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Implementation of Isolated DC-DC converter for MOSFET Driver circuit

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Abstract— ***Now a days isolated DC-DC converters are widely used in power metering, industrial programmable logic controllers (PLCs), insulated-gate bipolar transistor (IGBT) driver power supplies, industrial fieldbus, and industrial automation. These converters often are used to provide galvanic isolation, improve safety, and enhance noise immunity. In this paper different types of DC-DC converters (chopper) are listed out and paper also includes hardware design and implementation of isolated buck DC-DC Converter specially used for MOSFET/IGBT driver circuit. Design of high frequency transformer is also described in this paper with help of mathematical equations. Output of PWM controller IC and hardware results of high frequency transformer and also is shown in this paper.***

Keywords— MOSFET, IGBT, PWM, PLCs, Chopper, SMPS.

INTRODUCTION

A DC-DC converter converts an input DC voltage into a regulated or non-regulated DC output voltage which can be higher or lower, inverted or non-inverted and isolated or non-isolated. Converters are broadly categorized as isolated and non-isolated converters. They are sub-categorized as follows:

(i) Non-isolated DC-DC Converters
- Buck (Step-down)
- Boost (Step-up)
- Buck-boost (Step-up and Step-down)
- Inverting
- SEPIC

(ii) Isolated DC-DC Converters
- Flyback
- Forward
- Push-pull
- Half-bridge
- Full-bridge

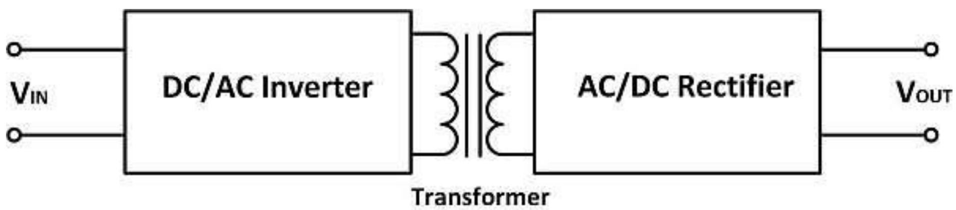


Fig. 1 Block Diagram of an Isolated DC-DC Converter Power Stage.

The non-isolated converters represent an inexpensive solution for many applications and are often used for small voltage conversions. However, they cannot offer much protection against high input voltages or transients. In contrast, the isolated DC/DC voltage converters have a high isolation voltage and can therefore be used for isolating floating ground connections between input and output. The isolated converters are more complex circuits and require a higher number of components and hence costly solutions. In this paper Push-pull converter is used for implementation of isolated DC-DC converter.

PUSH-PULL CONVERTER

Push-pull converter uses two power switching devices Q1 and Q2 (like MOSFETs) and a high frequency transformer with mid-taps on both primary and secondary sides. Inductor L and Capacitor C are the filter components.

When Q1 is turned on, Vin is applied to lower half of transformer primary. Therefore V_2 = Vin*(n_s/n_p) voltage is induced in both secondary windings. Voltage V_2 in the upper half secondary forward biases diode D1, therefore load voltage Vo_1 is given by Vin*(n_s/n_p) = α*Vin.

When Q2 is turned on, -Vin is applied to upper half of transformer primary. Therefore V_2 = -Vin*(n_s/n_p) voltage is induced in both secondary windings. As V2 is negative diode D2 gets forward bias, therefore load voltage Vo_2 is given by Vin*(n_s/n_p) = α*Vin. This shows that voltage on primary swing from +Vin with Q1 on and –Vin with Q2 on. Power MOSFETs operates with high frequency with duty cycle of nearly 0.5. So output voltage Vout = Vin*D*(n_s/n_p)*2. (where D=duty cycle=T_{on}/T)

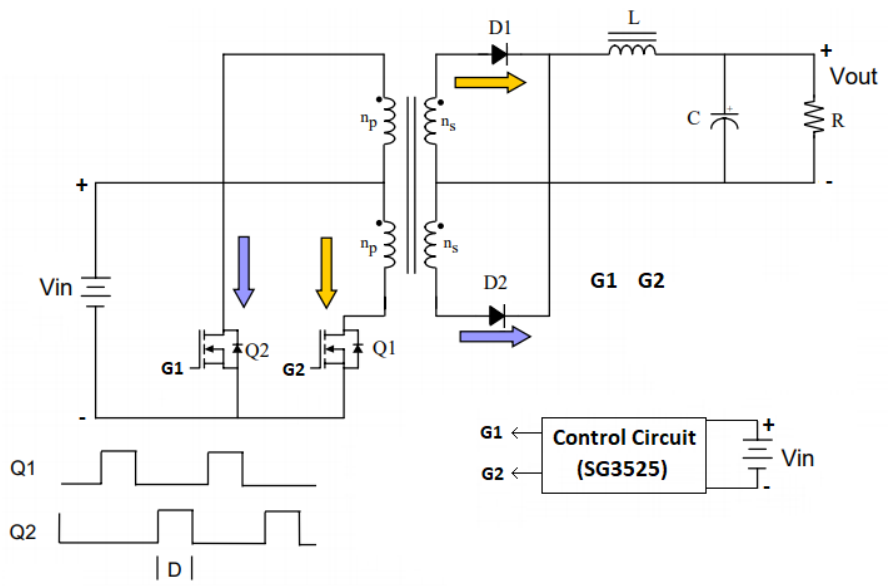


Fig. 2 Working Principle of Push-Pull Converter.

CONTROL CIRCUIT

In this converter PWM Gate pulses are generated using PWM controller IC SG3525. It is a 16 pin integrated circuit. It has two PWM outputs both are inversion of each. Another advantage of SG3525 is that it has built in totem pole base PWM driver.

Some features of this IC are:

(i) 8.0 V to 35.0 V Operation

(ii) (ii) 5.1 V, 1% trimmed reference

(iii) (iii) 100 Hz to 400 kHz Oscillator range

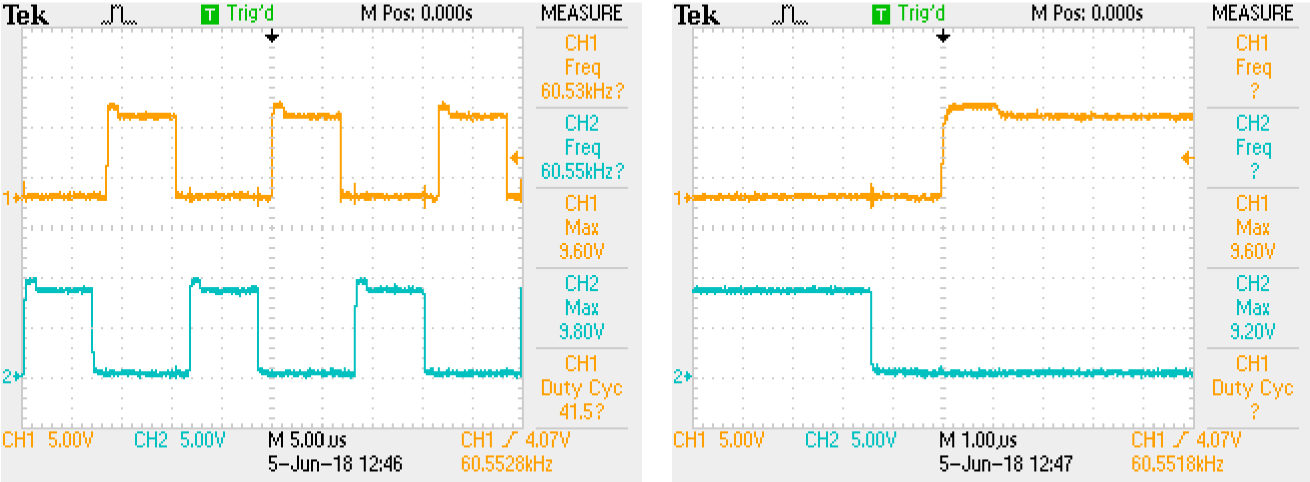
(iv) (iv) Separate Oscillator Sync pin

(v) (v) Adjustable dead time control

(vi) (vi) Input Under voltage lockout

Internal oscillator frequency of SG3525 is given by: f= 1 / C_T (0.7 * R_T + 3 * discharge. By selecting discharge Resistance = 22 Ω, C_T = 1nF and R_T = 10.5 kΩ is set (20k trim POT is used), we get frequency of 130 kHz nearly. As the oscillator frequency is 130 kHz, the switching frequency will be the half of oscillation frequency because of push-pull topology.

Hardware result of SG3525 IC using above components values



(a) *(b)*

Fig. 3 (a) Inverted PWM pulses of PWM IC SG3525 (b) Dead time between two Pulses

Fig.3 (a) shows output inverted pulses of PWM ic SG3525. Here output frequency of pulses is 60 kHz. So it is as per calculations. And fig.3 (b) shows dead time between two pulses. Dead time is around 1.5 uSec.

HIGH FREQUENCY TRANSFORMER

As name suggests this transformer works on few kilo Hz switching frequency. The main significance of these transformers is in “Switched Mode Power Supplies”. The switching frequency of these SMPSs (Switched Mode Power Supply) system will be very high as a concern it reduces the size of magnetics (like transformer and inductor) and it reduces the ripple and so on. There are two main core requirements of High Frequency Transformer in the SMPS system.

1. To match the voltage levels of Source and the Load
2. To provide electrical isolation between the power circuits.

Now let’s take V_1 and V_2 are HF transformer primary and secondary voltage respectively. Secondary current requirement for this project is 0.8 A. So take V_1=15V, V_2=15V and I_2 = 0.8 A.

Assumptions: Let the maximum flux density B_m = 0.2 T, Current density of copper J = 3 A/mm2, window space factor K_w = 0.35. For core selection we need $A_c.A_w$ (Product of core area and window area)

We can find out Ac.Aw from following equation.

Ac.Aw = (V_2 * I_2) / (2 * K_w * B_m * F_s * J) .Take Fs = 60kHz and find out Ac.Aw. From the data sheets of the Core we need to select the appropriate core. For this example $A_c.A_w$ = 476 mm^4. From datasheet of E16/8/5 Ac.Aw is 22.1*24.5 = 541 mm^4. So EE core is used for High Frequency Transformer.

Now let’s derive no. of primary and secondary turns.

$N_p = V_1 / (4 * B_m * A_c * F_s)$ Here N_p=No. of primary turns and take A_c = 22.1 mm^4 from datasheet of E core.

$N_s = V_2 / (4 * B_m * A_c * F_s)$ Here N_s=No. of secondary turns.

Deriving primary and secondary conductor size/gauge (a_1 and a_2)

J = Current / Area. So, $a_1 = I_1 / J\ mm^2$ and $a_2 = I_2 / J\ mm^2$.

HARDWARE IMPLEMENTATION AND RESULTS

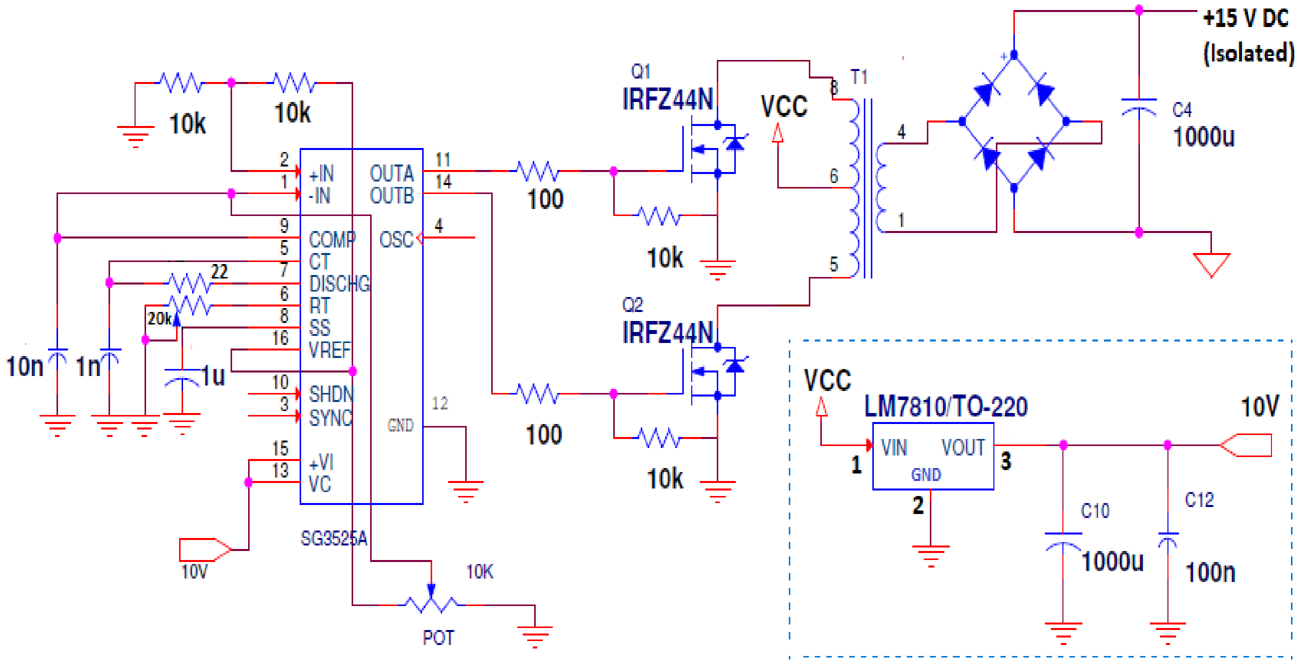
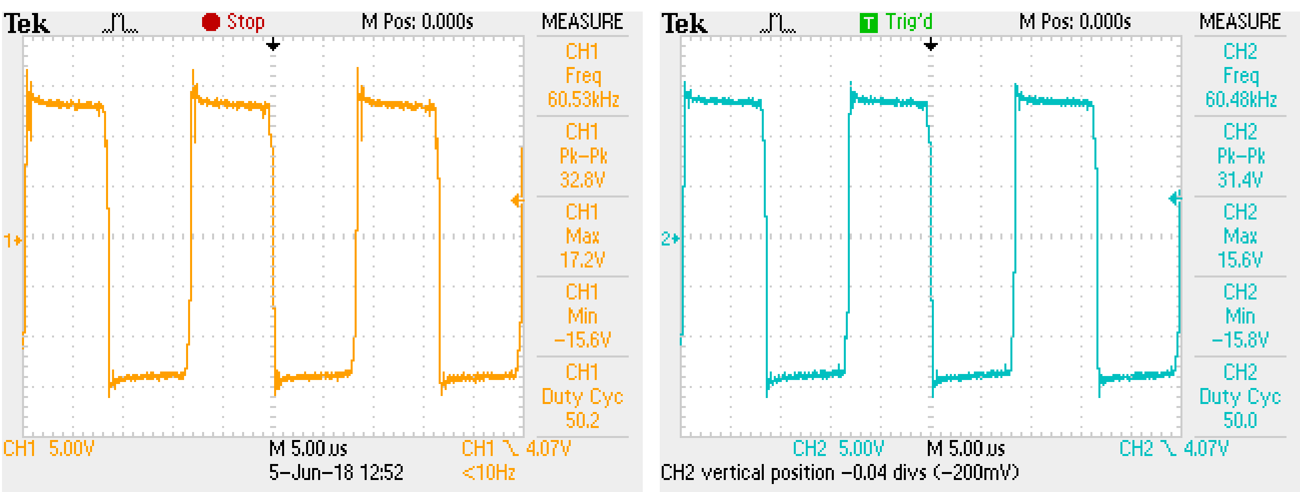


Fig. 4 Complete Hardware circuit diagram

Fig. 4 shows complete hardware circuit diagram with all component details. PWM controller IC working voltage is 10 V. So first 15 V dc (Vcc) to 10 V dc voltage is converted using 7810 voltage regulator IC. As shown in dotted box in circuit diagram. 60kHz frequency gate pulses are generated using PWM controller IC. Then these two inverted pulses (with dead band of 1.5 uSec) are given to gate terminal of MOSFET through 100 Ω resistances. Two MOSFETs (Q1 and Q2) switches turns ON in inverted mode with some dead band. So generated 60kHz Square AC is given to transformer and in secondary side we will get 15V isolated DC through high frequency uncontrolled Rectifier. Waveforms of generated Gate pulses are shown in Fig. 3(a) and Fig. 3(b) shows dead band between two pulses. Primary and secondary voltage of High frequency transformer is also shown in this paper.



(a) *(b)*

Fig. 5 (a) Primary voltage of HF Transformer (b) Secondary voltage of HF Transformer

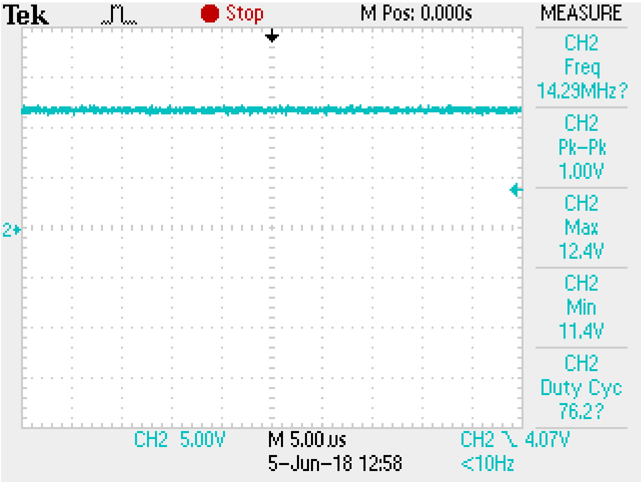


Fig. 6 Isolated Output DC 12 V

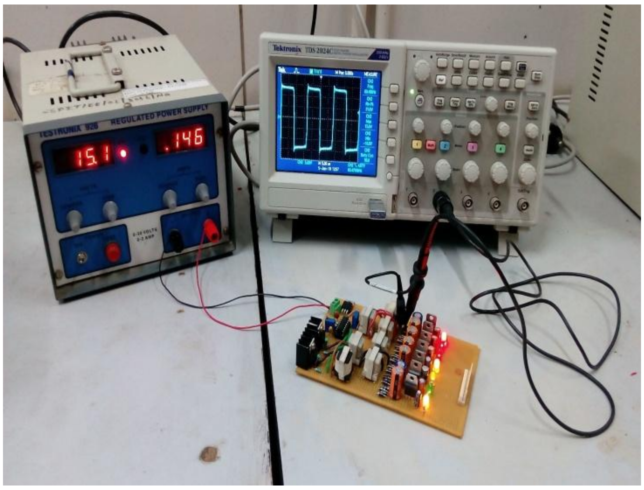


Fig. 7 Hardware setup

Fig. 5(a) & (b) shows primary and secondary voltage of high frequency transformer. Fig. 6 shows output 12 V isolated DC and Fig. 7 shows hardware setup of isolated DC-DC converter. In hardware total 7 no. isolated DC-DC converter is implemented. So total 7 High frequency transformers is implemented and 7 high frequency rectifiers are also implemented on hardware. 7812 voltage regulator ICs are put on output side of rectifier as 12 V DC is required for our project.

Conclusion

Using PWM ic SG3525 and two MOSFETs isolated DC-DC converter is designed implemented for 0.8 A load. This can use for gate driving circuit of MOSFET / IGBTs used in inverter or converter circuits. Hardware result shown the exact output frequency of PWM ic and primary-secondary voltage of High frequency Transformer. For designing of High frequency transformer given design equations satisfy the hardware results.

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