APPLICATION NOTE

THE VB027: ELECTRONIC IGNITION IN VIPOWER™ TECHNOLOGY

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ABSTRACT

This paper describes a solid state integrated ignition driver circuit designed to drive a high energy coil in a microprocessor based EMS (Engine Management System) under the direct control of a micro-controller.

The paper begins with a review of the principal characteristics of SGS-THOMSON Microelectronics' Vertical Intelligent Power technology, and then introduces the VB027, a novel fully-protected switch for electronic ignition which directly interfaces with a microprocessor controller.

INTRODUCTION

The trend for cleaner, lean-burn engines has lead to the increased use of microprocessor-based Engine Management Systems (EMS) with electronic ignition.

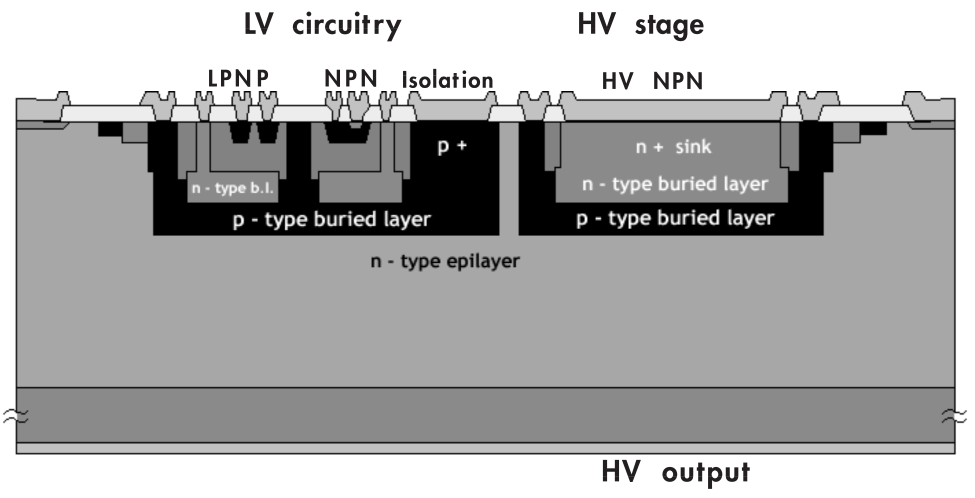
The main requirements for the power switch in ignition applications are for an easy to drive, rugged device capable of blocking 350 to 400 Volts and conducting 8 to 9 Amperes with less than a 2 Volts drop. Bipolar Darlington Transistors have traditionally been used, but recently alternatives have appeared on the scene. VIPower (Vertical Intelligent Power) devices are the most promising.

Smart power technologies attempt to close the gap between discrete power devices and integrated circuits. They have been developed with two goals in mind: to achieve the same current capability and breakdown voltage as a discrete power device, and to integrate smart functions with only a small increase in the cost of the device. These technologies are inevitably the result of a compromise between optimum power handling and signal processing versatility. VIPower M1 technology has allowed the development of a family of devices for automotive ignition, for example the VB027, that allows a simple logic-level driving circuit together with increased ruggedness. Moreover, the latest generation permits TO-220 packaging rather than TO-218 and, at the same time, offers more intelligence on a single chip.

TECHNOLOGY OVERVIEW

The VIPower M1 structure shown in Figure 1 combines a vertical current flow NPN power transistor and a low-voltage junction insulated IC on the same silicon substrate. The signal processing section is constructed inside a diffused p-type buried layer that takes the place of the reverse-biased p-substrate of conventional ICs, and must be connected

Figure 1. VIPower M1 technology overview

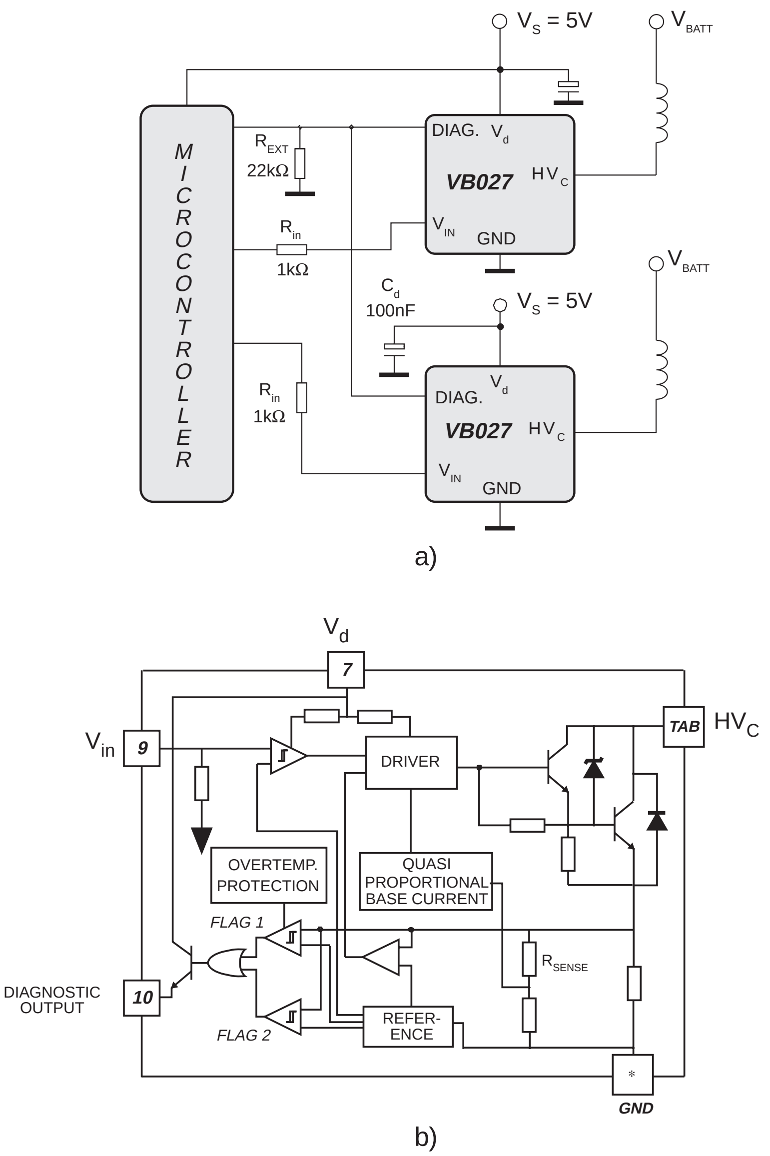


to the most negative supply. The selection of an n-type substrate as the starting point allows complete compatibility between vertical NPN and IC fabrication steps. As in standard power NPN, the thickness and resistivity of the first epi layer set the BV_{ceo} and the ruggedness of the high voltage device, whereas the second epi growth defines the characteristics of the low voltage device. The choice of a suitable value for the substrate thickness and resistivity, together with an appropriate edge termination, allows the structure to handle any blocking voltage up to 1.2kV.

FUNCTIONAL DESCRIPTION

The VB027 is a solid state integrated ignition driver circuit designed to drive a high-energy coil under the direct control of a micro-controller. It is constructed utilising VIPower M1 technology, the Vertical Intelligent Power technology from SGS-THOMSON Microelectronics. The typical system configuration and block diagram of the device are shown in figure 2.

Figure 2. a) Application circuit
b) Block diagram



Its main features are:

- minimum external components required
- coil current limit internally set
- built-in collector-emitter voltage clamping
- TTL/CMOS compatible input
- output diagnostic to microprocessor for dwell angle control and overtemperature protection
- die-size compatible with TO-220 package.

The input V_{in} of the VB027 is fed by a low power signal generated by an external controller that determines both dwell time and ignition point.

During V_{in} high, Figure 3, the power output of the VB027 is turned on and the current in the primary of the ignition coil increases until it reaches the internally set maximum current level.

The device then regulates the output current in a stable dwell regulation loop through an internal sensing resistor.

A voltage signal is generated on the diagnostic output to inform the micro-controller of the primary coil current level. The diagnostic signal goes high typically when the coil current exceeds 4.5A, and low when it exceeds 5.8A. This information allows the micro-controller to govern the dwell angle and to detect coil saturation. The spark is generated by turning off the device, which is under the control of the micro-controller through the diagnostic line. An internal clamping device ensures that the voltage on the primary output is limited typically to 360V, even in case of spark plug disconnection: see Figure 4.

Figure 3. Normal operating cycle

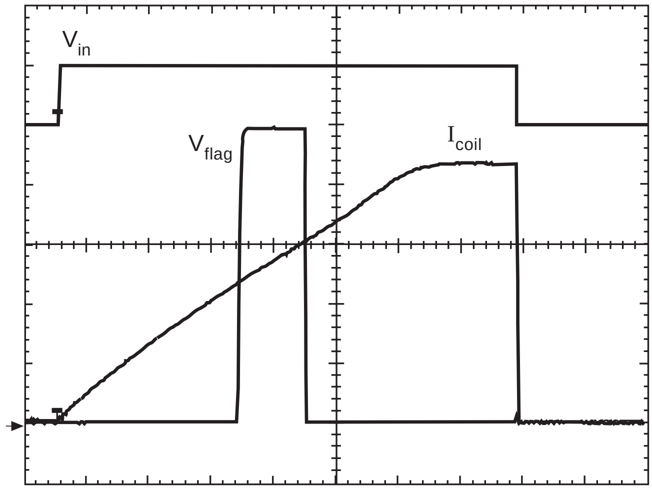
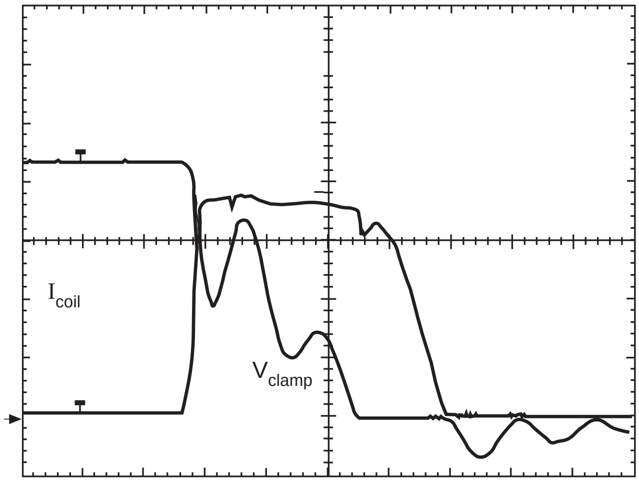


Figure 4. Primary voltage limitation



A. Current Limitation and Quasi Proportional Base Driving

Due to the low resistance of the high energy ignition coil, a current limitation system has to keep the output current within the boundaries of the Safe Operating Areas (Reverse and Forward), and limit the energy stored in the coil.

The coil current is converted to a voltage by an internal sensing resistor in series with the emitter of the Darlington. This voltage is monitored by two functional blocks: the current limiter block and the quasi-proportional base current block, which perform the functions described in the following paragraphs.

The current limiter block compares the monitored voltage to an internal reference. When the internally fixed threshold is reached, a feedback amplifier drives the power Darlington to keep the voltage across the sensing resistor (and hence also the coil current) constant, until the falling edge of the input signal starts the turn-off of the device. An active pull-down is performed to accelerate the turn-off of the output power.

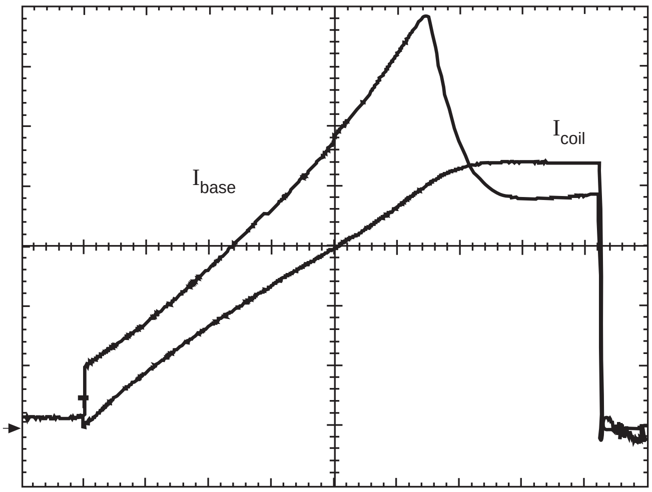
The quasi-proportional base current block generates a base current which increases proportionally to the collector current. The base driver circuit must supply a base current to the output power Darlington large enough to turn on the device with an operating supply voltage ranging from 4.5V to 5.5V. A conventional driving circuit performs this function, supplying a constant current to the device, regardless of the output current value.

The driving circuit built inside the VB027 functions in more complex manner, allowing energy saving and lower stress of the low voltage supply circuit.

Figure 5 shows how the circuit works.

The current supplied to the V_d pin, which is very close to the base current supplied to the output Darlington, increases quasi-proportionally to the output current.

Figure 5. Base driver operation

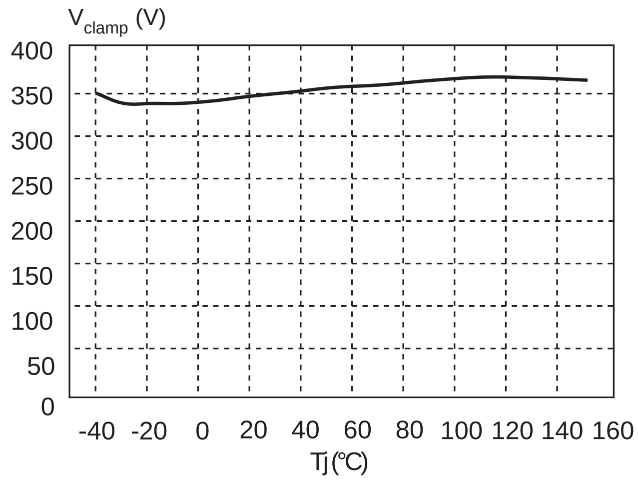


B. High Voltage Clamp

An integrated high voltage zener is connected between the collector and the base of the output stage of the Darlington. Its typical value is 360V, and the voltage versus temperature characteristics are shown in Figure 6.

In reality this clamp is not realized with a single high voltage zener, but with a series of low voltage zeners, allowing accurate trimming of the zener voltage without any process modification.

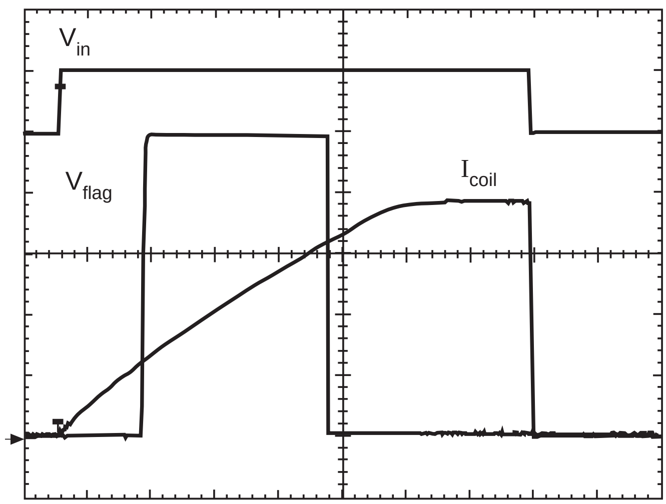
Figure 6. V_{clamp} versus temperature



C. Diagnostic Output and Over-temperature Protection

The diagnostic signal indicates the primary coil current level to the micro-controller. The diagnostic output goes high when the coil current exceeds 4.5A, and low when it exceeds 5.8A, as shown in Figure 3. This information allows the micro-controller to govern the dwell angle and to detect the coil saturation. In addition information on the chip temperature is supplied. If the temperature of the die exceeds 150°C, the diagnostic signal goes high when the collector current exceeds 2.5A, Figure 7, allowing the micro-controller to start taking suitable action. It returns to normal working mode when the chip temperature falls to 130°C.

Figure 7. Over-temperature behaviour



D. Dynamic Bias of the P-type buried layer

At turn-on, when the current in the primary coil is close to zero, it is evident that the effect of the oscillation of the secondary current is due, mainly, to the ignition coil parasitic element. An oscillating current is added to the primary magnetizing current and it forces, during its negative phase, the collector-emitter voltage to reverse, thus directly biasing the p-buried-layer/n-epi junction. This effect could lead to excessive sinking current from Vd and to undesirable effects on the control circuit because of failure of the insulation. A patent pending circuit has been designed to perform a dynamic bias of the p-type buried layer, whose voltage is forced to follow the collector voltage when it becomes negative. Figure 8 shows the operation of this circuit.

E. Power Darlington

In the horizontal layout, shown in Figure 9, the power Darlington is, in some respects, very similar to a standard discrete transistor. The main differences are in a novel, patent pending, vertical structure, the cross section of which is shown in Figure 10. The deep-base structure and the original layout of the emitter and base ballast resistors have allowed a considerable increase in the current density and in the Safe Operating Areas of the device. The device has an energy handling capability of up to 1 Joule.

Figure 8. Dynamic bias of p-type buried layer

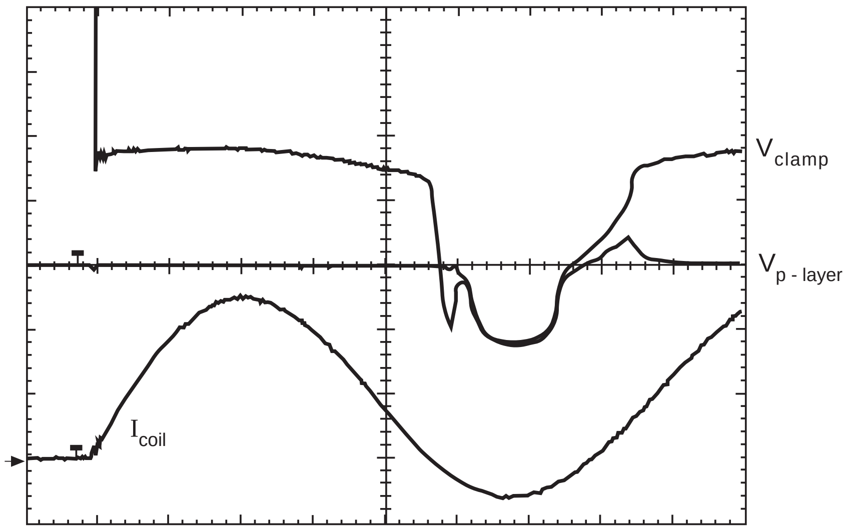


Figure 9. Standard package (TO-220 - 5 leads) and top view of the device

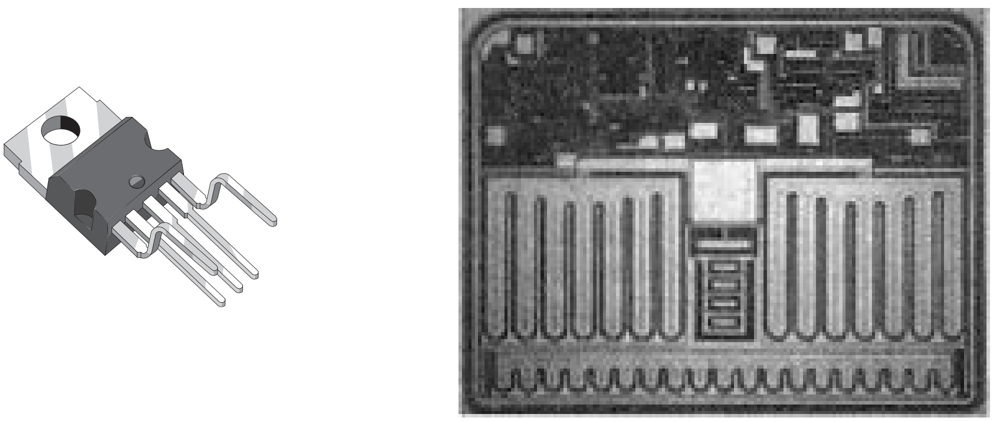
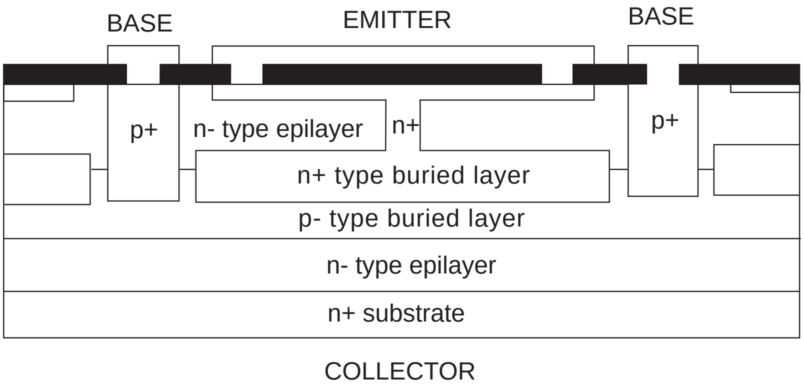


Figure 10. VIPower M1 technology overview - power cross section



CONCLUSION

The VB027 is the latest and the most representative element of a new family of automotive devices developed in VIPower™ M1 technology. The main characteristics of the device can be summarized as follows: the coil current is internally limited, built-in collector-emitter voltage clamping is present, the input is TTL/CMOS compatible, and a diagnostic output to the micro-processor for the dwell angle control and overtemperature protection is available. Moreover the die-size is compatible with the TO-220 package. These features, which are unique in a single device, make the VB027 one of the most aggressive competitors in microprocessor based EMS.

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