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APPLICATION NOTE

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International Rectifier • 233 Kansas Street El Segundo CA 90245 USA

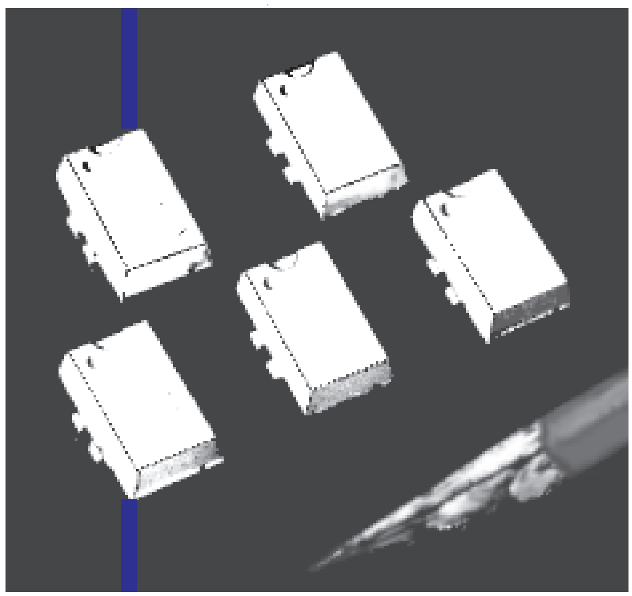
The PVI — a Versatile New Circuit Element

D. W. Moore, Technical Manager, International Rectifier Co (GB) Ltd

The PhotoVoltaic Isolator (PVI) from International Rectifier, is a revolutionary component that can simplify many existing circuits, allow the creation of new designs, and achieve miniaturisation and cost reduction.

This article will explain the internal workings of the device, discuss its characteristics and give some application examples.

From this starting point the circuit designer will soon realise the further application potential of this new technology component and turn imaginative designs into practical solutions.



The Function Basics

In the simplest terms, the PVI is an isolated 5V source powered by a LED, all in an 8-pin dual-in-line package; of course there's more to it than that, but just think for a moment how this function could be achieved with "traditional" components:

- an oscillator, transformer, rectifier solution; probably 6 or 7 components, slow to start up, radiating electrical noise and acoustic noise from the transformer, output filtering required to remove the AC content, maybe 15 or 20 solder joints, etc, certainly larger than an 8-pin DIP and also costly to assemble.
- an extra transformer winding solution; it has to be built into the transformer from the start reducing the winding window for the main power windings, it would still need rectifier and smoothing components to produce DC; but would the extra winding achieve 2500V AC isolation and how would you control the DC — probably by a photo coupler! Yet more components and complications.
- a charge pump solution; this would need a switching component, diodes and storage capacitors, but the produced voltage would not be floating nor would it be easily controlled.
- a battery solution; fine if you need a fixed floating voltage for a limited time, but how could it be recharged, and how could it be varied? Another photo coupler/transformer link is required to control the load connected to the battery.

All of these solutions are considerably more complex than using a single PVI device since it provides in one package a floating variable and controllable DC source with only four connections, all in a volume of 0.25 cubic centimetres!

This new technology device can be considered as a building block in any of the following types of applications:

- it is a miniature source of 5V,
- it is a floating bias supply,
- it is an optocoupler,
- it is a signal isolator,
- it is a linear current transformer,
- it is a DC to DC transformer,
- it is a Solid State Relay driver,
- it is an I/O interface,
- it is a versatile component that enables a whole new approach to circuit designs, allowing previously complex circuits to be banished forever.

Mechanical Specifications

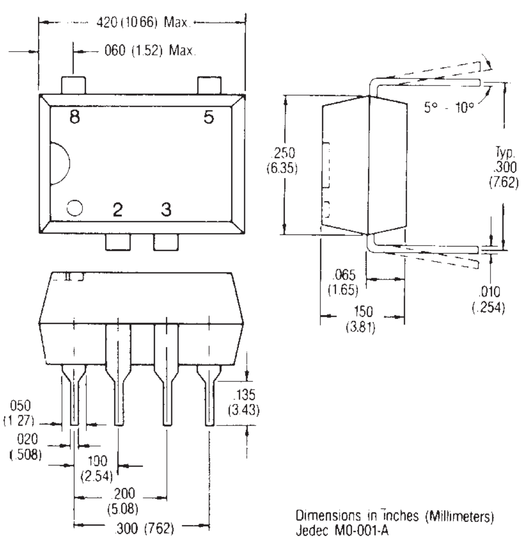
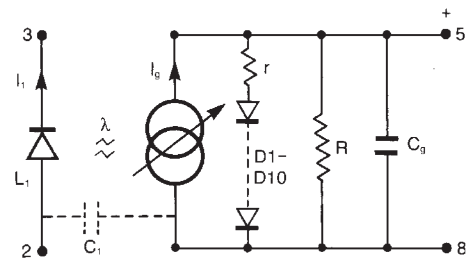


Fig. 1. Dual-in-Line Package.

How it Works

The heart of the PVI is a miniature array of alloyed silicon photo cells, 3mm long by less than 0.5mm wide, this is positioned about 1mm from a high output stability Gallium-Aluminium-Arsenide light-emitting diode and moulded within a clear plastic optical cavity to produce an efficient transfer of infra-red energy from the LED to the photovoltaic pile. This sub-assembly is then further plastic moulded to exclude ambient light, the finished package is the standard 8-pin dual in-line as shown in Fig. 1. Although the photovoltaic cells can generate around 5V, they are really quite small and have a limited current generating capability. A better understanding of the PVI's characteristics is obtained by examining the equivalent circuit shown in Fig. 2. The input current I1 is converted to infra red radiation by the LED L1. This



Typical Values for PVI5100

I_1 = 20mA
I_g = 20 μA
r = 30 kΩ
R = 100MΩ
$I_g = I_1/1000$
C_g = 100pF
C_1 = 1pF at 2500V AC

Fig. 2. PVI Equivalent Circuit.

radiation is optically directed to the surface of the photocells to generate a current Ig which is directly proportional to the incident energy. The physical, electrical and mechanical arrangements determine the current transfer ratio at about 1000:1 (approximately linear but does have negative temperature coefficient).

Unfortunately, in any photocell, the current source is shunted by the diode-like forward characteristics of its own elements, this is represented by the series string of 10 diode junctions D1 to D10 in parallel with the current source, it is these that limit the maximum output voltage to around 6V and also introduce a negative temperature coefficient for the output voltage. These diodes have a total bulk slope resistance "r", and because of surface leakage across the photocell array and diodes as well as through the package, there is a parallel resistor "R". The coupling capacitance between L1 and the photovoltaic array is only 1 pF, and the dielectric can withstand at least 2500V AC.

The photocell structure has an inherent self capacitance, this is represented by Cg and does to some extent limit the minimum switching times achievable but as we

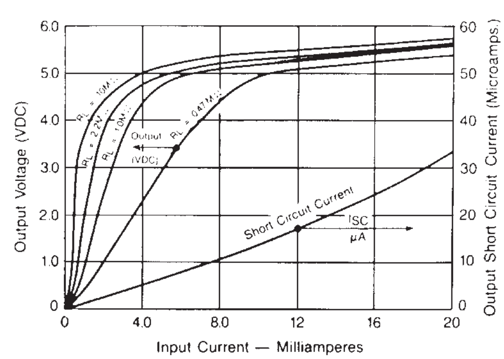


Fig. 3. PVI Output Characteristics.

shall see later, quite respectable turn-on and turn-off times of the order of 20 micro seconds can be achieved, although this does depend on the load resistance and capacitance.

Typical output characteristic are shown in Fig. 3, the short circuit current has a temperature coefficient of −0.66%/K and the maximum output voltage a −0.35%/K temperature coefficient.

To simplify the application examples, we shall show the PVI as just a variable voltage source as in Fig. 4, but remember it has a significantly high source impedance of about 500K ohm.

Applications

As this is a new type of device, there are no established or well known "traditional" applications, but once the novel features of the PVI are understood, the circuit designer will realise the simple solutions that it can offer, so to trigger the imagination here is a general discussion and some application examples.

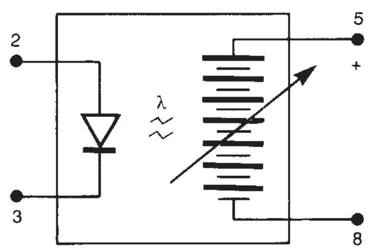


Fig. 4. Simplified PVI.

General

The output power of the PVI is about 50 micro watts, so the load has to be chosen carefully, but like any other building block they can be interconnected to give an enhanced signal, for example the nominal 5V can be increased to 10, 15, 20, 25, etc, by connecting parts in series, and the nominal 10 micro amps output current can be increased by parallel connection.

The output characteristics of the PVI are ideally suited to driving the gate of power MOSFETS, indeed it is the marriage of these two components which will produce the most popular and wide spread range of applications.

Since the gate of a MOSFET is mainly capacitance, this in conjunction with the PVI source impedance will determine the achievable switching times, for example the popular IRF620 (rated at 200V and 5A) has a gate capacitance of 600pF, and a simple calculation shows that this will be charged to 5V by 20 micro amps in 150 micro seconds, quite a respectable switch-on time. Although this turn-on action is by forcing a current into the gate capacitance, there is no such force available for the turn-off action and the charge on the gate must be allowed to leak away through the gate-source resistance. In a MOSFET this is extremely high, of the order of 2000M ohms resulting in turn-off times of several seconds, so an external discharge path must be added,

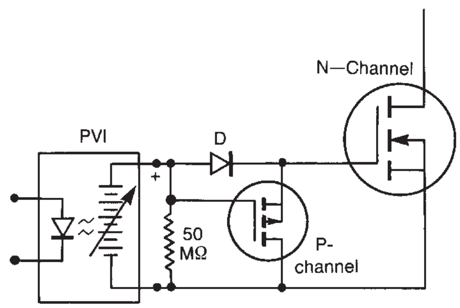


Fig. 5. Speed-up Circuit.

a typical value would be 470k ohm to bring the turn-off time down to about 500 micro seconds.

In this type of design the turn-off will always be about four times longer than the turn-on time because of the "passive" turn-off action. If there is an application where on-off times need to be more closely matched a pair of PVI devices may be used to provide a push-pull action, or the active charge dump circuit of Fig. 5 could be used. Normally the diode D is forward biased and the P-channel MOSFET is off, but when the PVI voltage drops, the diode is reverse biased, the P-channel MOSFET conducts and rapidly discharges the gate-source capacitance of the main N-channel MOSFET. With this circuit, the turn-off times can be considerable faster than the turn-on times.

A Highside Switch

To efficiently drive a MOSFET in the positive rail of a power supply it needs a gate voltage higher than that positive rail, the PVI can provide the additional voltage and at the same time isolate the control current to allow a more versatile signal source, the circuit is shown in Fig. 6. The PVI generates a floating voltage which is applied between gate and source, the resistor is to speed-up the turn-off time. The much lower on resistance of the fully enhanced MOSFET considerably reduces the losses.

The control signal and the load circuit do not need a common connection, they can be separated by up to 2500V AC, making this configuration useable as a general purpose DC Solid State Relay.

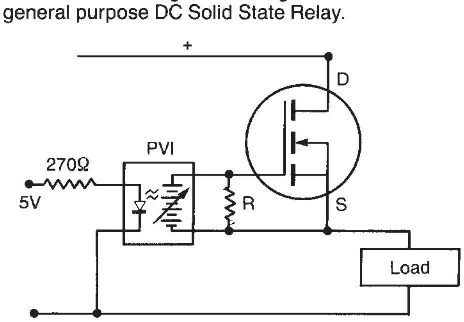


Fig. 6. High Side Switch.

The AC Switch

This is a compact, efficient and cost effective solution to controlling AC currents from a logic level signal. Fig. 7 shows the simple arrangement, the on-losses are lower than you might expect because the MOSFETS are also enhanced in their reverse direction to bypass the inherent drain-source diode. The PVI provides 2500V AC isolation between the control and AC supplies, the load capabilities are determined by the MOSFETS used, and the resistor provides a speedy turn-off to reduce switching losses. This circuit does not have the niceties of zero voltage turn-on and zero current turn-off associated with proprietary Solid State Relays, but does have the advantage of simplicity and ease to be matched to the application requirements.

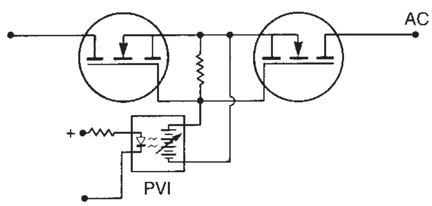


Fig. 7. An AC Switch.

The Low Power Latch

The sensitive voltage controlled attributes of a MOSFET and the characteristics of a PVI can be combined to produce a voltage triggered device with the latching characteristics of a thyristors as shown in Fig. 8. The trigger source momentarily makes the transistor conduct, the resultant current through the LED (50mA max) activates the PVI output which takes over supplying the gate and maintains the MOSFET on. To switch the device off, either the main drain current can be reduced to zero (for about 100 micro seconds whilst the gate charge is dissipated) or a negative pulse can be applied to the gate in the same manner as a Gate-Turn-off-Thyristor.

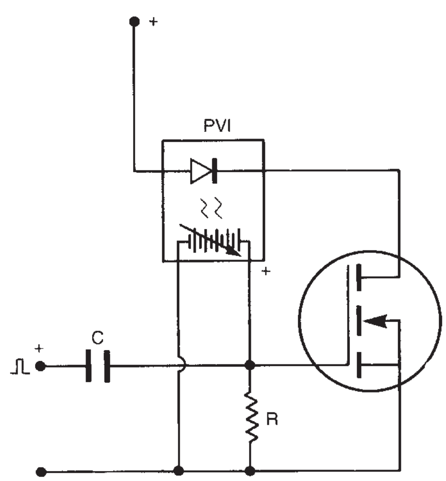


Fig. 8. A Sensitive Latch/GTO.

A Current Direction Detector

Fig. 9 shows a circuit that can control two separate loads depending on the direction of current flow in the path being monitored, the operation of the circuit is self explanatory but notice that the LED arrangement means that the "OR" function is built-in to the design, i.e. only one load can be activated at any one time.

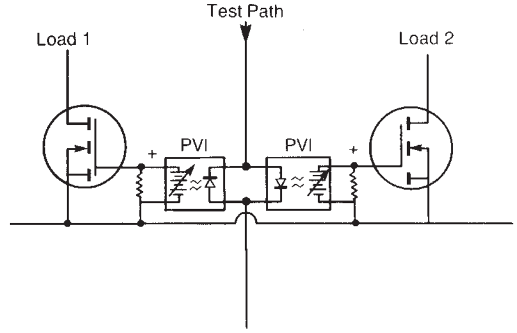


Fig. 9. Current Direction Detector.

A Miniature AC to DC Power Supply

To float charge small batteries, to power LCD displays and smoke detectors, or feed an AC derived signal to a microprocessor a very compact isolated 5 or 10V DC supply can be produced from an AC line. Fig. 10 shows the circuit arrangement with the two 5V sources in series, but they could also be in parallel to give a higher

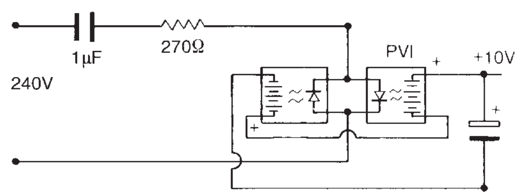


Fig. 10. An AC/DC Power Supply.

current. Because of the input current-to-output voltage characteristic of the PVI, the output has a built-in inherent voltage regulation, the output changing by less than 10% when the AC supply goes from 240V to 24V, this useful feature increases the range of application for a single functional building block in I/O systems.

A Bridge Driver

A perpetual problem with the bridge circuit used to reverse the direction of a DC motor or control an AC motor, has been coupling the control signals to the switching elements connected to the positive supply rail. If a combination of N-channel and P-channel MOSFETS are used, then signals referenced to the positive and negative rails are required, this can deteriorate the noise immunity and make start up and signal processing difficult. By using P-channel MOSFETS the design voltages must be kept low as P-channel devices are not available over 200V.

An alternative configuration is to use all N-channel (higher voltages available) but this introduces another complexity, the gate drive signals are referenced to the sources and these follow the output voltage supplied to the load, so for a single phase drive, two floating DC supplies are needed with isolated signal coupling (photo couplers) to the control signals, and the complexities start to accumulate.

International Rectifier manufactures an integrated circuit (the IR2110) which goes a long way to solving many of these bridge driving problems but still has certain limitations, for example it is limited to under 500V DC rail application, it needs continual refresh of the high side floating supply which it derives from the output semi-conductor switches using a bootstrap technique, thus is not appropriate for steady state directional control of a DC motor.

The PVI offers a simple solution to low frequency bridge driver requirements, it is its own floating bias supply, it is isolated to 2500V AC, it can be driven from a single 5V supply, etc. The circuit is shown in Fig. 11, the signals for each LED can be connected in various configurations to suit the control signals available, an even simpler design can omit the bottom two PVI devices and the gates driven directly from the control signals. To prevent simultaneous conduction of the power devices in one arm (fire through) it may be necessary to speed up the turn-off action of each device by incorporating the circuit of Fig. 5 into each of the four PVI's.

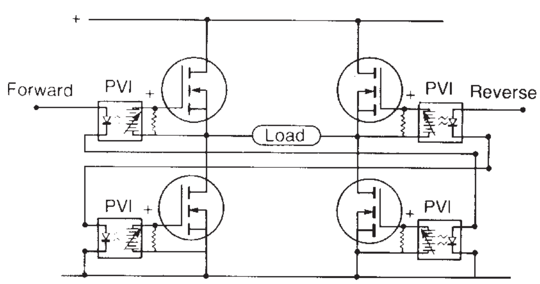


Fig. 11. Bridge Driver Circuit.

The same general arrangement of PVI-MOSFET can be used for 3 phase and 4 phase drives, used typically for inverters and stepper motors.

Conclusion

The PVI5100 is designed to match the gate characteristics of logic level MOSFETs as illustrated in this article. The PVI1050 unit is also available (see page E-1) which has a dual 5 volt output. These outputs can be series connected to drive the gates of standard power MOSFETs. This single 8-pin DIP PVI1050 can also be used with logic level MOSFETs in applications requiring dual outputs such as Figure 11.

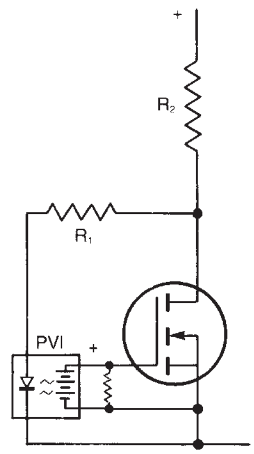


Fig. 12. What is the Action of this Circuit?

The applications for the PVI are varied yet simple and are spread across the whole spectrum of electronic/electrical design as these examples demonstrate, and to start you thinking, what is the behaviour of Fig. 12? Could you use the PVI in an audio amplifier to simplify the design? Or could an ultra efficient synchronous rectifier circuit be designed using PVI's?

Further designs and circuits incorporating the new technology/new function PVI, are limited only by your imagination to achieve innovative, efficient and economical solutions to those troublesome circuit problems — and we are always interested in feedback from our customers, so if you are proud of your application please phone us or write with the details.