HV9901

A novel LED driver

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LEDs have been around for years now but it's only recently that things have started to get interesting with white and superbright versions appearing at reasonable cost. LEDs of course require some form of driving circuit and there is a lot of interest in more efficient or versatile techniques for driving them. This circuit isn't fussy; it outputs a constant current suitable for high power LEDs and it doesn't care whether the input is 12 V or 230 V!

It sometimes happens that a chip manufacturer comes up with an IC to perform a specific function and later the chip is found to be useful in a different application, not anticipated by the original designer. The HV9901 Universal Relay Driver from Supertex Inc. is just such a device. It was originally designed to provide a constant current output drive for a relay coil from a very wide range of supply voltages from 10 V up to 450 V DC without the need to alter any of the circuit components. This device offers a number of benefits both to the designers of white goods where the variety of relays used in equipment can be reduced (optimising quantity discounts) and also to the maintenance engineer who does not need to check coil ratings of a replacement relay. The HV9901 operates at DC voltages only so for AC operation a bridge rectifier is also needed (but no reservoir capacitor is usually necessary).

How come that LEDs and relays are so alike that they can both be driven by the same chip? Well both require the drive current to be as constant as possible irrespective of the level of supply voltage. In the past with low current LEDs taking only a couple of milliamps the problem of driver design was not so great but with today's high power devices consuming a few hundred milliamps up to 1 A the need for efficient drivers is more acute to avoid excessive dissipation in the driver circuit.

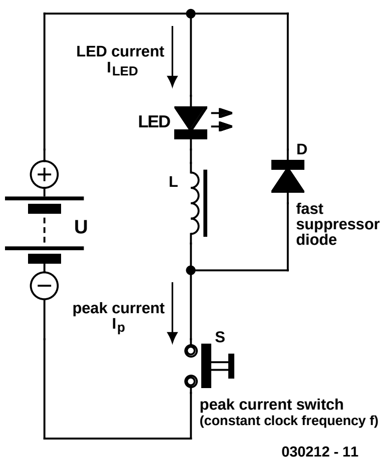

Figure 1. The switched current source configuration.

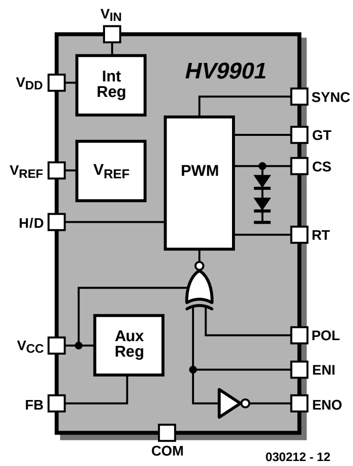

Figure 2. Internal diagram of the HV9901.

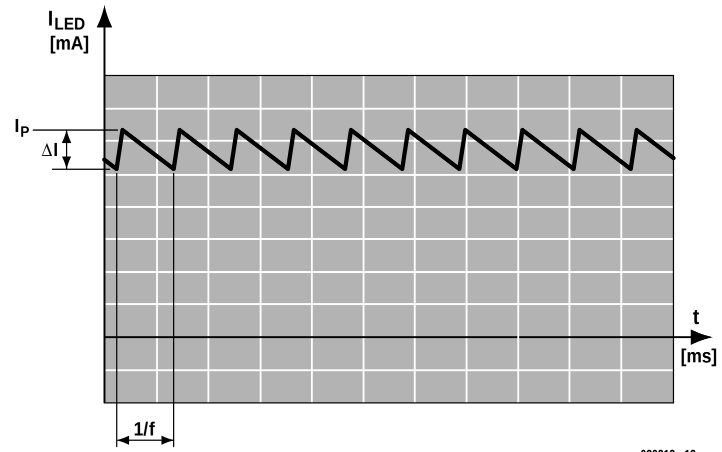

Figure 3. Load current waveform.

A switched current source

The step-down generator used in the HV9901 is a switched current source. **Figure 1** shows the principle of the circuit. When the switch is closed current through the coil begins to rise. The rate of current rise depends on the value of supply voltage and the coil inductance. Before current in the circuit rises too much the switch is opened and the flow is interrupted. The 'flywheel' diode allows current to continue to flow through the coil and back to the positive supply but it decays almost linearly because of the energy losses through the coil and LED. Once more the switch is closed and current increases again until it is interrupted. This process is continually repeated so that current through the load has a ripple characteristic. The faster the switching process repeats, the smaller the peaks and troughs of the ripple will be. The HV9901 shown in **Figure 2** generates the PWM signals to switch the high voltage input through an external power MOSFET to the load and measures the load current through a sense resistor to produce a (rippled) constant current output. The oscillator frequency is set by the value of resistance connected from the RT input to ground.

The ripple current ΔI (**Figure 3**) is governed by the coil inductance, clock frequency f and the peak LED current I_S. It is important to accurately control current through the LED because the maximum peak current of high current LEDs is only slightly more than their continuous current rating so it is important to achieve high brightness from the LED without over-driving it. Each time the peak value is exceeded the stress causes brightness reduction, colour change and can lead to the untimely death of the LED.

The ReLED driver

The circuit is capable of driving both relays (also electro mechanical valves and solenoids etc.) and all types of LED so the circuit was given the name ReLED (well it seemed like a good idea at the time). The circuit controls its output current by measuring peak current through the coil via a sense resistor and switching the supply on and off. This is not the conventional method of providing a constant current source but the circuit is very simple to use and performs reliably.

The HV9901 can accept input voltages in the range from 10 V to 450 V DC (providing that suitable MOSFETs and diodes are used) and not just 'pure' DC but also pulsed sup-

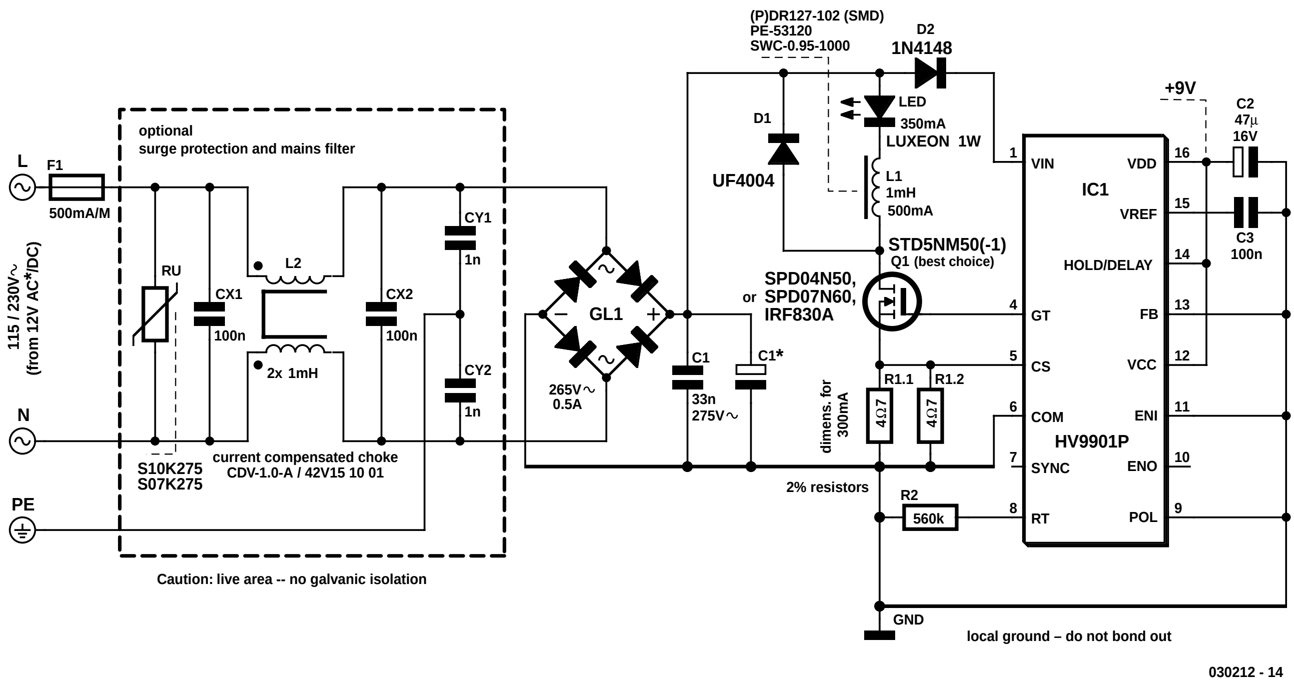

Figure 4. Circuit of the ReLED driver including the mains filter.

plies like unsmoothed rectified 50 Hz mains supply. This feature allows a high current output supply to be produced without the need for expensive and bulky electrolytic reservoir capacitors.

The circuit in **Figure 4** provides an output current of around 300 mA and is suitable to drive a blue or white 1 W Luxeon LED. Overvoltage protection and a mains filter is included on the input to the circuit to comply with EMC recommendations for any mains powered clocked circuit. Other types of LED can also be driven from this circuit providing that the value of the current sense resistors (R1.1 and R1.2) are changed if the LED current rating is different. The current sensing resistor should be of a type having low parasitic inductance, connecting two identical resistors in parallel helps to reduce any inductance and also shares the energy dissipation.

The coil inductance and the oscillator PWM switching frequency both play an important role in keeping the current ripple to an acceptable level.

In contrast to linear current regulators the value of input voltage has only a small effect on the power dissipation in the driver (and the efficiency of the circuit). Several individual LEDs can be connected in series and driven from this circuit provided there is sufficient supply voltage available. The minimum supply voltage required to drive an LED is 12 V DC or AC but with a rectified AC supply of less than around 30 V the period that the circuit cannot conduct around the zero crossing points of the rectified AC waveform is relatively long so the LED will noticeably flicker. A 220 µF reservoir capacitor (with an appropriate voltage rating) can be used to prevent this.

Connections to the LED are both open and short circuit proof provided that these leads are not shorted to ground! A fast-acting flywheel diode suitable for the 50 KHz switch frequency must be used in the circuit otherwise there is a risk that the MOSFET will be destroyed.

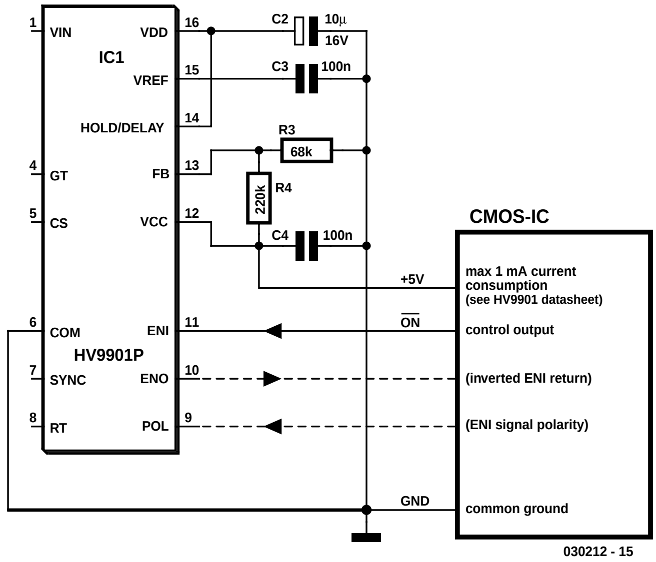

Figure 5. Auxiliary power for additional CMOS circuits.

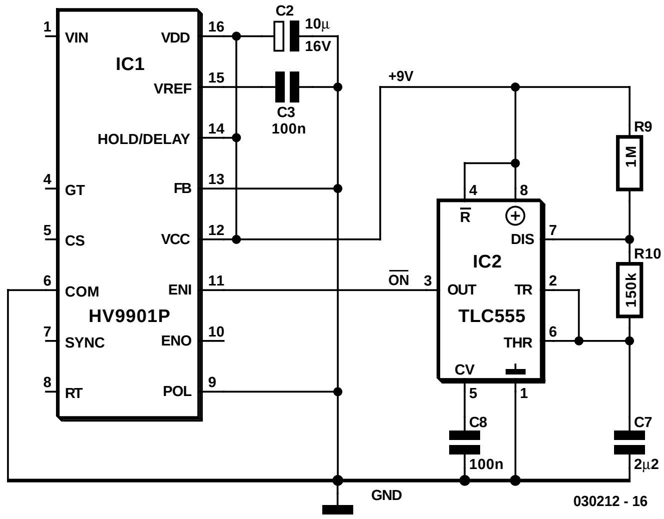

Figure 6. Flasher circuit showing VDD and VCC linked.

Component choice

One area often overlooked by newcomers to FET design is the gate characteristic of the MOSFET. At first glance we notice that the input impedance is very high and mistakenly jump to the conclusion that not much energy is necessary to switch the MOSFET. This is true if the device is operated at low frequencies or DC but if we are switching the MOSFET at speed another factor is important: the gate capacitance. The maximum switching frequency of the MOSFET will be governed to a large extent by how fast the gate driving circuit can charge and discharge this input capacitance. Unfortunately MOSFETs with low $R_{DS(ON)}$ have correspondingly high input capacitances so that switching power MOSFETs at speed gets more of a problem at high frequency and high supply voltages.

When choosing the MOSFET type it's therefore important to check out the gate capacitance and not just select the device with the lowest $R_{DS(ON)}$. The HV9901 can comfortably switch devices with a gate capacitance up to 500 pF and can also cope with 1 nF at a push. The suggested MOSFETs in this design can switch the LED supply at a PWM frequency of 50 kHz from mains supply voltage without the need for any heat sink.

The coil specification is also important to ensure that it does not become saturated at the peak current over the complete operating temperature. A check with an oscilloscope should indicate that the voltage rise across the sense resistor is more or less linear.

More features

In addition to providing a stable LED drive current from a wide range of input voltages the circuit also has a number of other features that may be

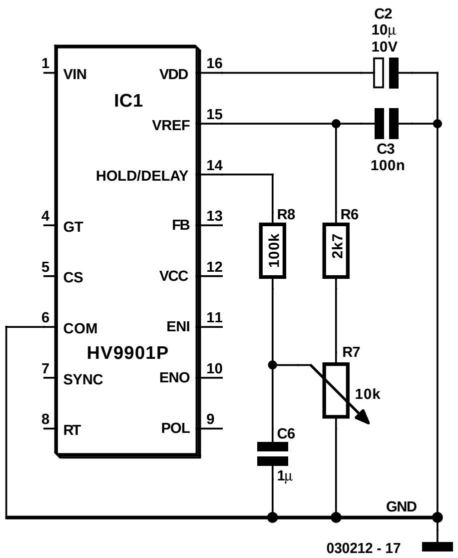

Figure 7. Simple dimmer control.

useful in some applications: The LED can be switched on and off by a logic signal applied to the ENI input (galvanically isolate this input logic signal via an optocoupler). The polarity of the ENI signal can also be inverted by changing the level on the POL input. The HV9901 also contains an auxiliary voltage regulator that can be used to power additional circuitry. Two resistors are used to program the auxiliary voltage in the range from 2 V to 5.5 V the maximum output current is only 1 mA but this is enough to power a couple of CMOS chips or a CMOS 555 timer or even a low power microcontroller so that many more applications can now be realised using flashing lights or timed light control etc. (**Figure 5**).

External circuits can also be powered from 9 V available from VDD, in this case the two resistors are not required and VCC is connected to VDD. The logic threshold levels of the ENI and POL inputs will also correspond to this supply voltage (**Figure 6**). The circuit flashes an LED (not shown) at approximately two-second intervals. The POL input is used to invert the sense of the timer output. In a similar manner a switch-on or switch-off delay can be simply implemented with some additional logic gates. Light level detector circuits or PIR movement detectors can also be powered from the HV9901.

Resistors connected to the H/D input of the HV9901 are used to program the relay pull-in and holding currents when the device is used to drive a relay coil but this feature can also be used to implement a simple dimmer when an LED is used in place of the relay (**Figure 7**).

The HV9901 can also be used as a step-up regulator by placing the load (e.g. a 12 V LED cluster) in series with the flywheel diode. In this mode the supply has a much higher ripple current.

Testing times

Before you try the circuit out with an expensive Luxeon LED it is a good idea to substitute a power zener diode instead of the LED. A zener diode has almost identical electrical characteristics providing you choose one with the same conduction voltage as the LED. The zener diode is a little more robust that the LED and any errors during testing will be far less costly. Connect a standard red LED together with a 180 Ω series resistor in parallel with the zener diode so that you can get a visual indication that the circuit is driving the LED with equal brightness at different input voltages.

All tests must be carried out initially using a low voltage (12 V) input. If the circuit is powered from the mains it is important to be aware that the chip will have lethal voltages on its pins and all appropriate safety guidelines **must** be adhered to. Early tests using an isolated variable transformer to provide an adjustable input voltage were unsuccessful but a mains transformer with tapped secondaries gave better results for test purposes. If the input mains filter is not fitted it is important to keep supply leads to the circuit as short as possible.
On the positive side the circuit does not employ large reservoir capacitors on the high voltage side so once the ReLED is disconnected from the mains supply any high voltages lurking around the circuit will be quickly discharged.

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Web Pointer

HV9901 datasheet from:
www.supertex.com/pdf/datasheets/HV9901.pdf