Demonstration Board EPC9105 Quick Start Guide

EPC2001 + EPC2015 1.2 MHz Intermediate Bus Converter

EFFICIENT POWER CONVERSION

The EPC9105 demonstration board is a nominal 48 V input, 12 V output, 1.2 MHz resonant intermediate bus converter (IBC) with a 30 A maximum output current and 36 V to 60 V input voltage range. The demonstration board features the EPC2001 (100 V rated) and EPC2015 (40 V rated) enhancement mode on silicon field effect transistors (eGaN® FETs) as well as the first eGaN FET specific integrated circuit driver – the Texas Instruments LM5113. The EPC9105 board is intended to showcase the performance that can be achieved using the eGaN FETs and eGaN driver together in high frequency resonant applications.

The EPC9105 demonstration board's active area is 1.18 x 1.76 inches, designed to occupy the same board area as a standard eighth brick converter. The demonstration board is oversized to allow connections for bench evaluation. The additional board area outside of the active IBC area contains a minimum number of connections to ensure an accurate thermal profile of the eGaN FET based IBC.

There are various probe points to facilitate simple waveform measurements and efficiency calculations. For more information on the EPC2001 or EPC2015 eGaN FETs, or the LM5113 driver, please refer to the datasheets available from EPC at www.epc-co.com and www.TI.com. For more detailed circuit information, see the block diagrams in figure 1, figure 2, and the demonstration board schematic.

For a discussion of the benefits obtained from applying eGaN FETs in high frequency resonant designs, see:

David Reusch and Johan Strydom, "The eGaN® FET-Silicon Power Shoot-Out Vol. 10: High Frequency Resonant Converters", Power Electronics Technology, Vol.38, No.9, September, 2012 [1] Or EPC Training Video: EPC eGaN® FET Application: High Frequency Resonant Converter [2]

Table 1: Performance Summary (TA = 25°C)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Bus Input Voltage Range		36	48	60	V
V_{OUT}	Switch Node Output Voltage			12*		V
V_{OUT}	Switch Node Output Current				30†	A
f_{SW}	Switching frequency			1200		kHz
	Peak Efficiency	48 V_{IN}, I_{OUT} = 20 A		96.5¥		%
	Full Load Efficiency	48 V_{IN}, I_{OUT} = 30 A		96.2¥		%

* See figure 8 for typical output voltage vs. output current

† Maximum Output Power ≤ 350W, must be operated with 400 LFM forced air cooling at maximum conditions

¥ dsPIC controller generating gate signals consumes 0.65 W, for power stage efficiency (including bias supply, linear regulators, and gate drive losses), 96.8% and 96.4% efficiencies at 20 A and 30 A conditions are achieved, respectively

Quick Start Procedure

The EPC9105 Demonstration board is easy to set up to evaluate the performance of the EPC2001, EPC2015 eGaN FETs and the LM5113 driver. Refer to Figure 3 for proper connection and measurement setup and follow the procedure below:

1. With power off, connect the input power supply bus between V_{IN}+ (J1) and $V_{IN\ RET}$ (J4) banana jacks as shown. If measuring efficiency, connect in series through a DC ammeter to measure input current, I_{IN}.
2. With power off, connect the active (constant current) load between V_{OUT}+ (J5) and $V_{OUT\ RET}$ (J6) banana jacks as shown. If measuring efficiency, connect in series through a DC ammeter to measure output current, I_{OUT}.
3. With power off, connect voltmeter between V_{IN}+ (J7) and $V_{IN\ RET}$ (J8) Kelvin measurement terminals as shown to measure input voltage, V_{IN}.
4. With power off, connect voltmeter between V_{OUT}+ (J10) and $V_{OUT\ RET}$ (J11) Kelvin measurement terminals as shown to measure output voltage, V_{OUT}.
5. Turn on forced air cooling oriented in the direction shown in figure 3. For maximum current and power (output current ≤ 30 A for output power ≤ 350 W); use a minimum fan speed of 400 LFM.
6. Manually ramp up supply voltage to the nominal input voltage, 48 V, from 0 V. When the input voltage reaches 20 V, the converter will become operational and an output voltage and input current will be seen.
7. Measure the output voltage at nominal input voltage, 48 V, to make sure the board is fully functional and operating no-load. A no load input current of 0.1 A and an output voltage around 12 V is expected.
8. Turn on active load to the desired load current while staying below the maximum current (≤ 30 A for output power ≤ 350 W)
9. Once operational, adjust the bus voltage and load current within the allowed operating range and observe the output switching behavior, efficiency and other parameters.
10. For shutdown, follow steps in reverse.

NOTE. When measuring the high frequency content switch node and gate voltage, care must be taken to avoid long ground leads. Gate (J12), source (J13), and drain (J2) measurement points are given referenced to ground for primary switch Q4 to allow user to measure zero voltage switching transition of primary side transistor Q4.

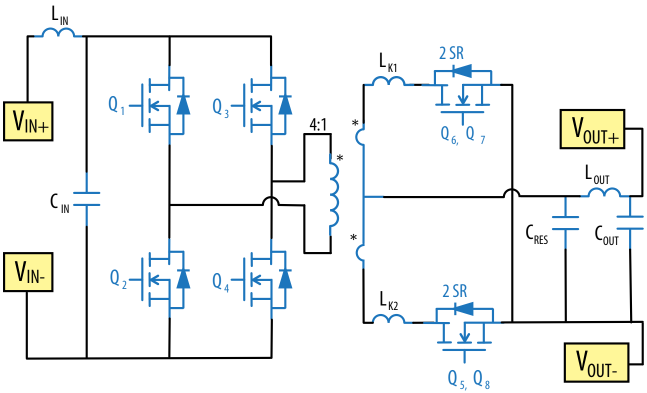


Figure 1: Power Circuit Diagram of EPC9105 Demonstration Board Power Stage

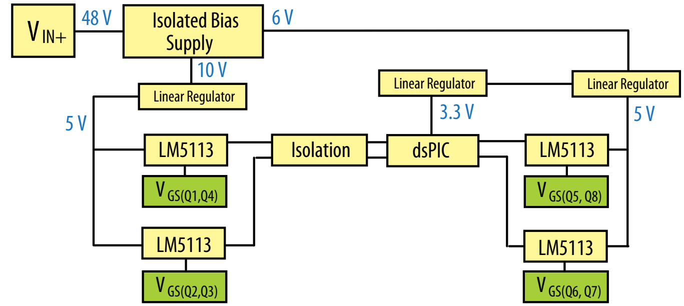


Figure 2: Block Diagram of EPC9105 Demonstration Board Gate Drive Generation

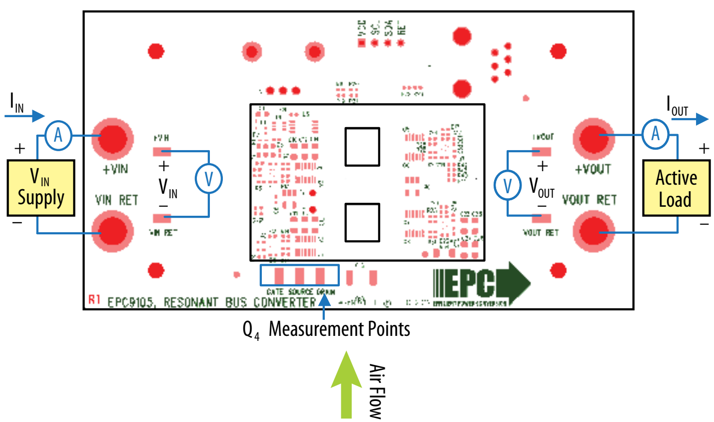


Figure 3: Proper Connection and Measurement Setup

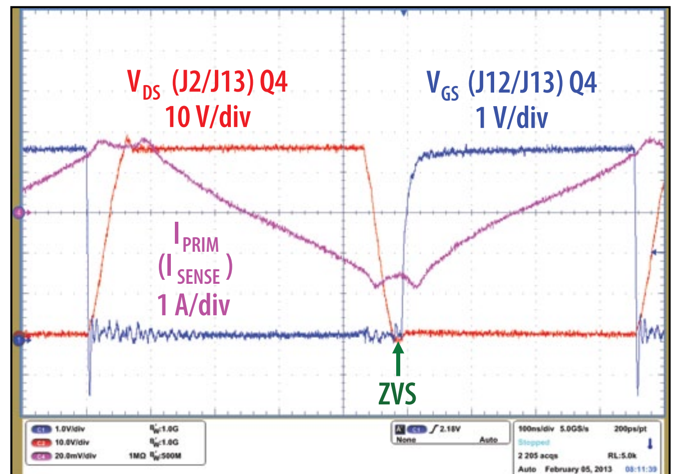


Figure 4: Typical primary waveforms taken at $V_{IN} = 48$ V, $I_{OUT} = 0$ A

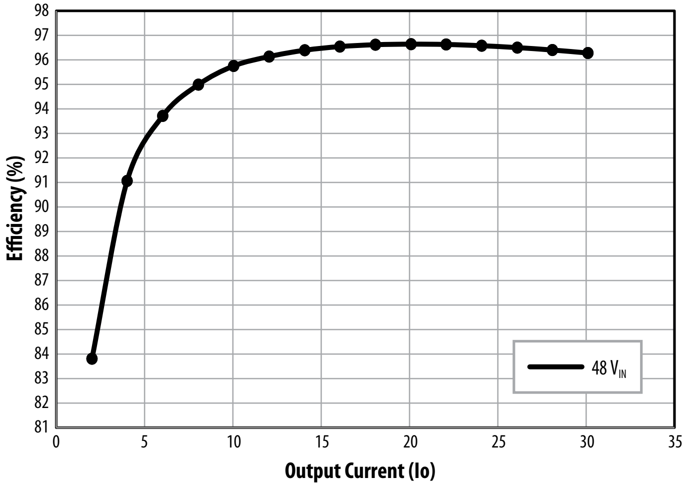


Figure 5: Typical efficiency curve vs. output current at nominal input voltage V_{IN} =48 V

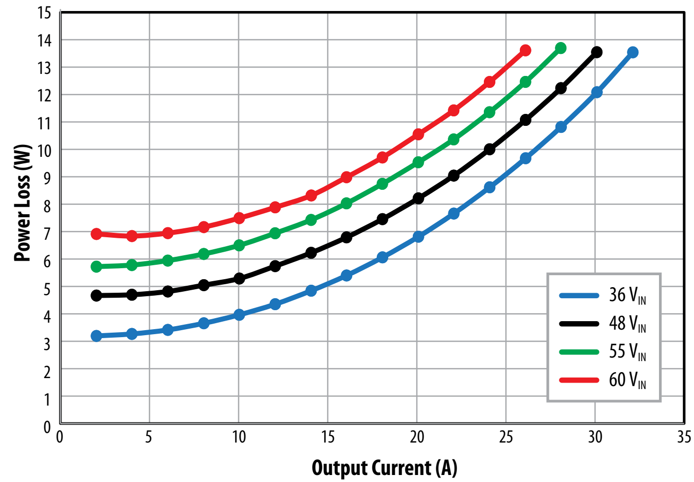


Figure 6: Typical power loss curves vs. output current

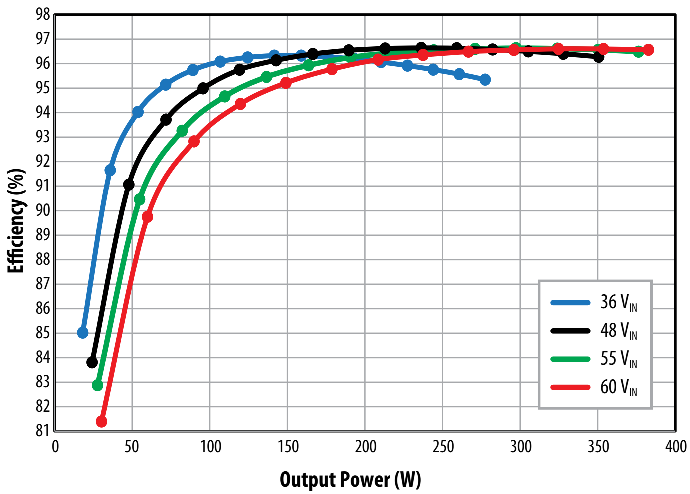


Figure 7: Typical efficiency curves vs. output power

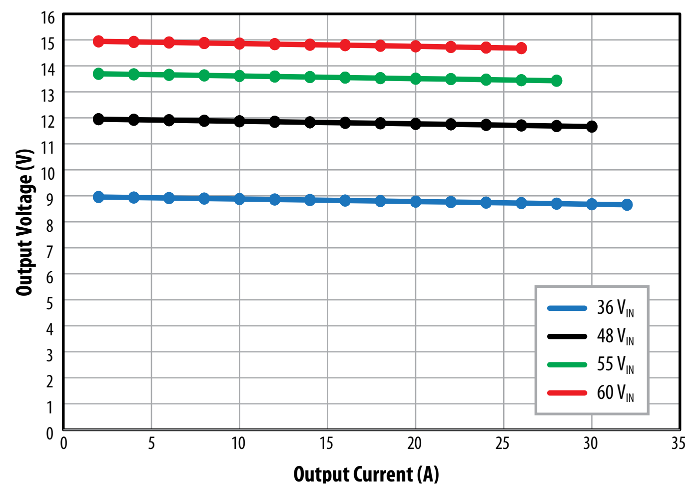


Figure 8: Typical output voltages vs. output current

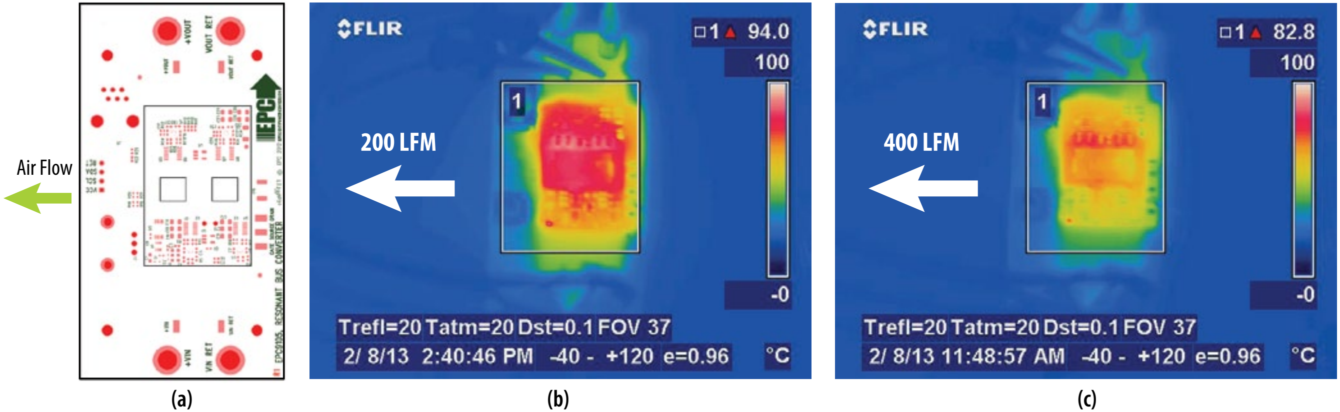


Figure 9: (a) Recommended board orientation for forced air cooling (b) Thermal plot, 200 LFM, 25°C, 48 V_{IN}, 28 A output current, 325 W output power (c) Thermal plot, 400 LFM, 25°C, 48 V_{IN}, 30 A output current, 350 W output power

THERMAL CONSIDERATIONS

The EPC9105 demonstration board thermal images for steady state full load operation are shown in Figure 9. The EPC9105 is intended for bench evaluation with low ambient temperature and forced air cooling. Operation without forced air cooling it is possible for limited power operation and the board will quickly become thermally limited. Care must be taken to not exceed the absolute maximum junction temperature of 125°C for the devices.

NOTE. The EPC9105 demonstration board does not have any overvoltage or over-current protection on board. Care must be taken to avoid failure due to over temperature, over current, and over voltage.

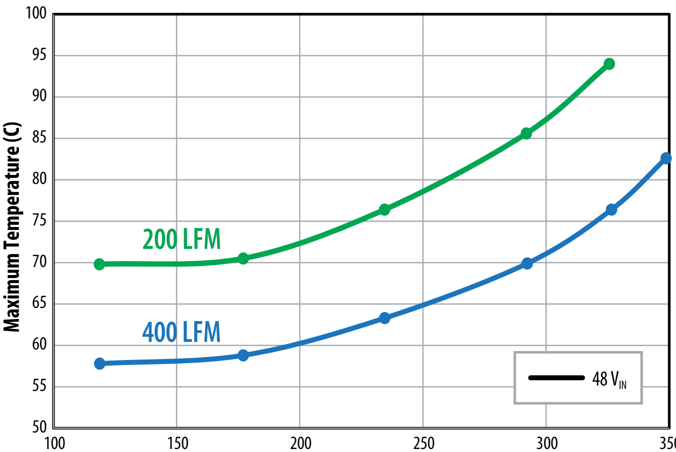


Figure 10: Maximum board temperature vs. output power at nominal input voltage V_{IN} =48 V at 25°C

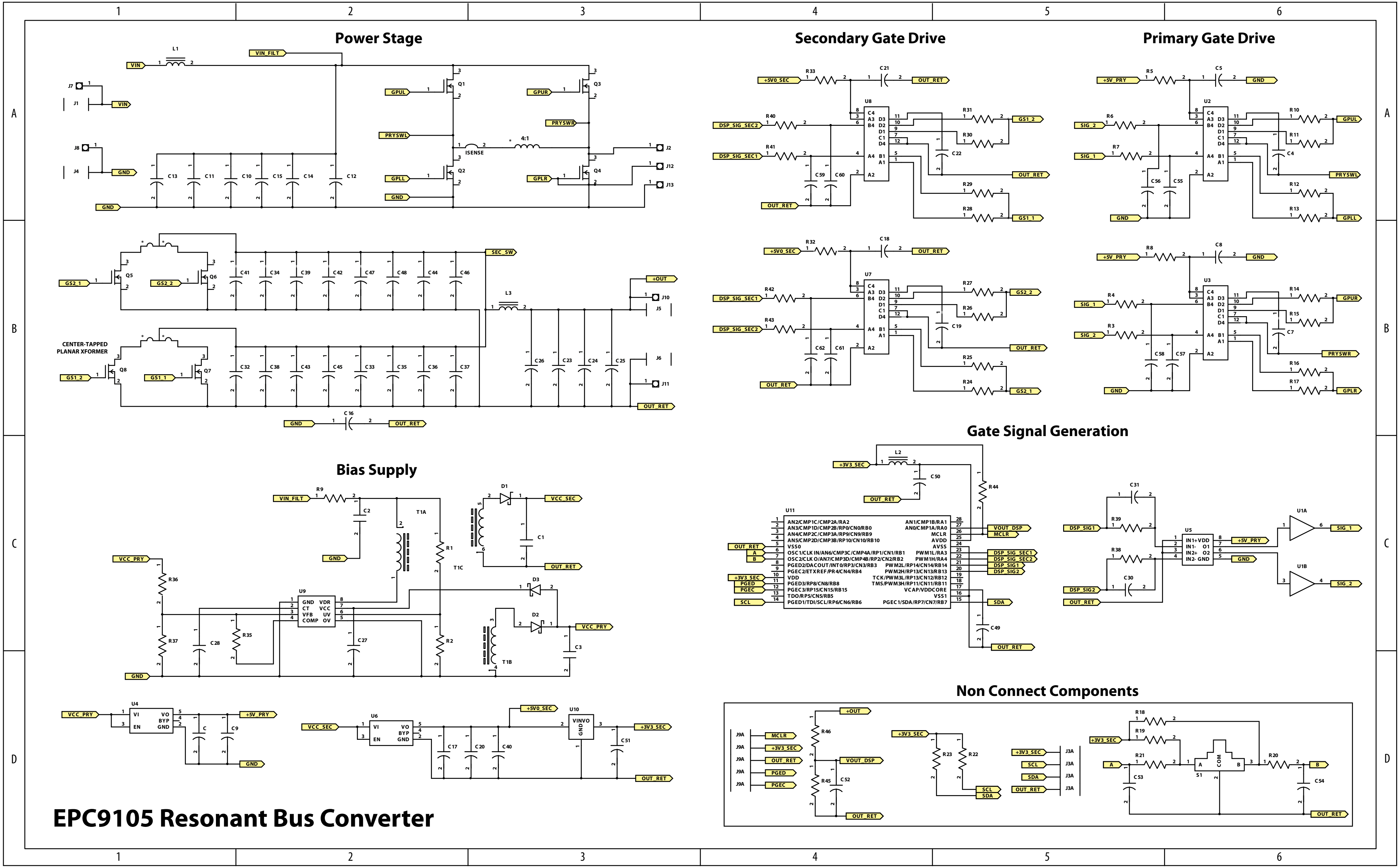
Table 2 : Bill of Material

Item	Qty	Reference	Part Description	Manufacturer / Part #
1	3	C52, C53, C54	CAPACITOR CERAMIC 0402 1000P 50V X7R	Murata Electronics, GRM155R71H102KA01D
2	9	C4, C5, C7, C8, C18, C19, C21, C22, C27	CAPACITOR CERAMIC 0402 0.1U 16V X7R	Murata Electronics, GRM155R71C104KA88D
3	10	C30, C31, C55, C56, C57, C58, C59, C60, C61, C62	CAPACITOR CERAMIC 0402 22P 50V NPO	TDK, C1005C0G1H220J
4	6	C6, C9, C17, C20, C40, C51	CAPACITOR CERAMIC 0402 2.2U 6.3V X5R	TDK, C1005X5R0J225M
5	1	C28	CAPACITOR CERAMIC 0402 330P 50V NPO	TDK, C1005C0G1H331J
6	1	C2	CAPACITOR CERAMIC 0603 0.1U 100V X7R	Murata Electronics, GRM188R72A104KA35D
7	2	C1, C3	CAPACITOR CERAMIC 0603 3.3U 16V 10% X5R	TDK, C1608X5R1C335K
8	2	C49, C50	CAPACITOR CERAMIC 0603 4.7U 10V X5R	Taiyo Yuden, LMK107BJ475KA-T
9	6	C10, C11, C12, C13, C14, C15	CAPACITOR CERAMIC 0805 1.0U 100V X7S	TDK, C2012X7S2A105K
10	4	C23, C24, C25, C26	CAPACITOR CERAMIC 0805 4.7U 25V 10% X7R	TDK, TMK212AB7475KG-T
11	16	C32, C33, C34, C35, C36, C37, C38, C39, C41, C42, C43, C44, C45, C46, C47, C48	CAPACITOR CERAMIC 0805 0.22U 50V 10% X7R	TDK, C2012X7R1H224K
12	1	C16	CAPACITOR CERAMIC 1812 3300P 2000V X7R	JOHANSON, 202S43W332KV4E
13	4	J1, J4, J5, J6	JACK NON-INSULATED 0.218"	KEYSTONE, 575-4
14	1	J3	CONN HEADER VERT 4POS .100	TE Connectivity, 640454-4
15	1	J9	CONNECTOR MODULAR JACK	TE Connectivity, 5520425-3
16	7	J2, J7, J8, J10, J11, J12, J13	TEST POINT PC MINIATURE SMT	KEYSTONE, 5015
17	3	D1, D2, D3	DIODE SMD 100V 0.2A SCHOTTKY SOD-523	ST MICROELECTRONICS, BAT41KFILM
18	1	S1	ENCODER 12MM ROTARY VERT 17.5MM	Panasonic, BAT41KFILM, EVE-GA1F1724B
19	1	U11	IC DSP POWE SUPPLY DSPIC33FJ16GS502	MICROCHIP, DSPIC33FJ16GS502-I/MM
20	1	U5	ISOLATOR TX/RX CMOS 8MSOP IL611 CMOS	NVE, IL611-1E
21	4	U2, U3, U7, U8	IC GATE DRIVE1 12SMD CSP LM5113 5V 5A HALF BRIDGE 100V	Texas Instruments, LM5113TME/NOPB
22	2	U4, U6	IC SMD SOT23-5 LINEAR REGULATOR LP2985 5V	Texas Instruments, LP2985IM5-5.0/NOPB
23	1	U10	IC LINEAR REGULATOR SMD 3V3 0.4% 0.25A LOW DROP SOT89	MICROCHIP, MCP1703T-3302E/MB
24	1	U1	IC SCHMITT-TRIG SGL INV 6TSSOP	NXP Semiconductor, 74LVC2G14GW,125
25	1	U9	IC PWM CONTROLER MSOP8	ON Semiconductor, NCP1030DMR2G
26	1	L2	FERRITE CHIP BEAD 180 OHMS 100MHZ 1.5A 0603	Murata Electronics, BLM18PG181SN1D
27	1	L1	INDUCTOR SMT 0.33U 20A IHLP2524	VISHAY, IHLP2525CZERR33M00
28	1	L3	INDUCTOR POWER 105NH 30A SMD	WURTH, 744302010
29	4	Q1, Q2, Q3, Q4	MOSFETGAN 100V 25A	EPC, EPC2001
30	4	Q5, Q6, Q7, Q8	MOSFETGAN 40V 33A	EPC, EPC2015
31	3	R38, R39, R45	RESISTOR 0402 1% 1.00K	YAGEO, RC0402FR-071KL
32	7	R18, R19, R22, R23, R37, R44, R46	RESISTOR 0402 1% 10.0K	ROHM, MCR01MZPF1002
33	4	R5, R8, R32, R33	RESISTOR 0402 1% 10	ROHM, RMCF0402FT10R0TR-ND
34	1	R2	RESISTOR 0402 1% 15.0K	ROHM, MCR01MZPF1502
35	2	R35, R36	RESISTOR 0402 1% 33.2K	VISHAY, CRCW040233K2FKED
36	10	R3, R4, R6, R7, R20, R21, R40, R41, R42, R43	RESISTOR 0402 1% 499	VISHAY, CRCW0402499RFKED
37	8	R10, R12, R14, R16, R25, R27, R29, R31	RESISTOR 0402 1% 4.99	VISHAY, CRCW04024R99FKED
38	1	R9	RESISTOR 0402 5% 1.0 OHM	VISHAY, CRCW04021R00JNED
39	8	R11, R13, R15, R17, R24, R26, R28, R30	RESISTOR 0402 ZERO OHM	Stackpole Electronics, RMCF0402ZT0R00
40	1	R1	RESISTOR 0603 1% 100K OHM	Panasonic, ERJ-3EKF1003V
41	1	T1A	Bias supply transformer	Custom Coils, P/N 7082

REFERENCES:

[1] David Reusch and Johan Strydom, "The eGaN® FET-Silicon Power Shoot-Out Vol. 10: High Frequency Resonant Converters", Power Electronics Technology, Vol.38, No.9, September, 2012 (http://powerelectronics.com/power_semiconductors/gan_transistors/egan-fet-silicon-power-shoot-out-volume-10-high-frequency-resonant-converters-0904/)

[2] EPC Training Video: EPC eGaN® FET Application: High Frequency Resonant Converter (http://epc-co.com/epc/DesignSupportbr/TrainingVideos/Appl cationHighFrequencyResonant-Converter.aspx)



Power Stage
Secondary Gate Drive
Primary Gate Drive
Gate Signal Generation
Bias Supply
Non Connect Components
EPC9105 Resonant Bus Converter
CENTER-TAPPED PLANAR XFORMER
VIN
VIN_FILT
GND
PRYSWL
PRYSWR
GPUL
GPUR
GPLL
GPLR
ISENSE
4:1
SEC_SW
+OUT
OUT_RET
GS1_1
GS1_2
GS2_1
GS2_2
+5V0_SEC
+5V_PRY
DSP_SIG_SEC1
DSP_SIG_SEC2
SIG_1
SIG_2
DSP_SIG1
DSP_SIG2
+3V3_SEC
VCC_SEC
VCC_PRY
VOUT_DSP
MCLR
PGED
PGEC
SCL
SDA
U11
AN2/CMP1C/CMP2A/RA2
AN3/CMP1D/CMP2B/RP0/CN0/RB0
AN4/CMP2C/CMP3A/RP1/CN5/RB1
AN5/CMP2D/CMP3B/RP10/CN10/RB10
VSS0
OSC1/CLKIN/AN6/CMP3C/CMP4A/RP1/CN1/RB1
OSC2/CLKO/AN7/CMP3D/CMP4B/RP2/CN2/RB2
PGED2/DACOUT/INT0/RP3/CN3/RB3
PGEC2/EXTREF/RP4/CN4/RB4
VDD
PGED3/RP8/CN8/RB8
PGEC3/RP15/CN15/RB15
TDO/RP5/CN5/RB5
PGED1/TDI/SCL/RP6/CN6/RB6
AN1/CMP1B/RA1
AN0/CMP1A/RA0
MCLR
AVDD
AVSS
PWM1L/RA3
PWM1H/RA4
PWM2L/RP14/CN14/RB14
PWM2H/RP13/CN13/RB13
TCK/PWM3L/RP13/CN12/RB12
TMS/PWM3H/RP11/CN11/RB11
VCAP/VDDCORE
VSS1
PGEC1/SDA/RP7/CN7/RB7
U9
GND VDR
CT VCC
VFB UV
COMP OV
T1A
T1B
T1C
U4
U6
U10
VI VO
EN BYP GND
VINVO
U5
IN1+VDD
IN1- O1
IN2+ O2
IN2- GND
U1A
U1B
S1
COM

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