DN1158

200W Resonant Power Supply Reference Design Using the DGD2113 Gate Driver

Introduction

LLC Converter is becoming a popular converter choice due to its high efficiency and low EMI noise, benefitting from Zero Voltage Switching (ZVS). LLC converters are found in power supplies of 100W – 500W, levels commonly used for LCD TVs, hence we present a Reference Design for a 200W Resonant Power Supply with the DGD2113 Gate Driver.

An ease of design and shortened development time are the highlights of this reference design, with 92% efficiency at full load. LLC converter transformers utilize the magnetizing inductance and leakage inductance of the transformer to produce the resonant circuit, and this can be difficult to implement. Hence an off-the-shelf transformer lies at the heart of the LLC converter.

The DGD2110/DGD2113 High Voltage gate driver IC provides the drive to the high-side and low- side gate of the MOSFETs. With the gate driver IC, development is made easier with a lower BOM count, since a high voltage floating transformer drive is not required.

LLC Converter Specifications

	Value	Units
Minimum Input Voltage	380	VDC
Nominal Input Voltage	400	VDC
Maximum Input Voltage	420	VDC
Output Voltage	24	VDC
Maximum Output Current	9	A
Resonant Switching Frequency	90	kHz
Mains under-voltage protection	V_{ON} = 360 , V_{OFF} = 300	VDC

Circuit Description

In a typical LCD TV power supply, a Power Factor Correction (PFC) circuit is included between the AC line voltage and the LLC converter circuit. This PFC functions to correct the power factor that is altered from the SMPS but also the output of the PFC is a high voltage DC line (typically between 380V and 400V). Hence the operating conditions of this reference design is V_{IN} = 380VDC - 420VDC, which falls at the optimal level for PFC and LLC converter circuits.

Half-bridge

The half-bridge implements the power switching function of the LLC converter with the DGD2113, high-side low-side gate driver, providing the gate drive for 16A MOSFETs (STF18N55M5). The 600V floating well of the DGD2113 functions in a bootstrap operation (by C6) providing the supply for the high-side driver. Other important features of the DGD2113 are under voltage lockout (UVLO) for V_{CC} and V_{BS}, and a high-side driver with good performance with -V_S undershoot. As is typical for a half bridge, the VS line is the output of the half-bridge, driving the LLC transformer. As seen in Figure 10, with the conditions of V_{HV} = 400V and at full load, I_S is very close to a sinusoidal current displaying the resonant nature of the LLC converter (V_S is the voltage at the primary winding input and I_S is the transformer current).

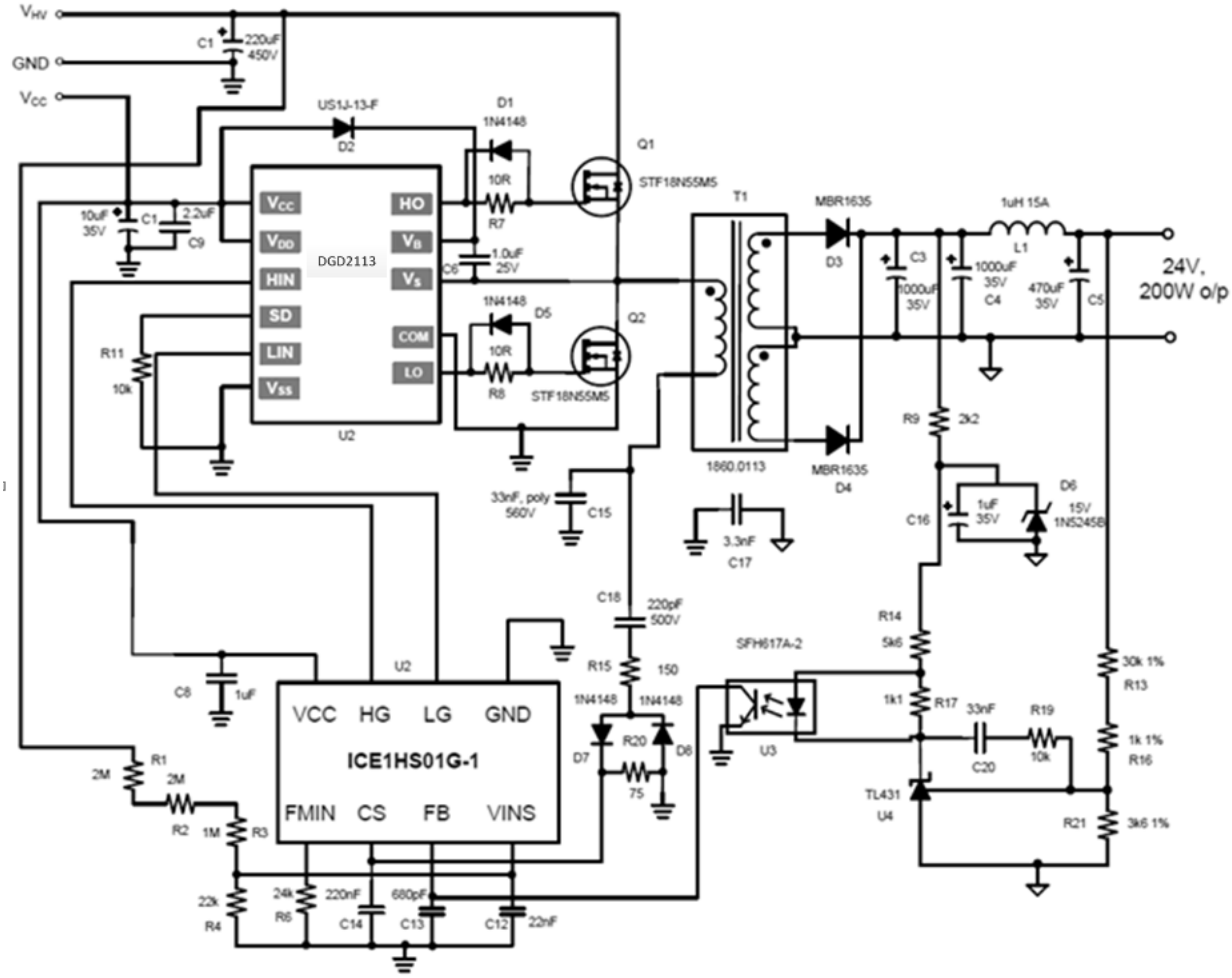

Figure 1: Schematic of the 200W resonant power supply using the DGD2113 gate driver

Transformer and secondary

LLC resonant transformers can be particularly difficult to design and implement with accuracy because the magnetizing inductance and leakage inductance of the transformer are the inductance of the LLC circuit itself. For short development time, ease of design, and high performance, the Magnetica 1860.0113 resonant switch mode transformer was used. These transformers have reinforced insulation and provide a high power/volume ratio. Magnetica is RoHS and ISO9001 qualified. Schottky rectifier diodes are used in the secondary to minimize power dissipation and a secondary filter is used to decrease output noise. The transformer has a 300W capability, and the 16A MOSFETs can take the extra current, so if increased power capability is necessary, higher current secondary diodes and a higher current secondary inductor would need to be chosen.

Feedback and control

The feedback is based off the industry standard TL431 regulator using an opto-isolator. This configuration was chosen as suggested by the controller manufacture to match the resonant controller, the ICE1HS01G-1. This resonant controller converts feedback voltage to input signals to the DGD2113. But in contrast to a typical PWM controller, the ICE1HS01G-1 varies frequency of the control signals and maintains duty cycle (to near 50%, with a built in dead time). Other features of this controller, and hence the whole power supply, is over current protection, over load protection, and mains under voltage protection. A typical gain response of an LLC converter can be seen in Figure 2. If operating at 100kHz, for example, and the input voltage is decreased, the controller will decrease the frequency of the control input. This can be seen in figure 8, operating at full load, but with an input voltage of 380V, and an operating frequency of 80kHz. At nominal input voltage (400V) and full load, the operating frequency is 90kHz, which is decided by the resonant capacitor (C15) and inherent leakage and magnetizing inductance of the transformer. For optimal performance of the Magnetica transformer, the resonant capacitor C15 must be a polypropylene film capacitor.

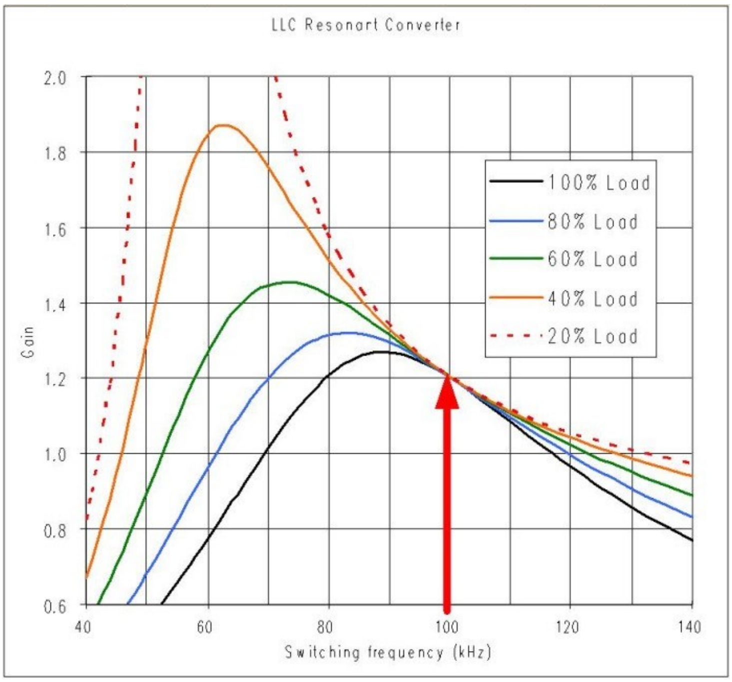

Figure 2: Gain response of typical LLC converter

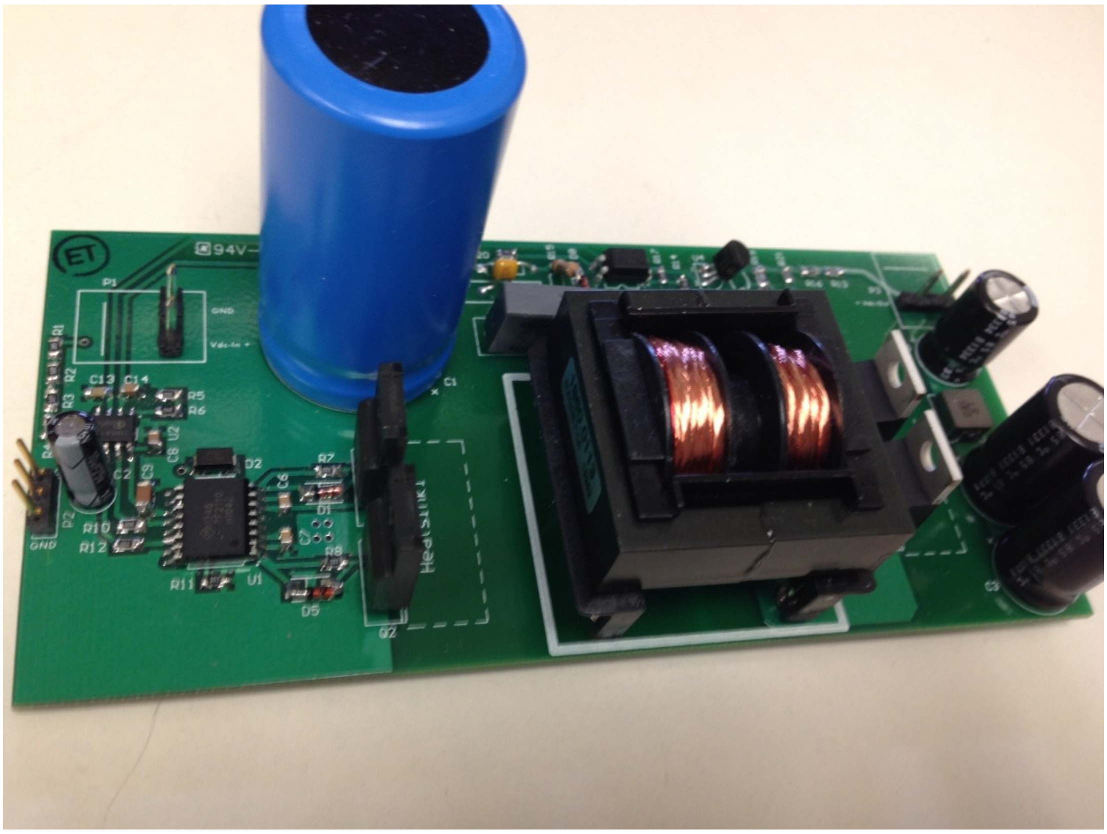

Figure 3: Photograph of the Resonant Power Supply board Layout

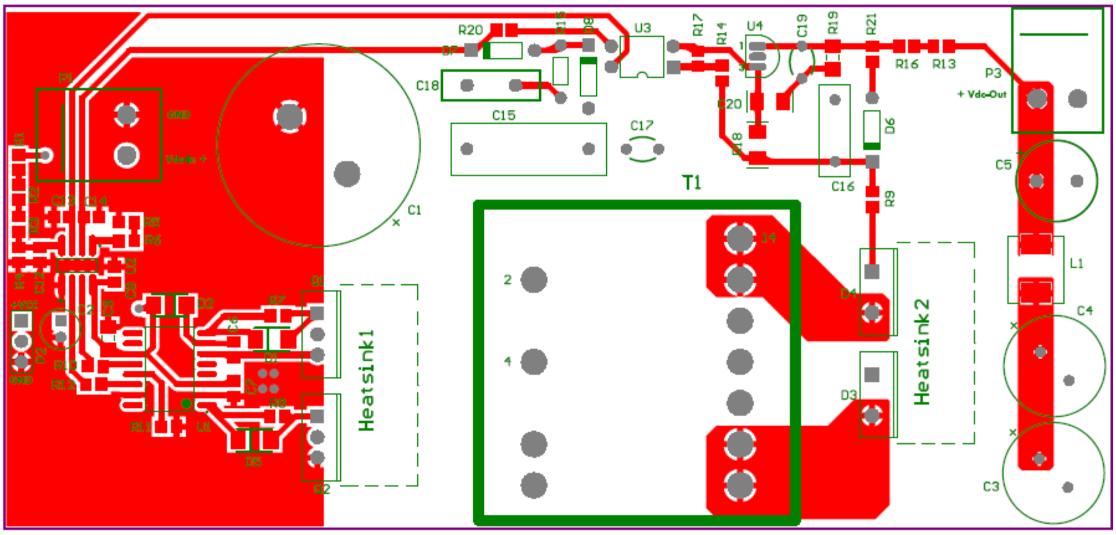

Figure 4: Layout (top layer) of the Resonant Power Supply board

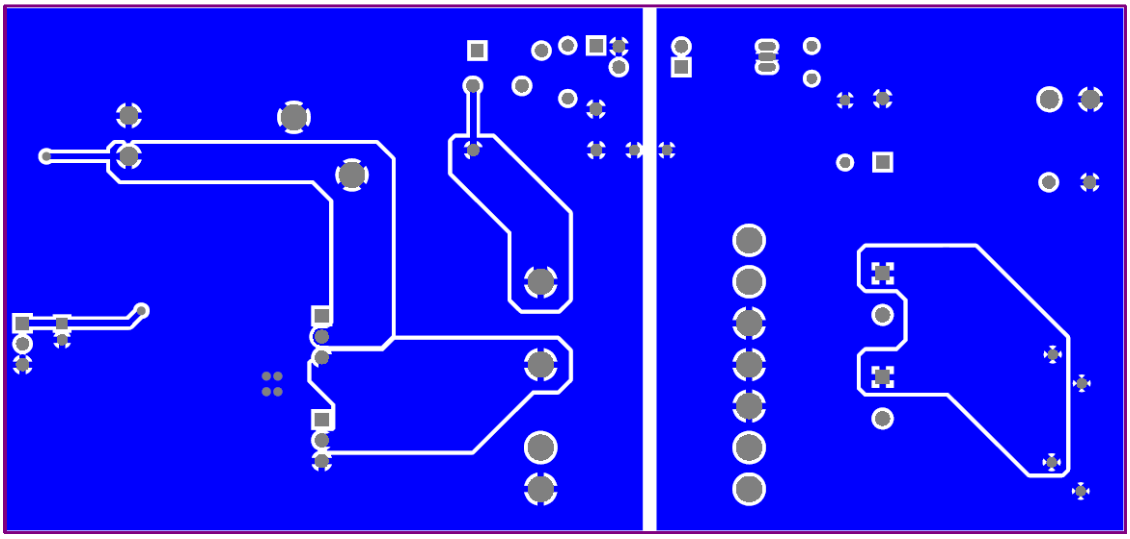

Figure 5: Layout (bottom layer) of the Resonant Power Supply board

Performance

The graphs and scope shots below show the performance of the Resonant Power Supply Reference Design. Figure 6 is a graph showing the efficiency vs. output power. As is typical of LLC converters, efficiency of >90% is easily achieved and for this design, efficiencies of >90% is achieved for loads of 70W to 200W, with an efficiency of 92% at full load. As can be seen in Figure 7, regulation is very tight over full load with less than 0.2% change over the full load conditions. Efficiency and regulation over line voltage is not shown because there is negligible change in either efficiency or regulation over the varied line voltage of 380VDC to 420VDC.

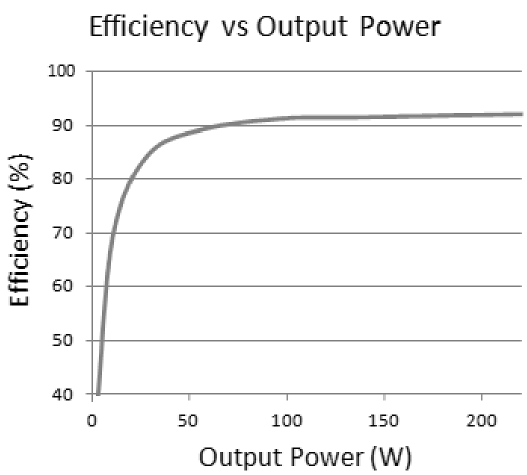

Figure 6: Efficiency vs. output power (V_{IN} = 400V)

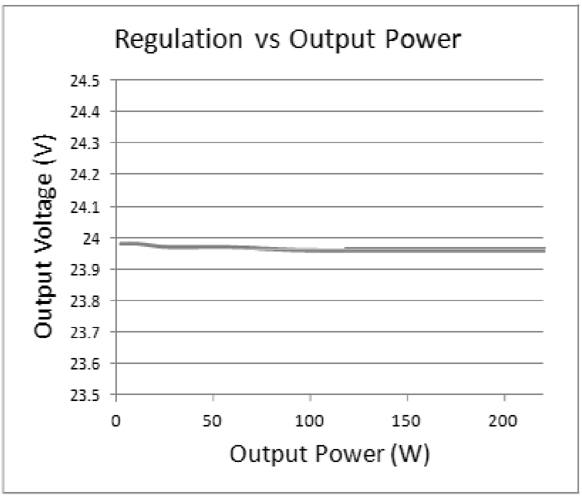

Figure 7: Regulation vs. output power (V_{IN} = 400V)

Operation at Full and Low load

Figures 8 – 13 shows the operation of the power supply by monitoring the V_S and I_S while varying load and input voltage (V_{IN}). In the optimal operating point, you would expect the transformer primary current (I_S) to be sinusoidal. Hence figure 10 shows the LLC converter's optimal operating point of Vin = 400V, for a resonant frequency of about 90kHz. Also LLC converters work less efficiently at lower loads where they are unable to maintain ZCS and ZVS. Figures 9, 11, and 13 show the significant difference in shape of I_S showing the lack of soft switching. And lastly, looking at the three full load pictures (Figure 8, 10, and 12), you see a frequency of operation of 80kHz for Vin = 380V and increasing frequency as input voltage is increased. This follows the expected gain response for this type of converter; as you decrease voltage; more gain is needed to maintain the same output voltage so the controller lowers the switching frequency as the LLC converter gain response is higher at lower frequencies (see Figure 8). The LLC converter power supply provides high efficiency over wide load, but the input voltage is limited.

Conditions for Figures below: Vout = 24V, Full Load at 220W, Low Load 2.3W

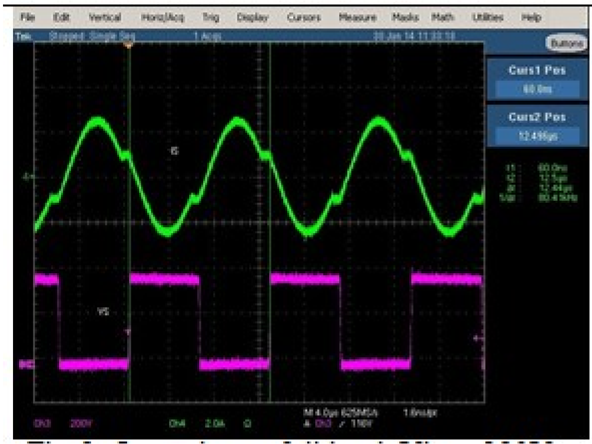

Figure 8: Operation at full load, V_{IN} = 380V, (V_S = green and I_S = purple)

Figure 9: Operation at low load, V_{IN} = 380V, (V_S = green and I_S = purple)

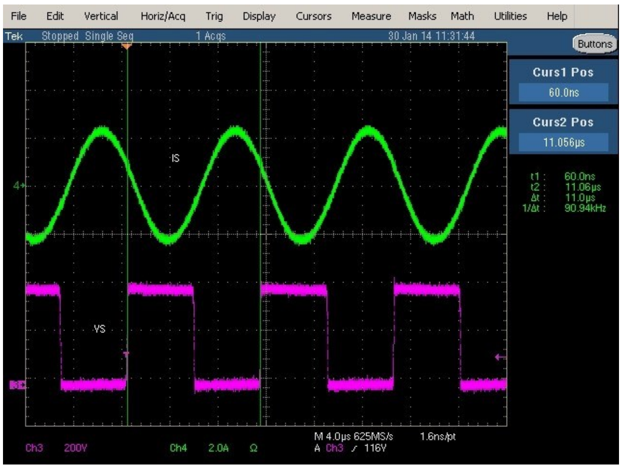

Figure 10: Operation at full load, V_{IN} = 400V

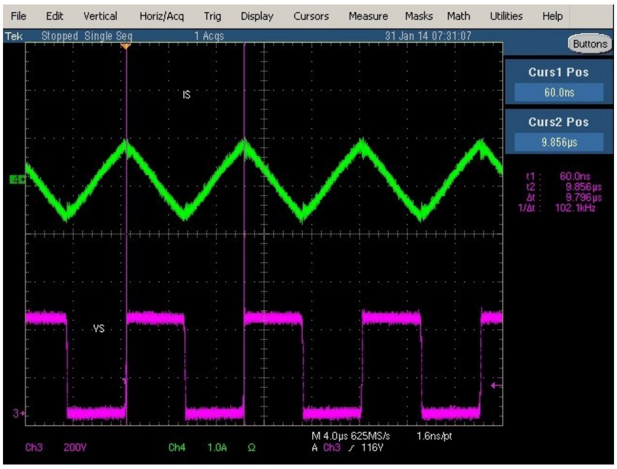

Figure 11: Operation at low load, V_{IN} = 400V

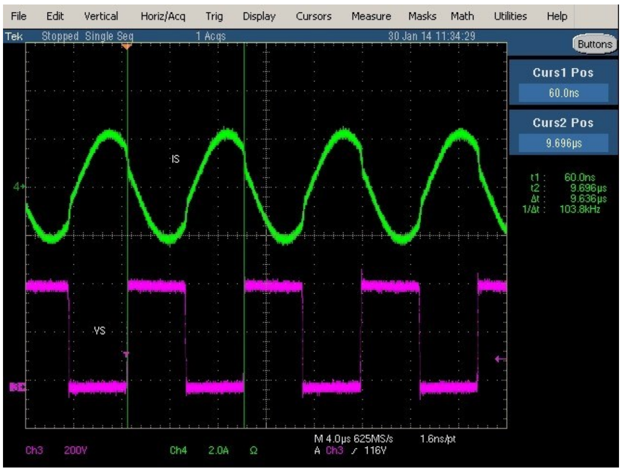

Figure 12: Operation at full load, V_{IN} = 420V

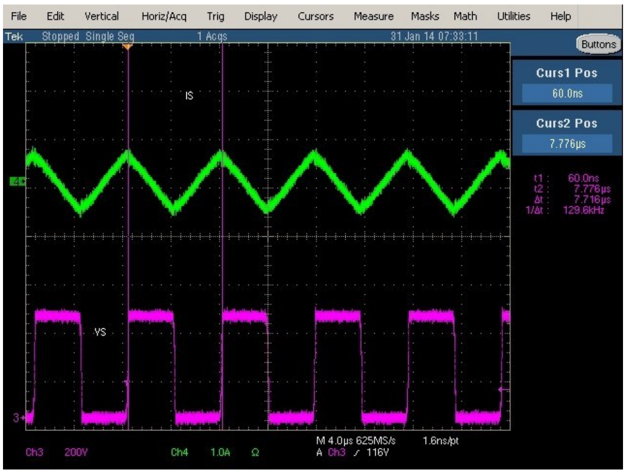

Figure 13: Operation at low load, V_{IN} = 420V

Turn on at Full and Low Load

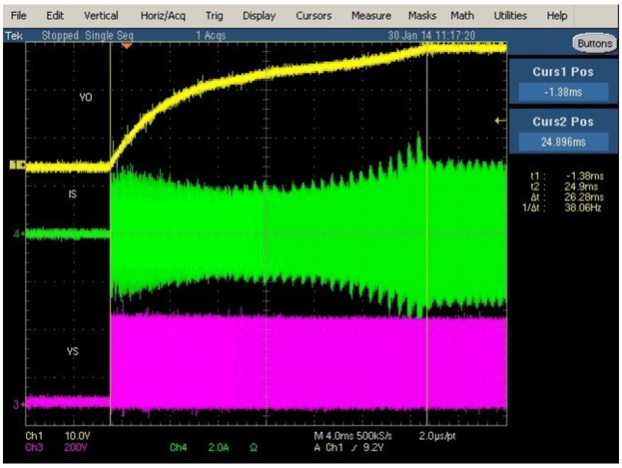

Figure 14: Turn on at full load, V_{IN} = 400V

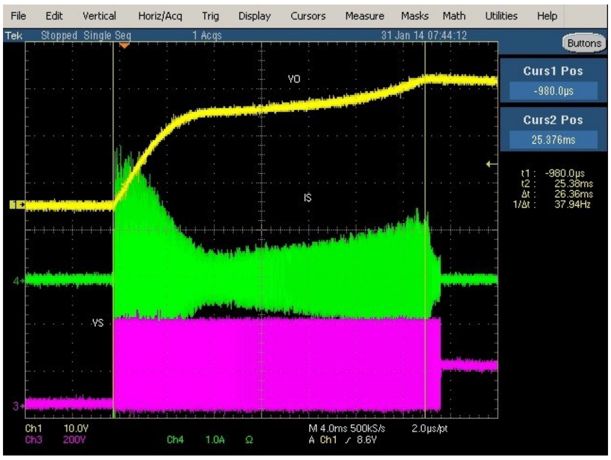

Figure 15: Turn on at low load, V_{IN} = 400V

No Load Power Consumption

V_{IN} (VDC)	Power (W)
380	1.8
400	1.3
420	0.84

Conclusion

A 200W Resonant Power Supply Reference Design with the DGD2113 High-Side, Low-Side Gate Driver was discussed and the evaluation data was presented. This reference design is suited for LCD TV applications, provides greater than 90% efficiency and very tight regulation over wide loads and is highlighted because of its ease of design and short development time.