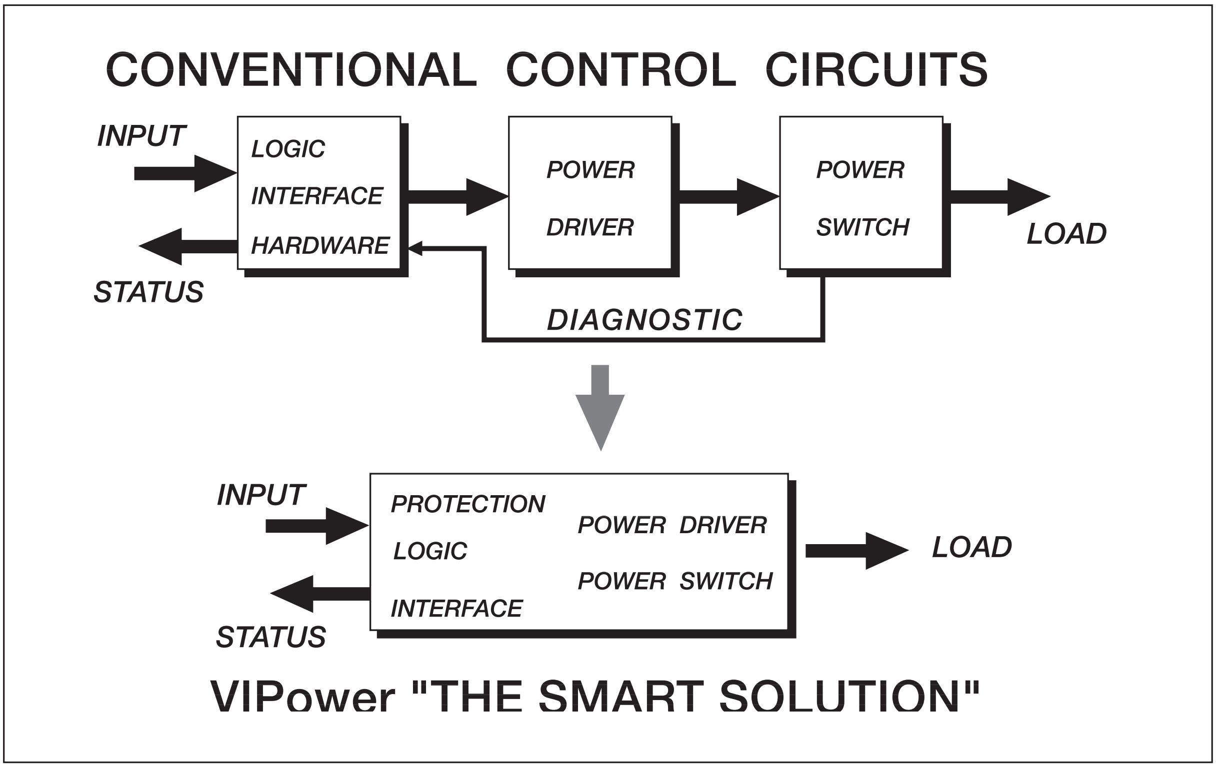
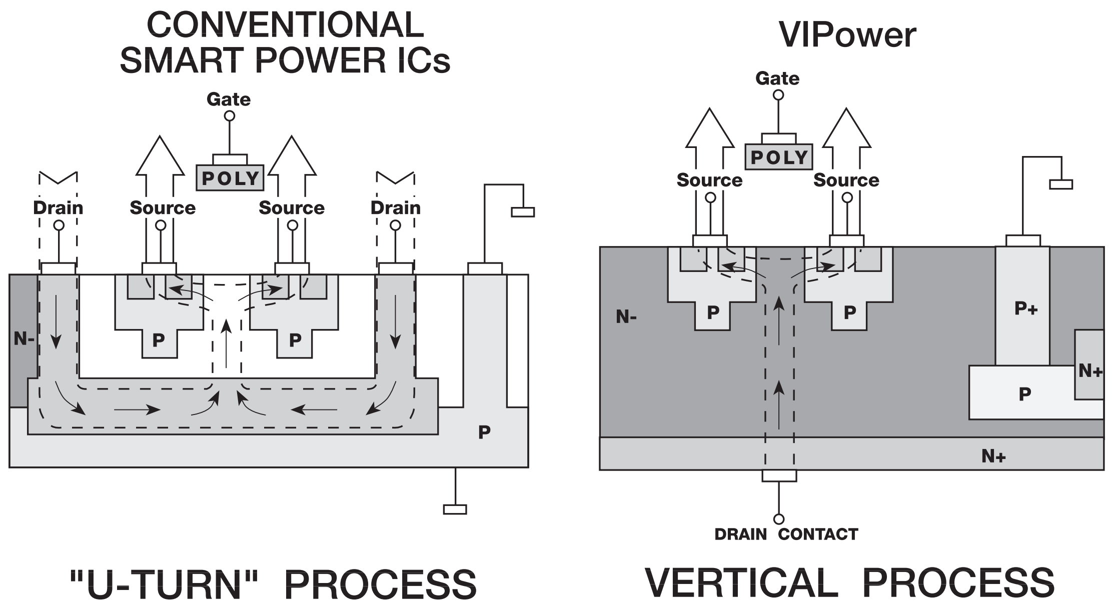
INTRODUCTION

The ever increasing demand for cost reduction and higher levels of circuit complexity and reliability have directed the semiconductor manufacturer's attention towards smart power technologies which allow the production of totally integrated monolithic circuit solutions that include a power stage, control, driving and protection circuits on the same chip.



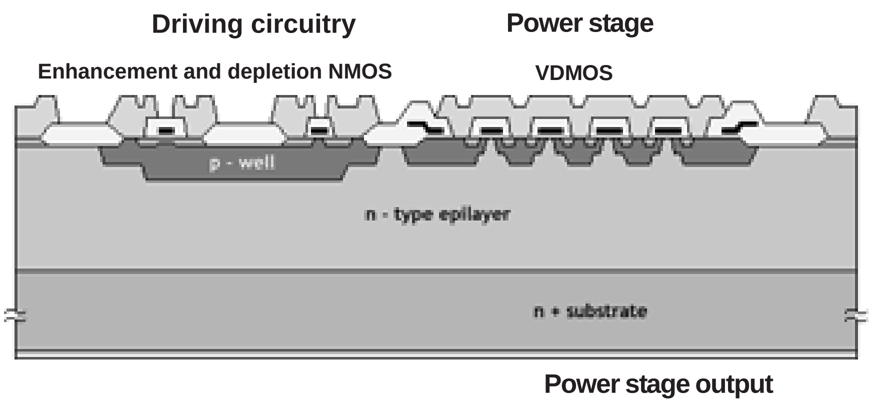
Vertical intelligent power, (VIPower ™) an SGS-THOMSON Microelectronics patented technology, established over 7 years ago, uses a fabrication process which allows the integration of complete digital and/or analog control circuits driving a vertical power transistor on the same chip. The power handling capability of this type of structure compares favourably with monolithic smart power devices of equivalent chip size which use lateral, or "U-turn" power output structures.

SMART POWER APPROACHES



The VIPower technology M0 used for making these High Side Drivers produces a monolithic silicon chip which combines control and protection circuitry with a standard power MOSFET structure where the power stage current flows vertically through the silicon.

CROSS SECTION OF MØ VIPower™ TECHNOLOGY



High Side Drivers, with their integrated extra features are power switches that can handle high currents and work up to about 40V supply voltage. They require only a simple TTL logic input and incorporate a fault condition status output. They can drive an inductive load without the need for a freewheeling diode. For complete protection the devices have an over-temperature sensing circuit that will shut down the chip under over-temperature conditions. They also have an under-voltage shutdown feature. It is simple to introduce some differences in the control logic to produce devices with features which cater for different working environments.

Each application exerts an external influence over the switch. A filament lamp or DC motor, for example, have in-rush currents that any switch has to handle. Solenoids and motors have an inductive effect and must lose the residual magnetism when the current is turned off. This gives rise to induced voltages and the need to remove this stored energy. External fault conditions can also stress the drivers and their associated circuitry. The following discussion has been designed to explain the basic principles involved in using these devices and to help to understand how they react under the influence of various applications.

Almost every electronic switch used in a modern automobile application is a high side switch. This configuration is preferred for automotive use because:

a) - This configuration protects the load from continuous operation and resulting failure, if there is a short circuit to the ground. Since the body of a car is metal and 95% of the total car is ground, the short to ground is much more common than short to V_{CC}

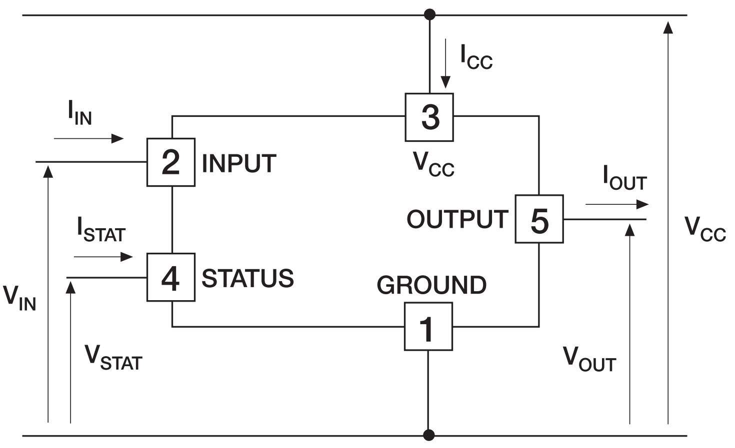
b) - High Side Drivers cause less problems with electrochemical corrosion. It is of primary importance in automotive systems because the electrical components are in an adverse environment, specifically adverse temperatures and humidity and the presence of salt. For this reason the series switch is connected between the load and the positive power source. Therefore when the electrical component is not powered (that is for the greatest part of the lifetime of the car) it is at the lowest potential and electrochemical corrosion does not take place.

Integrated High Side Drivers offer numerous advantages over the popular automotive relay used in cars today. Diagnostic information output from the High Side Driver helps the on-board microcontroller to quickly identify and isolate faults saving repair time and often improving safety. High Side Drivers can reduce the size and weight of switch modules, and where multiplexed systems are used, dramatically reduce the size of the wiring harness.

Process control applications offer another use for High Side Drivers. A considerable improvement in reliability and reduction in down time can be obtained by using them in place of relays. Process control systems, often consisting of powerful computers that control large numbers of actuators, are perfect environments for these devices. The semiconductor manufacturer has little control over the nature of the load being driven and these can vary - solenoids, motors, transducers, leds. In these situations, software process monitoring by a µP can detect a fault reported by a status output and offers the option of taking corrective action. In the unlikely event of a failure in a High Side Driver in critical processes, a second device can be programmed to operate instead.

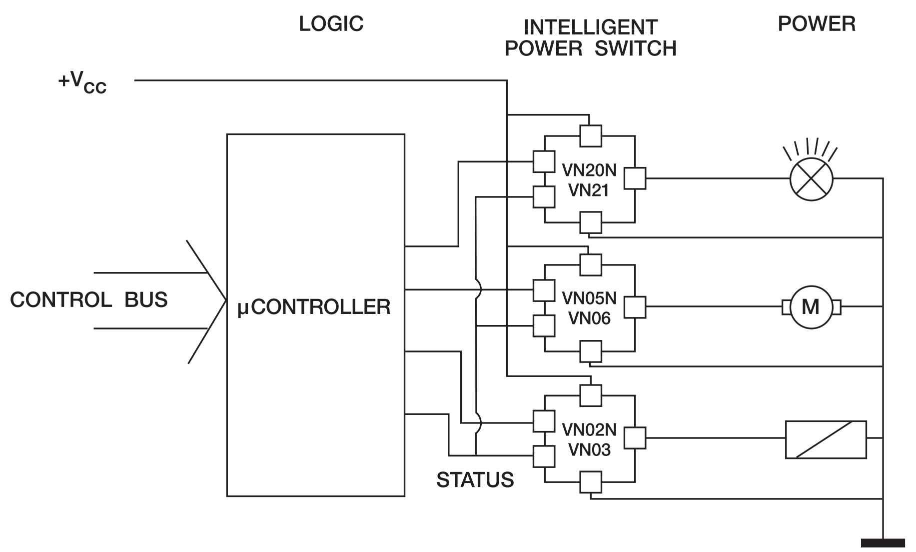
SGS-THOMSON High Side Drivers are designed to provide the user with simple, self protected, remotely controlled power switches. They have the general structure as shown in figure 1. Appendix I shows a table of the devices and summarizes their features.

Figure 1 : Standard current and voltage conventions



Some typical applications are shown in figure 2.

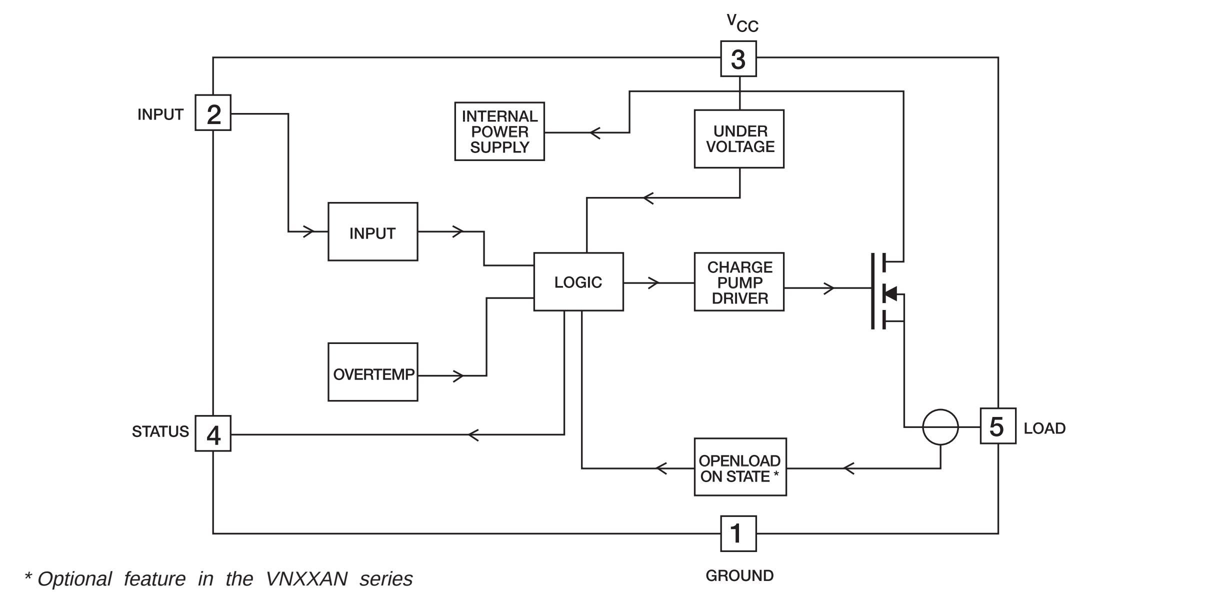
Figure 2 : High Side Drivers interfaces between control logic and power load



THE GENERAL FEATURES OF HIGH SIDE DRIVERS.

The diagram in figure 3 shows the control and protection circuit elements and the power stage of a basic device.

Figure 3 : Generic Internal Block Diagram



Input

The 5V TTL input to these High Side Drivers is protected against electrostatic discharge. General rules concerning TTL logic should be applied to the input. The input voltage is clamped internally at about 6V. It is possible to drive the input with a higher input voltage using an external resistor calculated to give a current not exceeding 10mA at the input.

Internal power supply

To accommodate the wide supply voltage range experienced by the logic and control functions, these devices have an internal power supply. Some parts of the chip are only active when the input is high, the status output and charge pump for example. This means it is possible to conserve power when the device is idle. The internal power supply has therefore been designed in two parts. One section supplies power to the basic functions of the chip all the time, even when the input is 0V. The second section supplies power only when the input is high. This ensures that the stand-by current is limited to 50µA maximum in the off-state.

THE CONTROL CIRCUIT.

Under voltage lock-out.

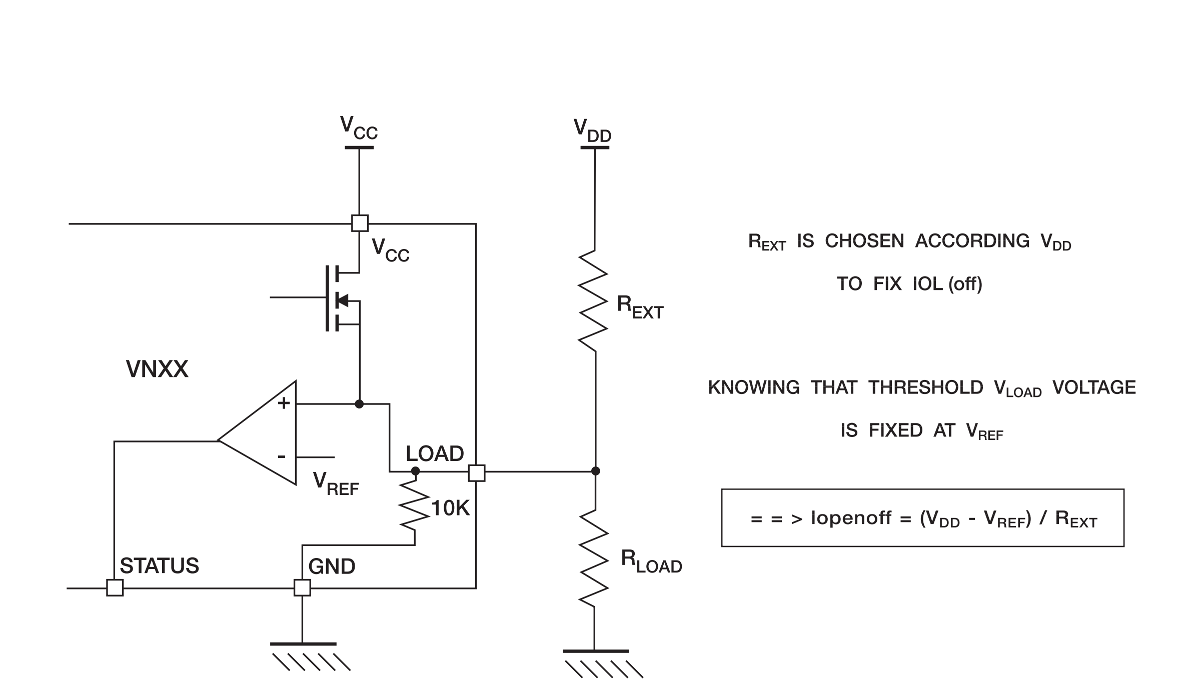
Under-voltage protection occurs when the supply voltage drops to a low level specified in the datasheet as V_{USD}. The under-voltage level set at this value ensures the device functions correctly. Inductive effects must be considered in understanding the function of this feature. The di/dt is controlled by the device and not by the external circuit. The controlled value is calculated for a line inductance of 5µH(≈5mt. of wire). Typically di/dt=0.5A/µs for a normal load and 1A/µs for a short circuit. At turn on this generates an opposing voltage. If this opposing voltage is too large, the apparent supply voltage will drop below the under-voltage lock-out level and the device will turn off. Using the specified conditions, the induced voltage will not be large enough to reduce the supply voltage below 6V. This is important in the case where the load is a near short circuit when in-rush current occurs, as in the case of a car headlamp filament turning on.

Open load detection and stuck-on to V_{CC}.

Open load detection occurs when the load becomes disconnected. In the VN20N family open load detection only occurs in the on-state.

An extra feature for load disconnection detection is that open load detection during the off-state as well as in the on-state can be provided. The circuit for the off-state open load detection requires an external resistor between V_{CC} and the output pin.

Figure 4 : Equivalent Schematic for the open load detection current in off-state



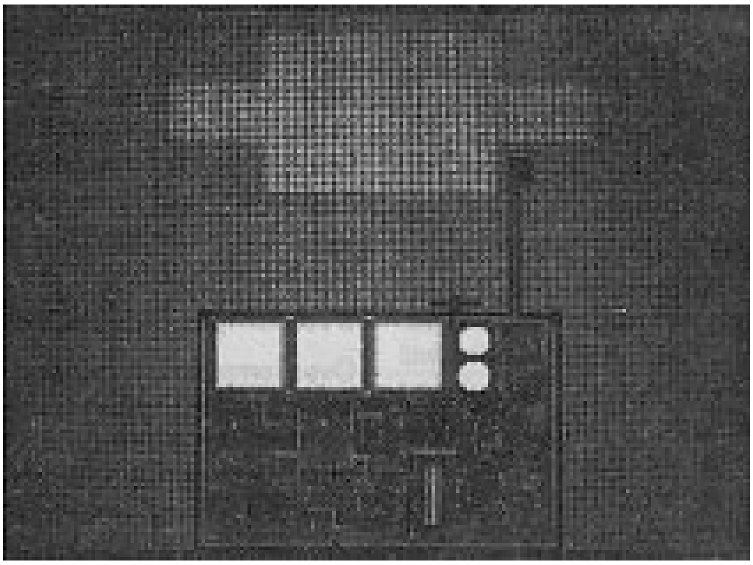
Open load detection is possible in the off-state in the VN21 family and it conforms to the I.S.O. norms for automotive applications. If an open load condition is detected the status flag goes low. Should an external supply be applied to the load (output pin) or the device is externally short circuited, the off-state open load detection can detect this “stuck-on” to V_{CC} condition.

Over-temperature protection

Over-temperature protection is based on sensing the chip temperature only. The location of the sensing element on the chip in the power stage area, ensures that accurate, very fast, temperature detection is achieved. The range within which over-temperature cutout occurs is 140°C - 180°C with 160°C being a typical level.

Over-temperature protection acts to protect the device from thermal damage and consequently also limits the average current when short circuits occur in the load.

Figure 5 : VN20N Die Layout - Note the thermal sensor inside the Power MOSFET Area



Driving the power MOSFET.

The power MOSFET output stage is driven by an internally generated gate voltage. A charge pump provides sufficient voltage to turn on the gate.

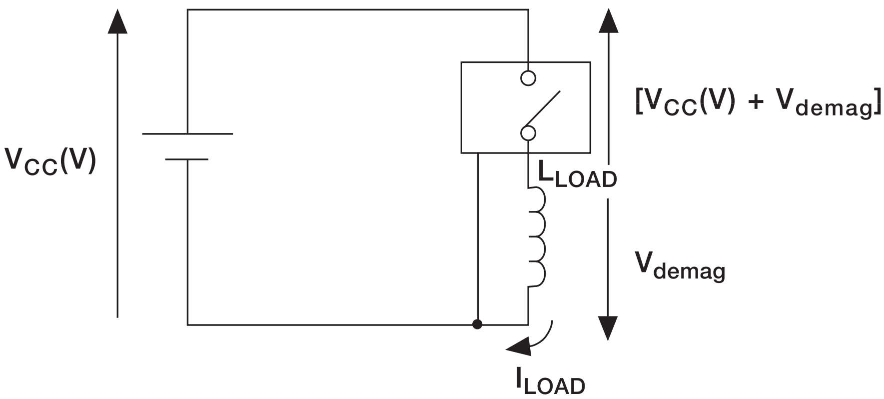
Turn-on

As previously explained, the High Side Drivers are turned-on with a controlled di/dt.

Turn-off: Normal and fast load demagnetization

When a High Side Driver turns off an inductance a reverse potential appears across the load. z

Figure 6 : Inductive load demagnetization turn-off for the VN20N family



The source of the power MOSFET becomes more negative than the ground until it reaches the demagnetization voltage, $V_{demag.}$, of the specific device. In this condition the inductive load is demagnetized and its stored energy is dissipated in the power MOSFET according to the equation shown below:

$$P_{demag.} = 0.5\ L_{load}\ [I_{load}]^2 \cdot \frac{[V_{cc} + V_{demag.}]}{V_{demag.}} \cdot f$$

where f is the switching frequency and $V_{demag.}$ the demagnetization voltage.

In the basic High Side Driver family the typical value of, $|Vdemag.|$ is = 4V.

In the I.S.O. and industrial series,to reduce the dissipated energy, an internal circuit has be added in order to have a typical $|Vdemag.|$ = 18V.

In this condition the stored energy is removed rapidly and the power dissipation in the power MOSFET is reduced - see equation. Figure 7a/b compares the waveforms of the normal and fast demagnetization techniques.

Figure 7a/b : VN20N-VN21 Driving an Inductive Load

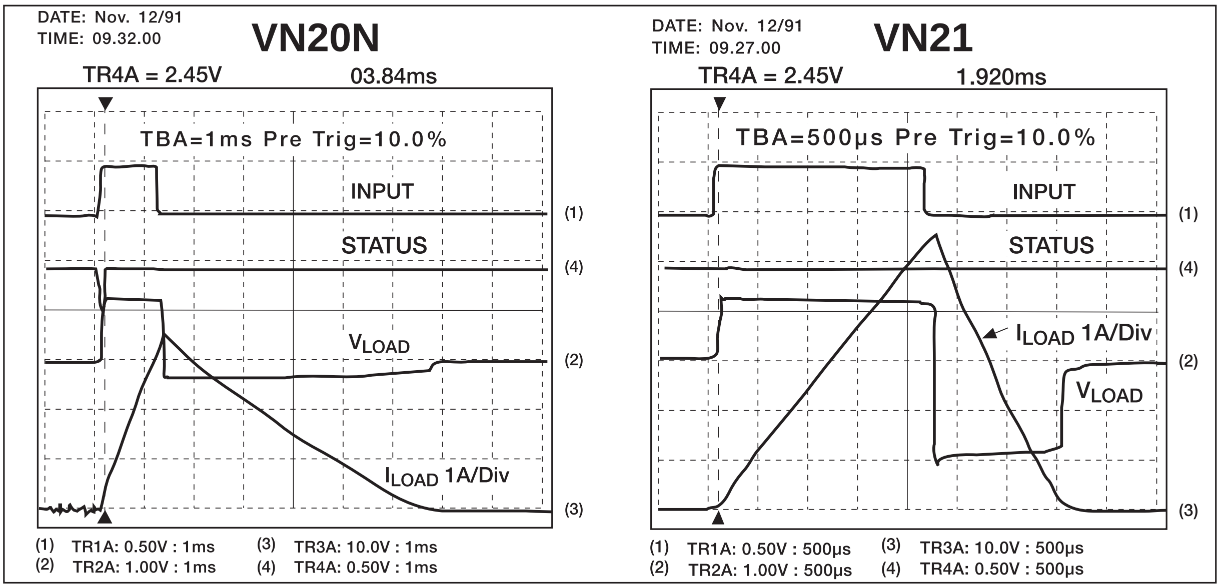
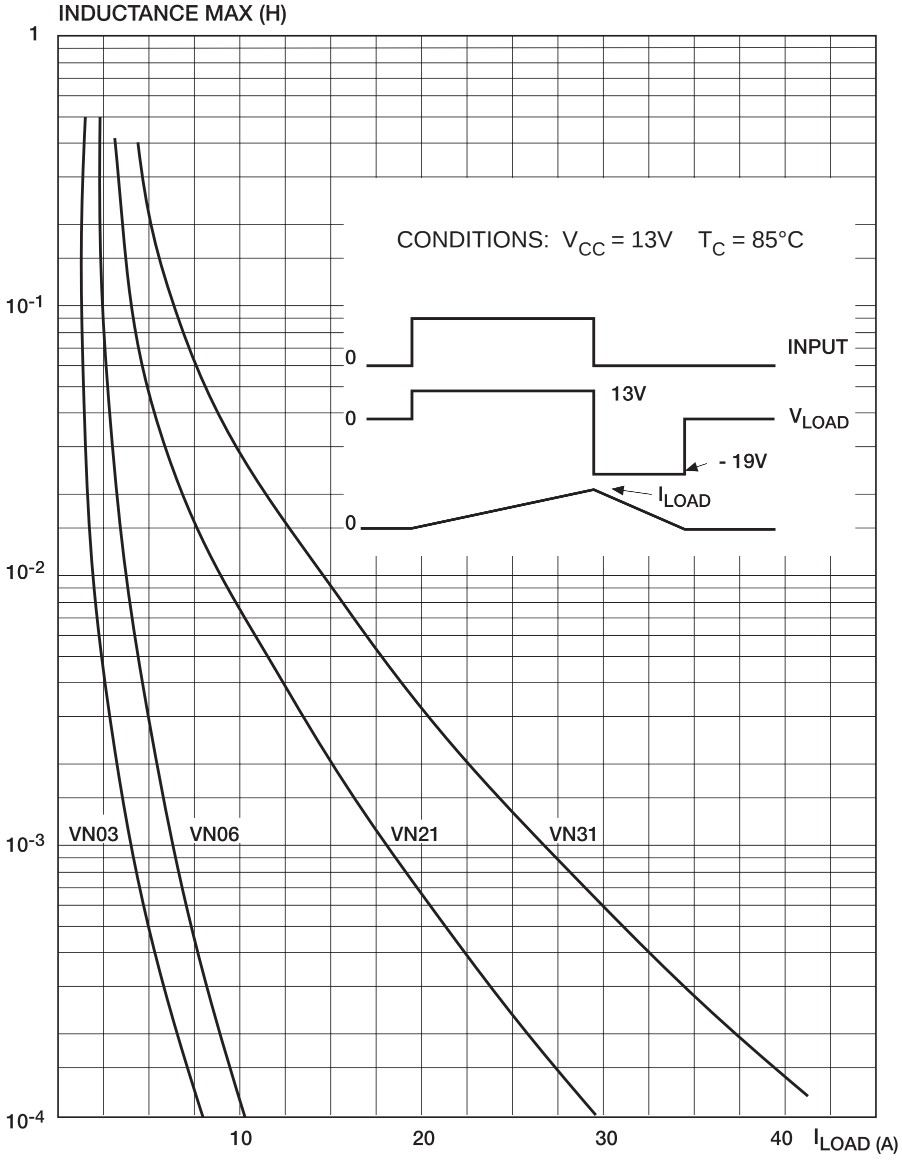


Figure 7b shows the VN21 driving an inductive load. During the on period, the current in the load rises linearly to a maximum. At turn-off the current decrease linearly, but, at a sufficiently fast rate for fast demagnetization of the load. There is no fault output from the status pin. In the VN20N, the basic High Side Driver with no special feature for fast demagnetization, the turn-off takes up to 5 times longer than the VN21. Note that the status output will pulse at turn on because the internal circuit detects a very short duration open load, see figure 7a.

The maximum inductance which causes the chip temperature to reach the shut down temperature in a specified thermal environment, is a function of the load current for a fixed V_{CC}, $V_{demag.}$ and switching frequency. This is the maximum rate at which the drivers can be demagnetized. Figure 8 shows the maximum inductance for a given load current for devices meeting I.S.O. requirements, assuming a chip temperature of 160°C at turn-off and a supply voltage of 13V. The values are for a single pulse with 85°C case temperature. Note that the devices are not protected against overtemperature during turn-off.

Figure 8 : Max inductance which produces a temperature of 160°C at turn off with Vcc = 13V. The values are for a single pulse with Tc = 85°C



Additional Features of the High Side Drivers

High Side Drivers are designed for use in various market segments, the precise requirements of the drivers varying a little with the application. There are additional features to accommodate these requirements.

To reduce the on-state quiescent current for some applications, particularly industrial ones, the open load detection circuit is not included. There will consequently also be a lower power dissipation, an important point when similar, multiple High Side Drivers are mounted on one board. It can means the difference between using or not using a heatsink.

The operating voltage range can vary e.g. 5.5V to 26V for automotive applications and 7V to 36V for process control. Some devices have fast demagnetization of the load, ground disconnection protection, on- and off- state open load detection and 5ms filtering of the status output.

Status output and status output signal filtering.

The difference in electrical behaviour between the non-filtered and the filtered High Side Drivers is that the status output filtering circuit provides a continuous signal for the fault condition after an initial delay of about 5ms in the filtered version. This means that a disconnection during normal operation, with a duration of less than 5ms does not affect the status output. Equally, any re-connection during a disconnection of less than 5ms duration does not affect the status output. No delay occours for the status to go low in case of overtemperature conditions. From the falling edge of the input signal the status output initially low in fault condition (overtemperature or open load) will go back high with a delay t_{POVL} in case of overtemperature condition and a delay t_{POL} in case of open load. These features fully comply with International Standards Office, (I.S.O.), requirements for automotive High Side Drivers.

ABNORMAL LOAD CONDITIONS:

Load short circuits

Should a load become short circuited, various effects occur and certain steps need to be taken to deal with them, particularly choosing the correct heatsink. Two clear cases of short circuit occur:

1. The load is shorted at start-up.
2. The load becomes short during the on-state.

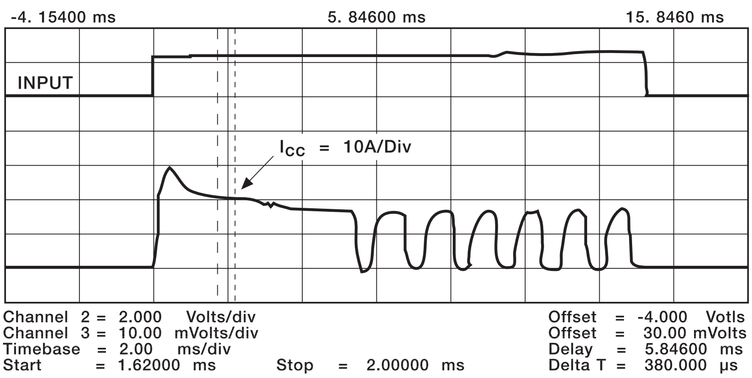
Start-up with the load short circuited.

At turn-on the gate voltage is zero and begins to increase. Short circuit current starts to flow and power is dissipated in the High Side Driver according the formula:

$$P_d = V_{DS} \times I_D$$

The effect is to cause the silicon to heat up. The power MOSFET stays in the linear region. When the silicon temperature reaches about 160°C the over temperature detection operates and the switch is turned off. Passive cooling of the device occurs until the reset temperature is reached and the device turns back on again. The cycle is repetitive and stops when the power is removed, the input taken low or the short circuit is removed.

Figure 9 : Automatic Thermal cycle at start - up with the load short - circuited.

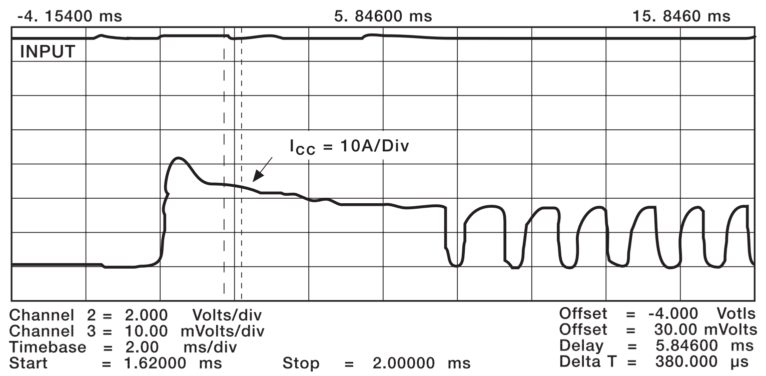


Even in this configuration, the device controls the di/dt. Figure 9 shows a start-up when there is a short circuited load driven by a VN05N. The initial peak current is 30A for this 180mΩ device.

A short circuit occurring during the on-state.

When a short circuit occurs during the on-state, the power MOSFET gate is already at a high voltage, about V_{CC}+ 8V, so the gate is hard on. Hence the short circuit di/dt is higher than in the first case, and only controlled by the load itself. After the steady state thermal condition is reached, thermal cycling is the same as in the previous case.

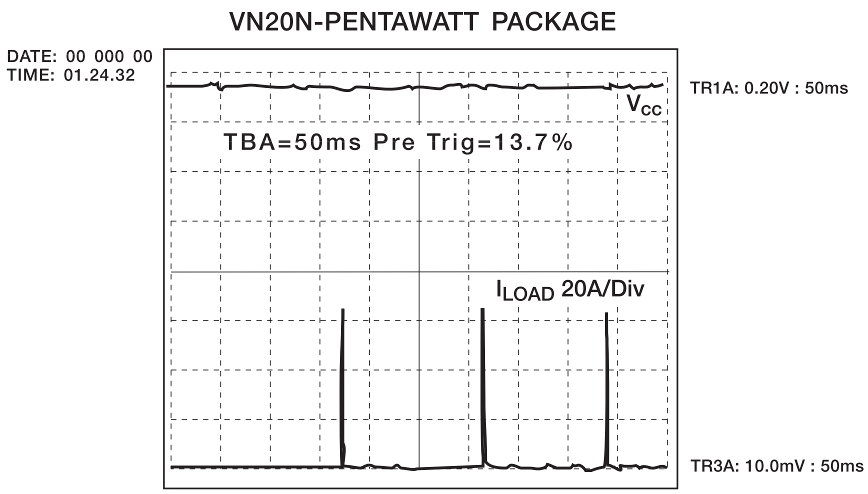
Figure 10 : Automatic thermal cycle for a short circuit occouring during the on - state



Automatic thermal cycle.

The thermal cycling in overload conditions produces repetitive current peaks. The device switches on, the silicon heats up until the over-temperature sensing acts to turn the device off. The rate of passive cooling depends on the thermal capacity of the thermal environment. This, in turn, determines the length of the off-state during thermal cycling.

Figure 11 : Automatic Thermal cycle in overload condition



It is important to evaluate the average and RMS current during short circuit conditions. This is required in order to determine the track dimensions for printed circuit boards and the correct value for any fuse used. In all practical situations there is no danger to pcb tracks from these high peak current for track designed to handle the nominal load current.

Evaluating the Average current

In steady state conditions the junction temperature oscillates between Tj (shutdown) and Tj (reset).

Tj(av.)=(Tj(shutdown)+Tj(reset))/2 $\approx$ 135°C

Dissipated power:

$P_D = I_{(AV)} \times V_{CC}$

For a specific package

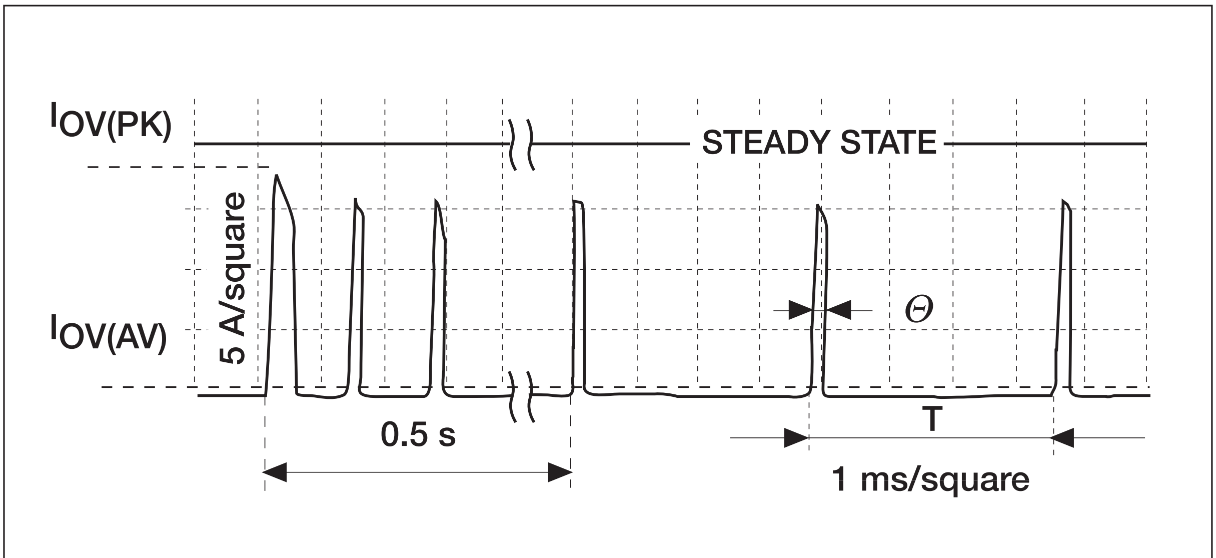
$P_D = (T_{J(AV)} - T_{case}) / R_{thj\text{-}case}$

$I_{(AV)}=(T_{J(AV)} - T_{case}) / (R_{thj\text{-}case} \times V_{CC})$

Note that $I_{average}$ does not depend on the peak current $I_{(PK)}$.

Example:
VN21 with T_{case} = 85°C has an average current, $I_{(AV)}$ = 3.85A,
at $R_{thj\text{-}case}$ = 1°C/W and V_{CC} = 13V
The average current is independent of the peak current.
Generally, a current limiter does not decrease the average current.

Figure 12 : Average current during an hard short - circuit test



Evaluating the RMS current

The RMS current, I_{RMS}, generates heat in the copper track on PCBs during short circuits.

$$I_{(RMS)}^{\ 2} = 1/T \int_0^T I^2(t)dt$$

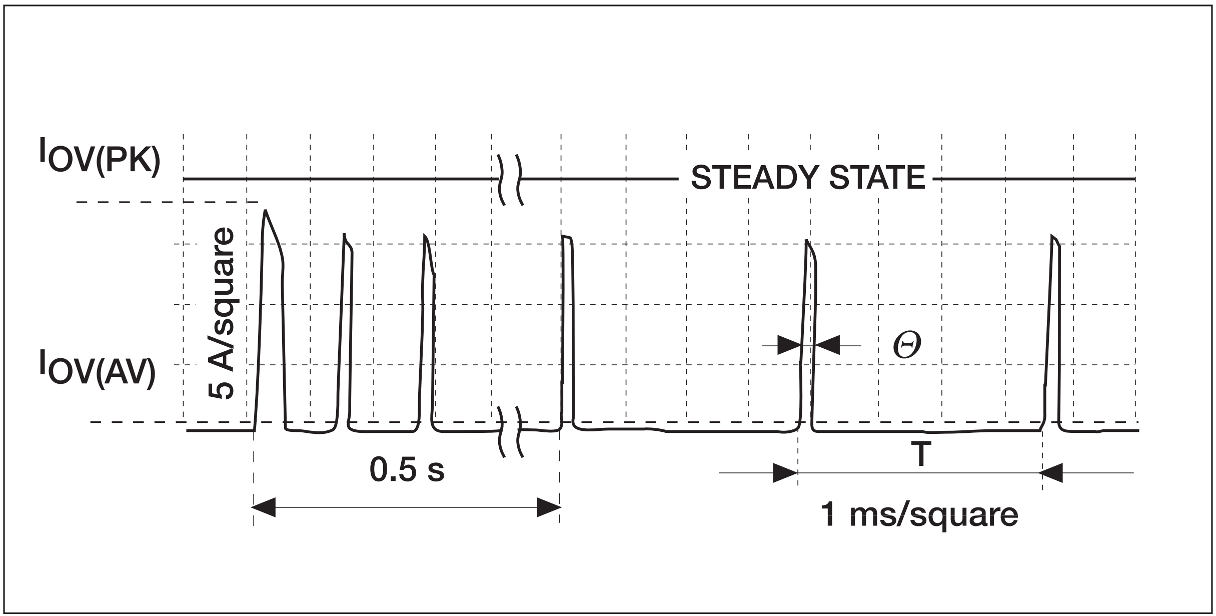
$I_{(RMS)} = I_{(PK)} \times \sqrt{\Theta/T}$, where Θ/T is the duty cycle.

with $I_{(AV)} = 1/T \int_0^T I(t)dt = I_{(PK)} \times \Theta/T$

$I_{(RMS)} = \sqrt{(I_{(PK)} \times I_{(AV)})}$

The RMS current increases proportionally to the square root of the peak current --> +40% if $I_{(PK)}$ is doubled. Schemes to limit the current do not decrease the RMS current significantly.

Figure 13 : RMS current during an hard short-circuit test



Heatsink requirements.

Overload protection is based on device heating. If you want to detect an overload, i.e a damaged load, the chip must be allowed to heat up so that the thermal sensor located on the chip is activated. This leads to the following general rules for sizing heatsinks for the VN High Side Drivers.

1. Do not use a too big heatsink.
2. Do not use a VN device which has R_{ON} much lower than that which the application requires.

This example illustrates a specific case.

Situation:

- a supply voltage of 14V,
- a load resistance of 2Ω,
- VN20N - $R_{DS(on)}$ at 25°C = 50mΩ
- load current = 7A

To detect an over current of 20A, assuming that $R_{DS(on)}$ at 150°C = 100mΩ (see datasheet) hence:

$P_D = (20)^2 \times 100 \times 10^{-3} = 40W$

R_{thj-a} should be dimensioned for

$\Theta_{thermal\ shutdown} - \Theta_{Ambient} < P_D \times R_{thj-a}$.

For example 160°C - 25°C < 40W x R_{thj-a}

The effects of load disconnection.

When a load becomes disconnected there can be over-voltages caused by the change of load current. Figures 14a/b summarizes the likely effects. Figure 14a, shows a load driven by a VN21. The supply to the VN21 has a very low parasitic inductance. When the load becomes disconnected, the current changes at a rate determined by the time taken for the load to disconnect. This controls di/dt .

Figure 14a/b : Example of possibles situations during a load disconnection

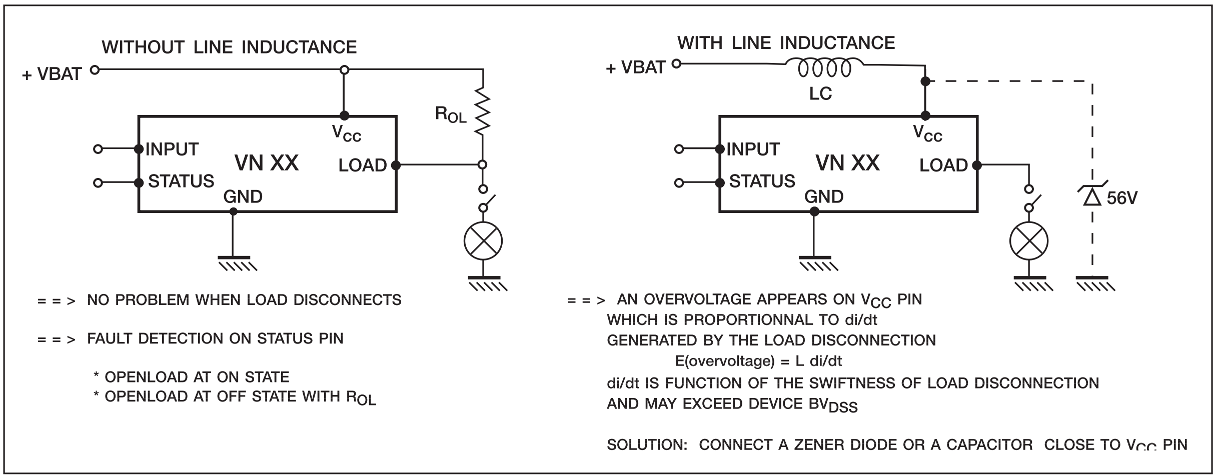
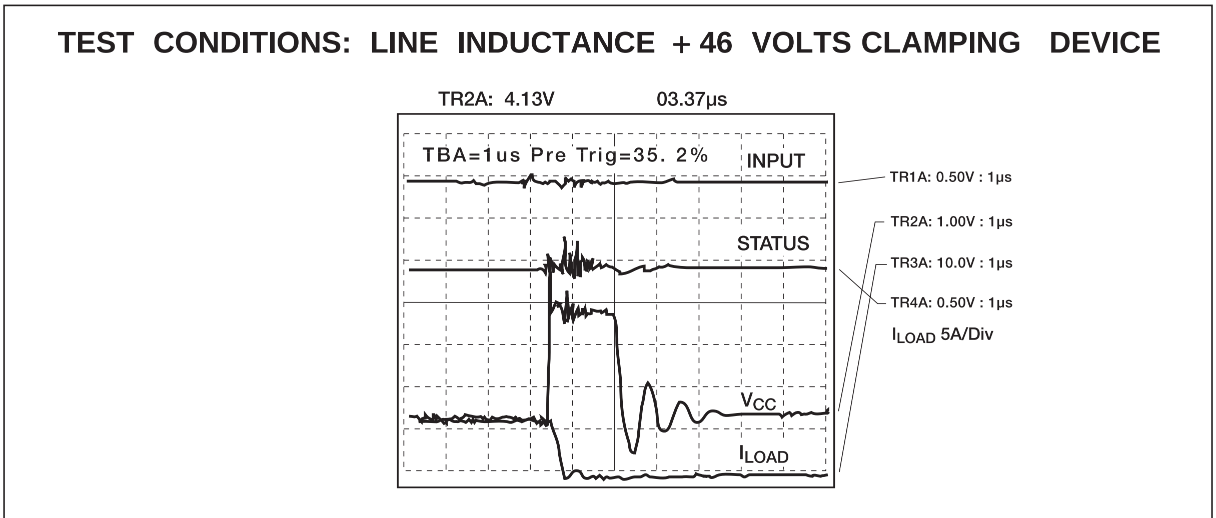


Figure 14c : Behaviour of a VN21 during a load disconnection



In this present case, there is virtually no inductance in the supply line. Hence no over-voltage is generated and V_{cc} is unaffected. The status pin goes low to indicate an open-load state

In the second case illustrated, figure 14b, the supply line has parasitic inductance and capacitance. When the load is disconnected an over-voltage is generated, ($V_{over\text{-}voltage}$ = L di/dt). The di/dt is not controlled by the device but by how fast the load is disconnected. It is possible that the over-voltage may exceed the breakdown voltage of the device. It is a wise precaution where the supply connection pins are likely to have some inductance, to use a 56V zener diode or a capacitor close to the supply pin of the switch. Figure 14c shows a test made using a zener clamp to overcome line inductance.

PROTECTION AGAINST GROUND DISCONNECTION

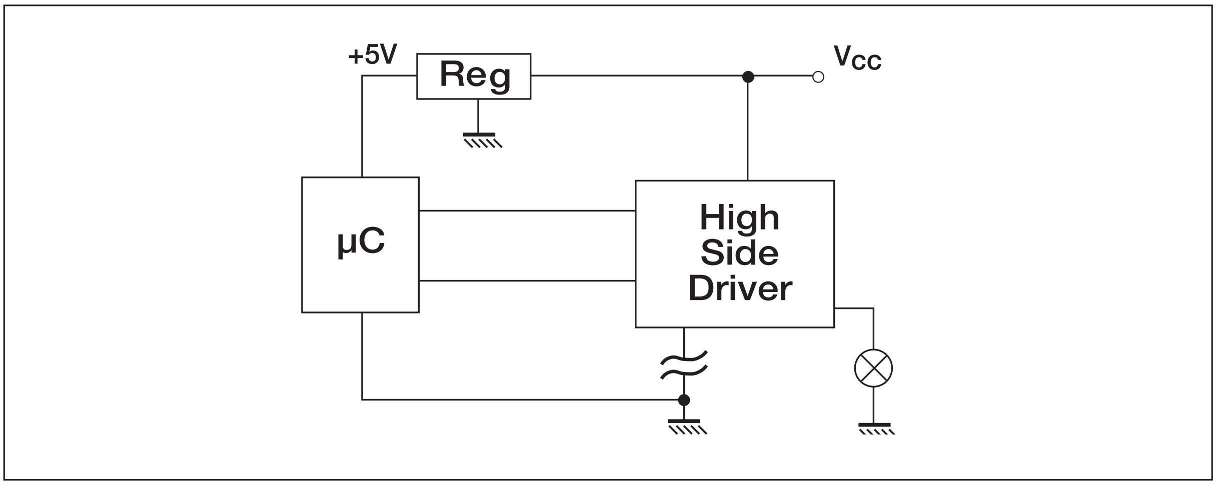
There are a number of distinct situations that can occur when one of the ground connections is broken in circuits using the High Side Drivers.

The first case, shown in fig. 15a, is when the GND pin of the High Side Driver is disconnected while the μC and the load are connected to ground. In this case in the I.S.O. and industrial High Side Drivers nothing happens and the device remains off. In the VN20N family a voltage of about 2V appers on the load and conseguently there is a power dissipation:

$P_D = (V_{CC} - 2) \cdot I_{LOAD}$

usually very low. In these conditions the diagnostic is not functioning.

Figure 15a : Possible ground disconnection occurring when a High Side Driver is connected to a μController (case 1)

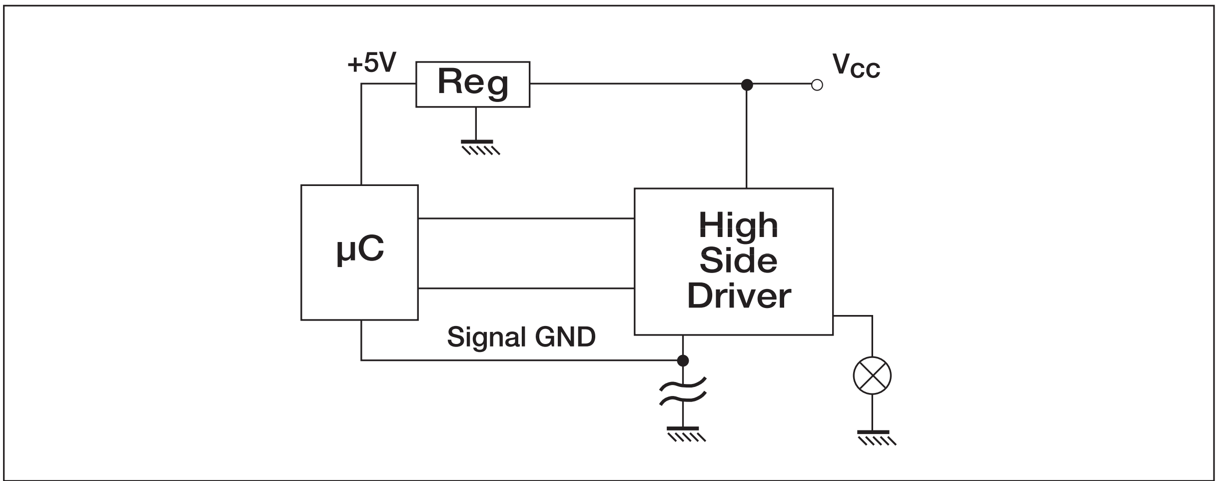


The second case, shown in fig. 15b, is when both the GND pins of the High Side Driver and of the μC are disconnected while the load is connected to ground. In this situation the signal GND rises up to V_{CC}. In the I.S.O. and industrial High Side Drivers nothing happens up to V_{CC}<18V and the diagnostic output remains in high state at V_{CC}. In the VN20N family a voltage of about 4V appears on the load and conseguently there is a power dissipation:

$P_D = (V_{CC} - 4) \cdot I_{LOAD}$

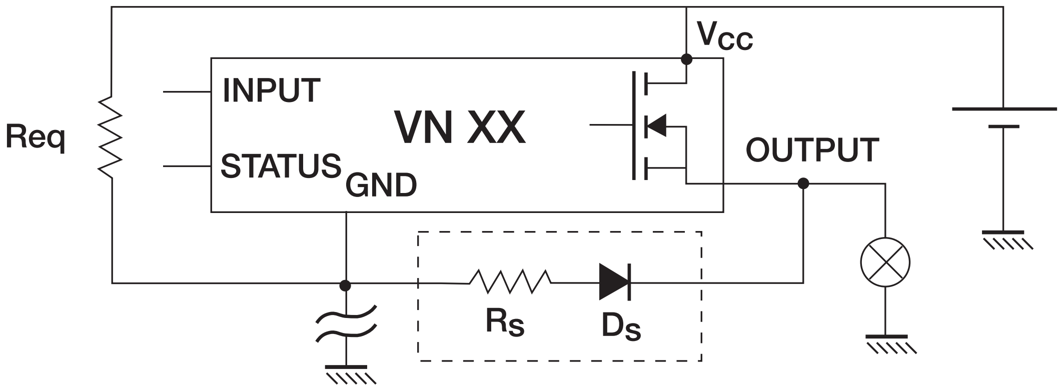
If P_D is excessive with respect to the heatsink capability, destruction may occurs since the protections are not functioning. The load is permanently activated.

Figure 15b : Possible ground disconnection occurring when a High Side Driver is connected to a μController (case 2)



Another practical case is when an external component supplies current to the High Side Driver GND pin which is disconnected from the ground. This might occur if the VN device is mounted on a local PCB with other devices and has a local ground while the load may be grounded to the frame or body of the equipment, figure 16. Also, in this case, for internally protected devices, the output remains off up to the point where the voltage on the GND pin is ≤ 18V with reference to real ground at 0V. This will reduce the maximum V_{CC} the High Side Driver is able to withstand before turning on with the control circuit in-operative. One solution to this problem is to insert a resistor and diode in between the device GND pin and the output pin. The series resistor, Rs, must be calculated so that the sum of the current, Is, of the High Side Driver chip connected to the GND node plus the current drawn by the external elements, produces a voltage drop of less than 18V across Rs + Ds + R_{load} for I.S.O. or industrial High Side Drivers and less than 2V for STD devices.

Figure 16 : Ground disconnection occuring when an equivalent resistor supplies current on the GND pin.



CONCLUSION

The VN series of High Side Drivers offers designers a highly attractive method of controlling a variety of inductive and resistive loads. The option to use a selection of extra features such as fast demagnetization or status filtering makes them equally suitable for general or specialised use, typically in the automotive environment.

VIPower

60V $B_{(BR)DSS}$ HIGH SIDE DRIVERS PRODUCT RANGE

DEVICE	$R_{DS(on)}$ @ 25°C (mohm)	V_{CC} Range (V)	PACKAGE	EXTRA FEATURES
VN02N	400	7 - 26	Pentawatt/PowerSO-10™	
VN05N	180	7 - 26	"	
VN20N	50	7 - 26	"	
VN30N	30	7 - 26	"	
VN03	500	5.5 - 26	Pentawatt/PowerSO-10	■ ○ ✱
VN06	180	5.5 - 26	"	■ ○ ✱
VN21	50	5.5 - 26	"	■ ○ ✱
VN31	30	5.5 - 26	"	■ ○ ✱
VN02AN	350	7 - 36	Pentawatt/PowerSO-10	■
VN20AN	50	7 - 36	"	■
VND05B(*)	200	6 - 26	Heptawatt/PowerSO-10	■ ○ □
VND10B(*)	100	6 - 26	"	■ ○ □
VN16B(*)	60	6 - 26	Pentawatt/PowerSO-10	■ ○
VN02H(*)	400	5 - 36	Pentawatt/PowerSO-10	

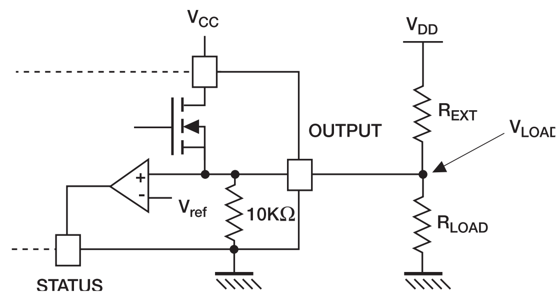
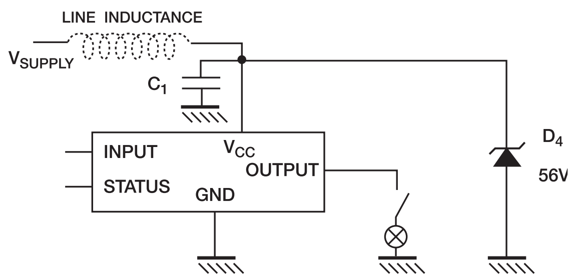
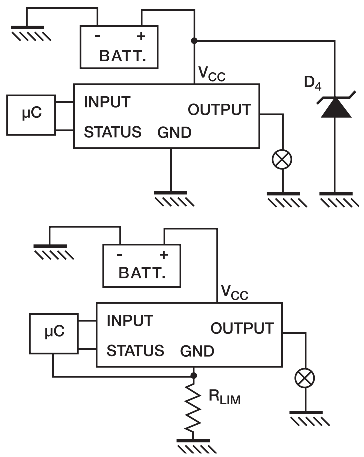
(*) Application information as described in the Note apply also to these devices

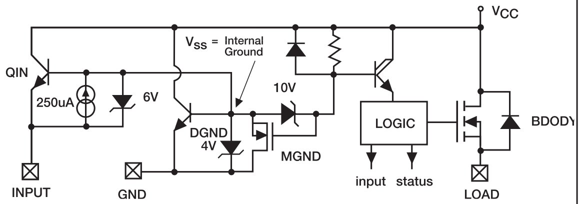
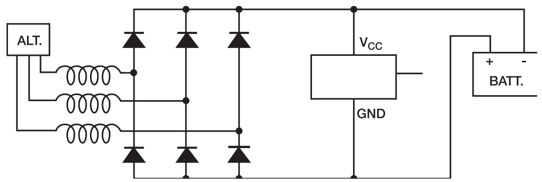
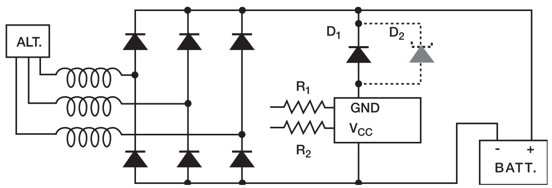
■ *Fast demagnetization & ground disconnection protection*

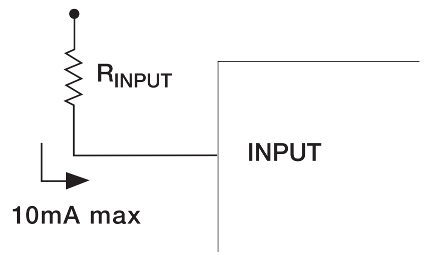
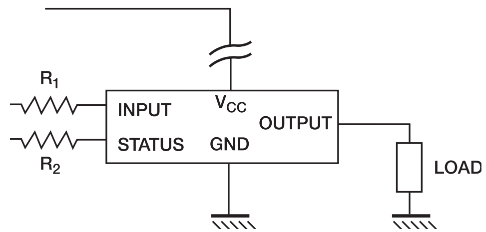
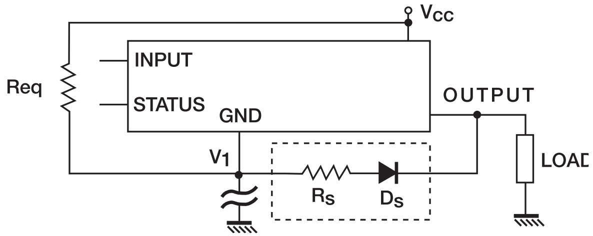
○ *Open load detection off state + stuck-on to V_{CC}*

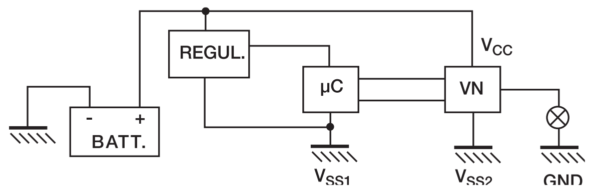
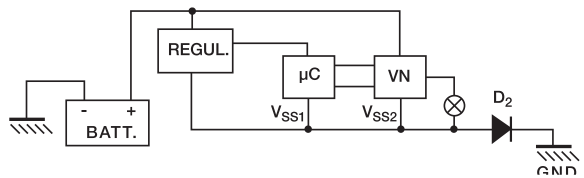
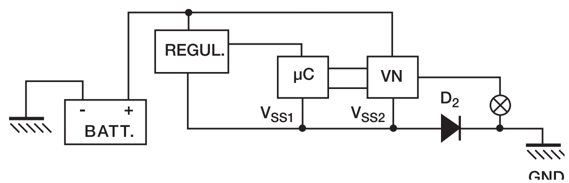
✱ *5msec STATUS FILTERING (ISO STANDARD)*

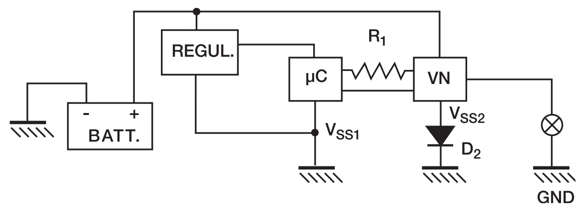
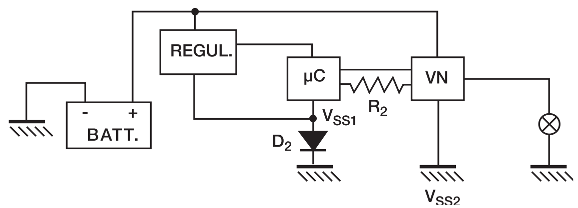
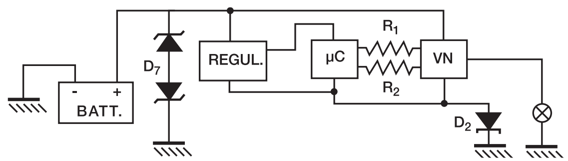
□ *Double channel*

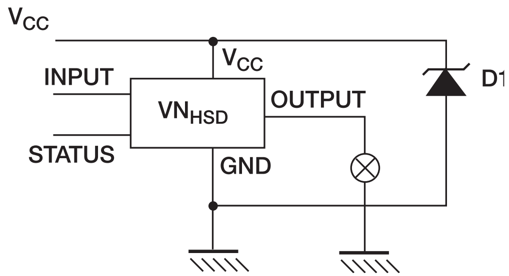
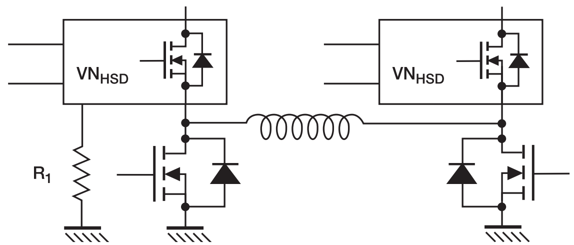
	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
1	Off-state open load detection	VN03 VN06 VN21 VN31 [illegible]	R_{EXT}	It is necessary to set the current that fixes the voltage, V_{LOAD}, in the off state. When R_{LOAD} fails - goes open or high resistance - V_{LOAD} increases and an internal comparator triggers the status flag to go low.		**Choose R_{EXT} to match V_{DD} to fix $I_{OL(off)}$. The threshold V_{LOAD} is fixed at V_{REF}.** **$I_{OL(off)} = (V_{DD} - V_{REF}) / R_{EXT}$.** **The open load detection in off-state is only possible for a nominal value of**
2	Voltage spike on V_{CC} when load disconnects.	**ALL**	D4 or C1	If the line inductance is not zero and di/dt caused by disconnection of the load is high, an over voltage $E = L \cdot di/dt$ appears on V_{CC}. The $V_{(BR)DSS}$ of the output power MOSFET could be exceeded.		Use a 56V zener diode to clamp V_{CC} or put a capacitor, C1 (about 100nF), near V_{CC} pin.
3	Over voltage on V_{CC} from external circuit	**ALL**	D4 or R_{LIM}	**D4 can be used as a decentralized clamp (V_{CC} clamp and energy clamp). Otherwise a resistor, R_{LIM}, can be added on the ground pin to limit the current in the signal section of the device in case it exceeds the signal path breakdown voltage.**		R_{LIM} = 150Ω is a general value to protect devices from the effects of a load dump. Refer to the specific data sheet.

	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
4	Supply reversal	ALL		Refer to the equivalent schematic seen by user through pins: Load, Input, GND		*V_{CC} > 1V →MGND"ON"→VSS= GND Normal case *-4 < V_{CC} < 0 →MGND OFF →No current accross input and GND pins →A DC current flows in the load and DBody WARNING : If the load is an inductance with a parallel free wheeling diode, the user sees 2 forward biased diodes between GROUND and V_{CC}. →Do not exceed imax to prevent damage.
5	Supply reversal - case 1	ALL		Battery connection reversed; correct connection of the High Side Driver devices.		If the battery is short circuited by 3 x 2 series diodes (typically an alternator diode configuration) the supply voltage, $V_{CC,}$ is clamped to about -3V and no damage occurs to the VN device.
6	Supply reversal - case 2	ALL	D1 or D2	**High Side Driver reverse connected with the battery correctly connected.**		**V_{CC} for the device is -13V. To prevent damage to the device use either a bipolar or Schottky diode in series with the ground pin connection. Use R1 and R2 to limit the negative current in the input and status pins because the internal ground drops to V_{CC}.**

	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
7	Input driving.	ALL	R_{INPUT}	Driving the input from a voltage greater than 6V		To drive the input from a line voltage > 6V insert a series resistor to limit the input current $I_{IN\ max}$ < 10mA
8	Pin disconnection - V_{CC}	ALL	R1 R2	Driving an inductive load, this kind of disconnection has the same electrical effects as V_{CC} reversal.		1) Resistive load - no problem of damage. 2) Inductive load - V_{CC} reversal occurs. If current and inductance of leads are too high the device may be damaged but the safety margin is wide - up to 100mH and 8A for the VN21 In this case, input and status pins are pulled to a negative voltage so it is recommended to insert resistors in series with these pins in order to protect the µC.
9	Pin disconnection - Ground	VN03 VN06 VN21 VN31 VN02AN VN20AN		An external component, Req, supplies current to the High Side Driver GND pin. The local ground is separate from the load ground.		The devices are internally protected (output stage off) if the voltage on the GND pin is ≤ 18V with reference to the real ground at Ø V. To avoid the High Side Driver to turn-on if GND is over 18V is possible insert Rs and Ds as shown in figure. Choose Rs so that V_1<18V

	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
10	Ground potential differences	ALL		Voltage range for all High Side Drivers is defined between V_{CC} and V_{SS2} (VNxx GND). All voltages V_{IL}, V_{IH}, V_{USD} are refered to V_{SS2}.		If V_{SS1} and V_{SS2} are different, recalculate V_{IL}, V_{IH}, V_{USD} and beware of application bugs. (See points 11/12/13/14)
11	Ground potential differences - case 1	ALL	D2	Using power diode to withstand reversed battery. Case 1: V_{SS1} = V_{SS2} =/= GND with V_{SS1} > GND		Voltage losses in power diode. Input and status levels are not effected. Under-voltage shutdown level increased by diode V_F. Off-state open load level, V_{REF}, increased by V_F. A general rule is: level shift is (V_{SS2} - GND).
12	Ground potential differences - case 2	ALL	D2	Using a diode to protect the High Side Driver against reversed battery. (See point 6 above) V_{SS1} = V_{SS2} =/= GND with V_{SS1} > GND		The input and status are unaffected. V_{USD} = (V_{SS2} - GND) + V_{USDo}. Off-state open load level, V_{REF}, is increased by (V_{SS2} - GND).Not suitable if the µController uses an analog transducer referred to ground.

	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
13	Ground potential differences - case 3	ALL	R1, D2	Using a diode to protect the High Side Driver against reversed battery. V_{SS1} =/= V_{SS2}. $V_{SS2} > V_{SS1}$		V_{IL} and V_{IH} shifted by (V_{SS2} - $V_{SS1)}$. R1 limits any negative current when the µController takes I/O to ground .On the status pin the zero corresponds to the V_F of D2, V_{USD} and V_{OL} being increased by (V_{SS2} - GND).
14	Ground potential differences - case 4	ALL	R2, D2	Using a diode to protect the µC against reversed battery. V_{SS1} =/= V_{SS2}. $V_{SS2} < V_{SS1}$		In fault conditions the device pulls the status pin down to V_{SS2} and the µController sees a negative voltage - (V_{SS1} - V_{SS2}). There is a risk of latch up for the µController CMOS output. Add R2 to limit the current. Undervoltage and off-state open load levels are not shifted.
15	Summary of the influence of ground differences, pin disconnections and over voltage protection.	ALL	R1, R2, D2, D7.	Recommended scheme		* common ground for µController and VN device * Reversed battery protection - Schottky diode * Series resistor for input and status pins * Over-voltage protection - bi-directional Zener

	SYMPTOM	DEVICE	COMPONENT	COMMENT	SCHEMATIC	NOTES
16	Load dump: battery disconnection whilst the alternator is working	ALL	D1	High voltages can be generated if the battery is disconnected when the generator is running in a car. Damaging effects can be overcome by using a clamping diode with at least V_{BR} > 26V as 2 x 12V batteries are often used to jump start cars. This for overvoltage transient higher than specified in datasheets.		Protection against over-voltages are efficient if connected between pin 3 (V_{CC}) and pin 1 (ground).
17	$V_{LOAD} > V_{CC}$ (Bridge circuit)	ALL	R1	In full bridge applications during the demagnetization phase $V_{LOAD} > V_{CC}$. A current will flow out of GND pin, possibly damaging the bonding.		Insert a resistance, R1 (suggested value 47Ω), in the ground pin to limit the ground current and avoid damaging the bonding.