

EPC9162

Bi-directional Evaluation Board

12 V Input, 60 V, 50 W Output (Boost)

48 V Input, 12 V, 60 W Output (Buck)

Quick Start Guide

Revision 1.0



DESCRIPTION

The EPC9162 demonstration board is a bi-directional buck or reverse-boost converter. It has a low and high voltage port. When powered from the low voltage port it can boost the voltage with output on the high voltage port up to 60 V maximum. If powered from the high voltage port, it operates as a buck converter. The simplified schematic diagram is shown in Figure 1. The synchronous converter features the 100 V **EPC2052** GaN FET, while the **EPC2038** GaN FET is used in the synchronous Bootstrap FET circuit. The EPC9162 is by default programmed as reverse boost converter that is powered from the low voltage port.

Other features include:

- High efficiency:
 - 96% @ 48 V input, 12 V/5 A output (buck)
 - 95% @ 12 V input, 60 V/0.85 A output (reverse-boost)
- Temperature rise: < 40 °C @ 60 V/0.85 A output
- Constant switching frequency: 500 kHz
- Digital control: Re-programmable

REGULATORY INFORMATION

This converter is for evaluation purposes only. It is not a full-featured converter and cannot be used in final products. No EMI test was conducted. It is not FCC approved.

FIRMWARE UPDATES

Every effort has been made to ensure all control features function as specified. It may be necessary to provide updates to the firmware. Please check the EPC website for the latest firmware updates.

Table 1: Electrical Characteristics (T_A = 25°C unless specified otherwise)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V _{HV}	High voltage bus port	Buck		48	65	V
		Boost		60	65	
V _{LV}	Low voltage bus port			12	40	
I _{HV}	HV bus current				0.85 ⁽¹⁾	A
I _{LV}	LV bus Current				5 ⁽¹⁾	
f _s	Switching Frequency			500		kHz
T _{rise}	Temperature Rise	Still air (natural convection)		40		°C

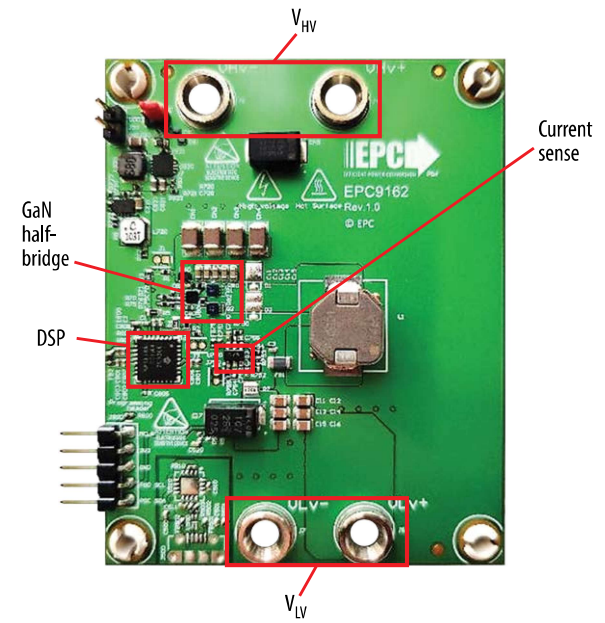
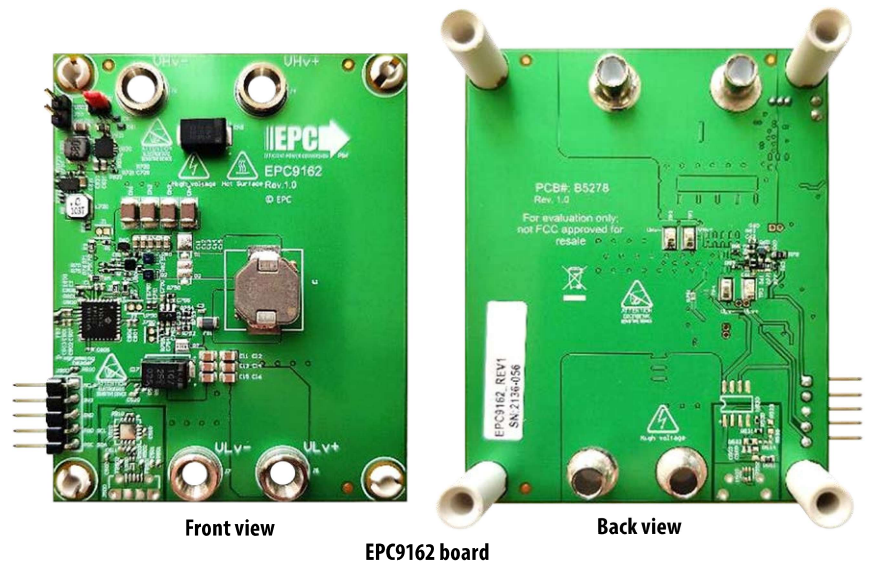


Figure 1: Functional diagram of the EPC9162 bi-directional DC-DC converter

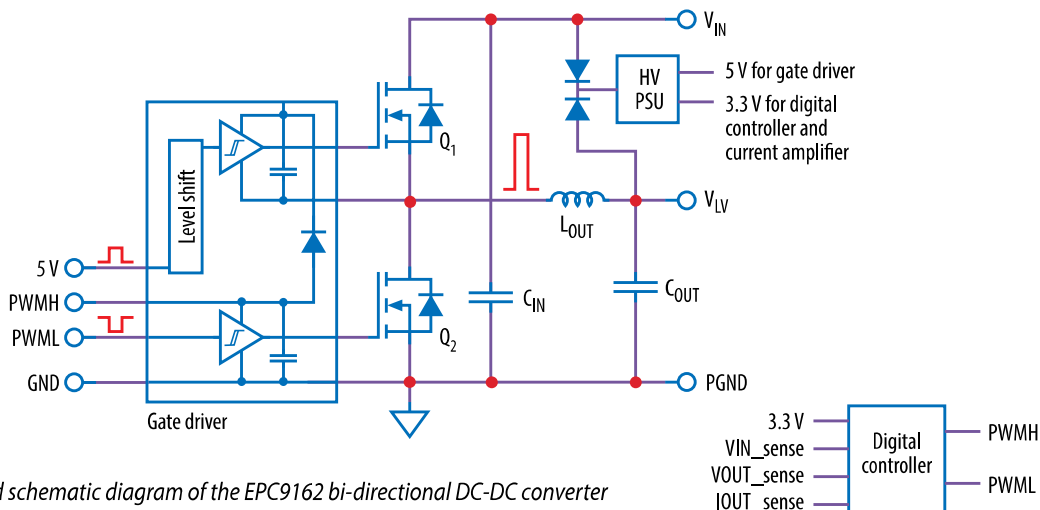


Figure 2: Simplified schematic diagram of the EPC9162 bi-directional DC-DC converter

ELECTRICAL PERFORMANCE

Typical efficiency and power loss

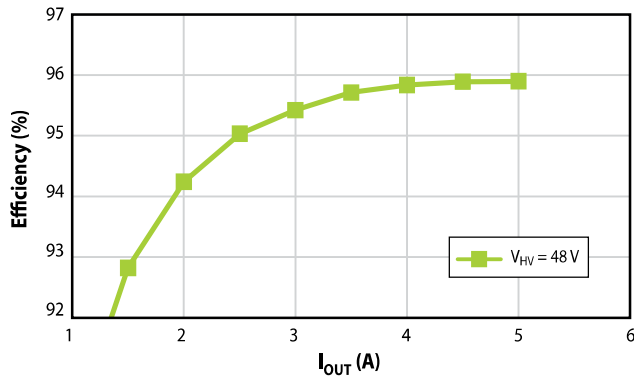


Figure 3: Buck mode of operation: 48 V input on high voltage port, 12 V output on low voltage port

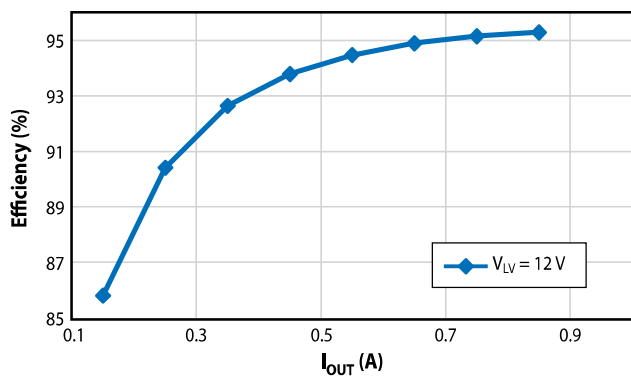
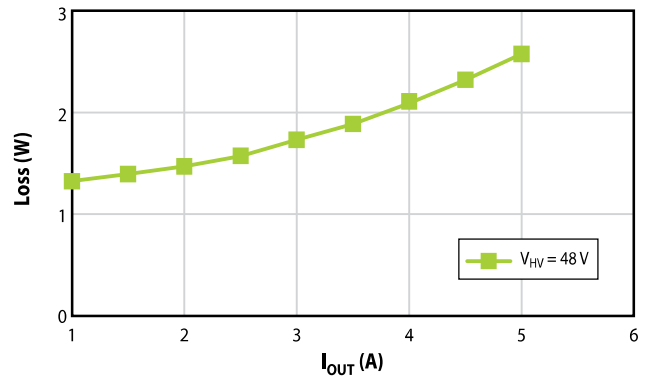
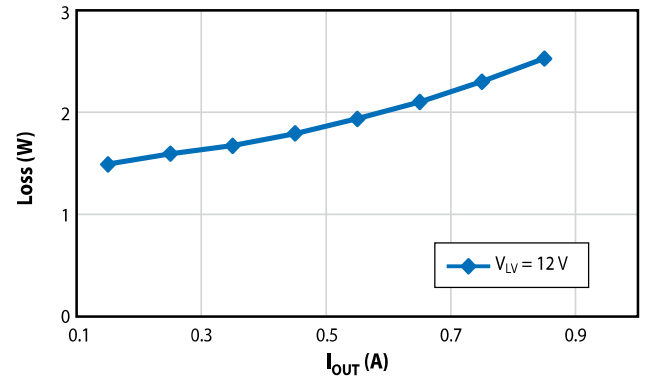


Figure 4: Reverse-boost mode of operation: 12 V input on low voltage port, 60 V output on high voltage port



Typical output voltage ripple

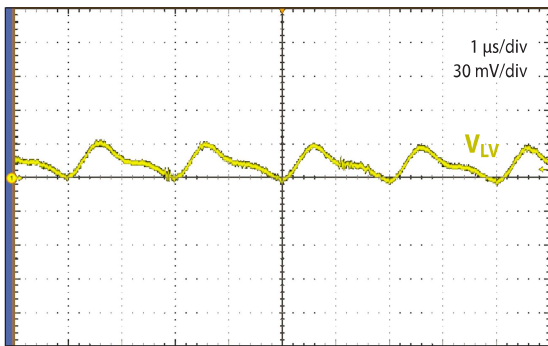


Figure 5: $V_{HV} = 48\text{ V}$, $V_{LV} = 12\text{ V}$, $I_{LV} = 1\text{ A}$

Typical transient response

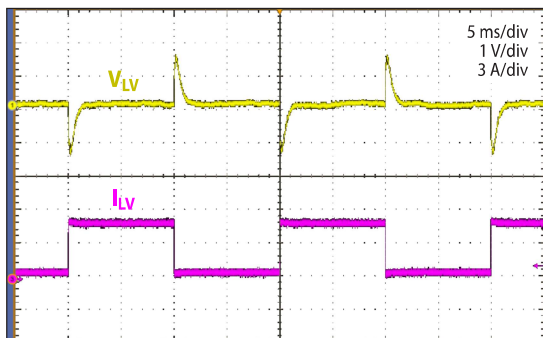


Figure 6: Transient response for buck operation at $V_{HV} = 48\text{ V}$, $V_{LV} = 12\text{ V}$, 10% (0.5 A) to 100% (5 A)

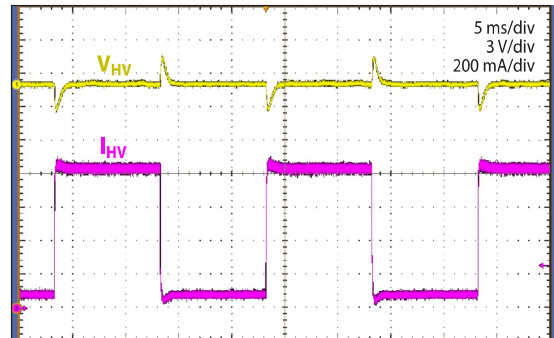


Figure 7: Transient response for boost operation at $V_{LV} = 12\text{ V}$, $V_{HV} = 60\text{ V}$, 10% (85 mA) to 100% (0.85 A)

Thermal Performance

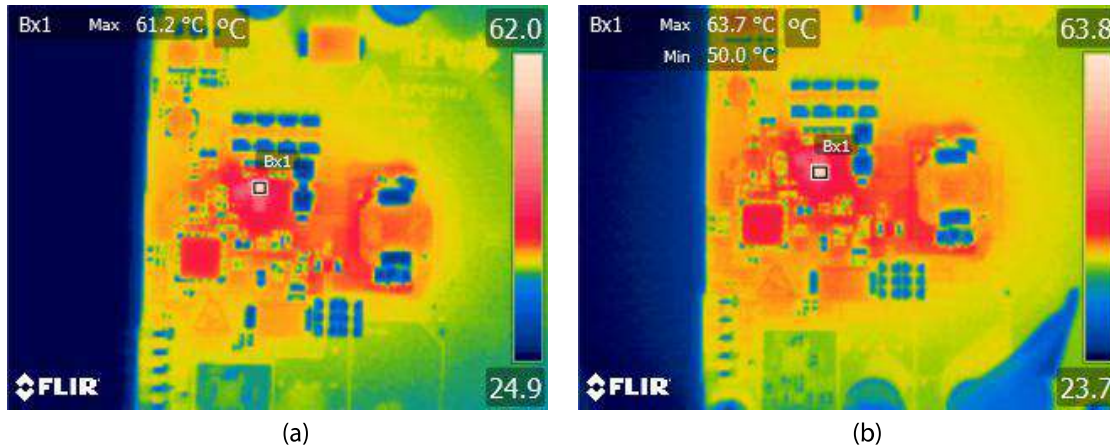


Figure 8: Thermal image taken at still air (no forced air cooling) for:
 (a) buck operation: $V_{HV} = 48\text{ V}$, $V_{LV} = 12\text{ V}$, $I_{LV} = 5\text{ A}$; (b) Boost operation: $V_{LV} = 12\text{ V}$, $V_{HV} = 60\text{ V}$, $I_{HV} = 0.85\text{ A}$

THERMAL CONSIDERATIONS

The EPC9162 demonstration board showcases the EPC2052 eGaN FET. The EPC9162 is intended for bench evaluation with low ambient temperature and with or without forced air cooling. There is no provision for attaching a heat-sink and so care must be taken to not exceed the absolute maximum die temperature of 150° C. The EPC9162 demonstration board does not have any current or thermal protection on board.

OPERATING CONSIDERATIONS

Controller

The EPC9162 power module features a Microchip dsPIC33CK32MP102 Digital Signal Controller DSC. This 100 MHz single core device is equipped with dedicated peripheral modules for Switched-Mode Power Supply (SMPS) applications, such as a feature-rich 4-channel (8x output), 250 ps resolution pulse width modulation (PWM) logic, three 3.5 Msps Analog-To-Digital Converters (ADC), three 15 ns propagation delay analog comparators with integrated Digital-To-Analog Converters (DAC) supporting ramp signal generation, three operational amplifiers as well as Digital Signal Processing (DSP) core with tightly coupled data paths for high performance real-time control applications. The device used is the smallest derivative of the dsPIC33CK single core and dsPIC33CH dual core DSC families. The device used in this design comes in a 28 pin 6x6 mm UQFN package, specified for ambient temperatures from -40 to +125° C. Other packages including a 28 pin UQFN package with only 4x4 mm are available.

The dsPIC33CK device is used to drive and control the converter in a fully digital fashion where the feedback loops are implemented and executed in software. Migrating control loop execution from analog circuits to embedded software enhances the flexibility in terms of applied control laws as well as making modifications to the feedback loop and control signals during runtime, optimizing control schemes and adapting control accuracy and performance to most recent operating conditions. As a result, digital control allows users to tailor the behavior of the converter to application specific requirements without the need for modifying hardware.

Programming

The Microchip dsPIC33CK controller can be re-programmed using the in-circuit serial programming port (ICSP) available on the 5-pin header. This interface supports the Microchip in-circuit programmers/debuggers, such as MPLAB® ICD4, MPLAB® REAL ICE or MPLAB® PICkit4 and previous derivatives.



Figure 9: Programming connection

Control loop

The EPC9162 bi-directional converter module adopts constant frequency, average current mode control implemented by a Microchip dsPIC33CK32MP102 Digital Signal Controller (DSC). The error between the output voltage feedback signal and the voltage reference is fed to an error amplifier and generate a current reference signal. Another error amplifier compares the sensed inductor average current with this current reference, and generates a command signal that drives the pulse width modulator. When the output current increases, the decrease in the voltage feedback signal causes the command signal to increase until the average inductor current matches the new output current.

QUICK START OPERATING PROCEDURE

The EPC9162 power module is easy to set up for evaluation. Refer to Figures 10-11 and follow the procedure below for proper connection and measurement setup (**Note: Make sure the correct firmware (either buck or boost) is programmed [Download firmware]**). The firmware for buck and boost mode are separate. Please make sure the correct firmware is programmed. The firmware is for demonstration purposes only and does not support advanced protection features. If you need more functionalities for your application, please contact EPC.

1. With power off, connect the input power supply to V_{LV} or V_{HV} as shown in Figure 10 for buck operation and Figure 11 for boost operation.

2. With power off, connect the load to V_{LV} or V_{HV} as in Figure 10 for buck operation and Figure 11 for boost operation.
3. Making sure the initial input supply voltage is 0 V, turn on the power and increase the voltage to the required value (do not exceed the absolute maximum voltage on each port).
4. Once operational, adjust the load within the operating range and observe the switching behavior, efficiency, transient response and other parameters.
5. For shutdown, please follow the above steps in reverse.

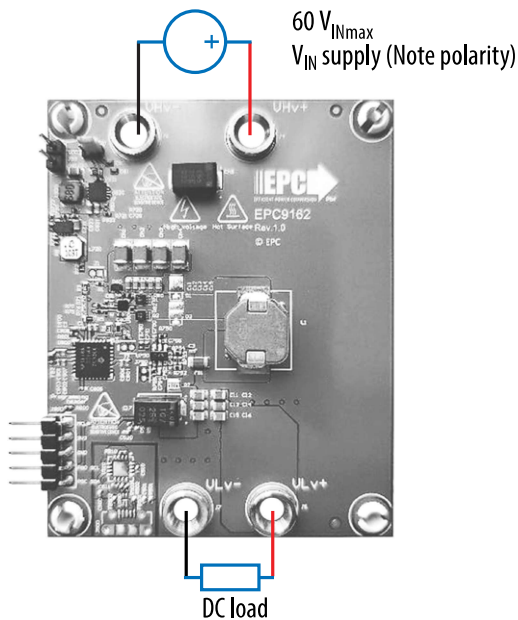


Figure 10: Input and output connection (buck)

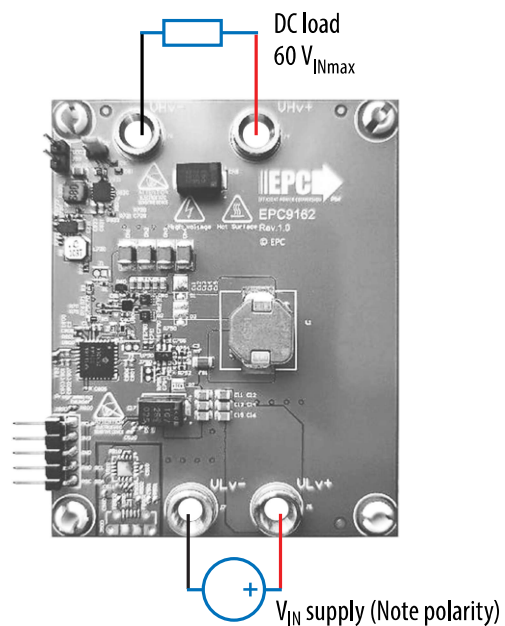


Figure 11: Input and output connection (boost)

MECHANICAL SPECIFICATIONS

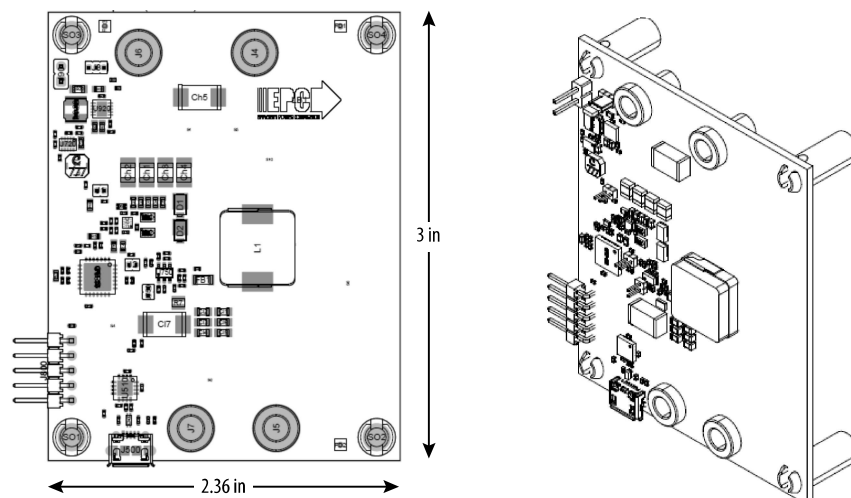


Figure 12: EPC9162 mechanical dimensions

Table 2: Bill of Materials

Item	Qty	Reference	Part Description	Manufacturer	Part #
1	2	C801, C804	CAP CER 10000 pF 25 V X7R 0402	KEMET	C0402C103K3RACTU
2	1	C2	CAP CER 680 pF 25 V COG/NP0 0402	Murata	GRM1555C1E681JA01D
3	1	C3	CAP CER 33 pF 50 V COG/NP0 0402	Samsung	CL05C330JB5NNNC
4	11	C60, C61, C81, C500, C501, C520, C750, C802, C803, C806, C807	CAP CER 0.1 μF 25 V X7R 0402	Yageo	CC0402KRX7R8BB104
5	1	C62	CAP CER 0.022 μF 25 V X7R 0402	TDK	C1005X7R1E223K050BB
6	1	C80	CAP CER 4.7 μF 10 V X5R 0402	TDK	C1005X5R1A475K050BC
7	2	C502, C503	CAP CER 47 pF 50 V COG/NPO 0402	Yageo	CC0402JRNPO9BN470
8	1	C510	CAP CER 1 μF 10 V X7S 0402	TDK	C1005X7S1A105M050BC
9	1	C511	CAP CER 0.47 μF 25 V X5R 0402	TDK	C1005X5R1E474K050BB
10	2	C720, C751	CAP CER 2.2 μF 25 V X5R 0402	Murata	GRM155R61E225ME15D
11	1	C721	CAP CER 22 μF 16 V X5R 0603	Samsung	CL10A226M07JZNC
12	1	C752	CAP CER 10000 pF 100 V X7S 0402	TDK	C1005X7S2A103M050BB
13	2	C754	CAP CER 47 pF 50 V COG 0402	Yageo	CC0402JRNPO9BN470
14	1	C800	CAP CER 51 pF 50 V COG/NP0 0402	Samsung	CL05C510JB5NNNC
15	2	C808,C1	CAP CER 220 pF 50 V X7R 0402	KEMET	C0402C221K5RACTU
16	1	C920	CAP CER 1 μF 100 V X7R 0805	AVX	08051C105K4Z2A
17	1	C921	CAP CER 1 μF 25 V X7R 0603	TDK	C1608X7R1E105K080AB
18	1	C923	CAP CER 10 μF 6.3 V X6S 0603	Taiyo Yuden	JMK107BC6106MA-T
19	4	Ch1, Ch2, Ch3, Ch4	CAP CER 10 μF 75 V X7R 1210	TDK	CGA6P1X7R1N106M250AC
20	1	Ch5	CAP TANT POLY 15 μF 75 V 2917	KEMET	T521X156M075ATE035
21	5	Ci1, Ci2, Ci3, Ci4, Ci5	CAP CER 0.1 μF 100 V X7R 0603	Murata	GRM188R72A104KA35D
22	6	Cl1, Cl2, Cl3, Cl4, Cl5, Cl6	CAP CER 4.7 μF 50 V X5R 0805	TDK	C2012X5R1H475K125AB
23	1	Cl7	CAP TANT POLY 100 μF 25 V 2917	KEMET	T521X107M025ATE030
24	1	D60	DIODE ZENER 5.1 V 150 mW 0603	Bourns	CD0603-Z5V1
25	2	D61, D63	DIODE SCHOTTKY 30 V 30 mA SOD523	Diodes Inc.	SDM03U40-7
26	2	D90, D91	DIODE GEN PURP 80 V 125 MA 2DFN	Diodes Inc.	1N4448HLP-7
27	1	D500	TVS DIODE 5 V 7.7 V SOT563	Wurth	82400152
28	1	FB1	FERRITE BEAD 50 Ω 1206 12 A 1LN	Murata	BLM31SN500SN1L
29	1	FB2	FERRITE BEAD 180 Ω 0603 1.5 A	Murata	BLM18PG181SN1D
30	2	FB501, FB502	FERRITE BEAD 600 Ω 0402 1LN	Murata	BLM15PX601SN1D
31	1	FB750	FERRITE BEAD 1.8 KΩ 0402 1LN	TDK	MMZ1005Y182CTD25
32	1	J3	Header Male 50 mil 1 row, 3 pos., Thru Vert.	Sullins	GRP031VWVN-RC
33	4	J4, J5, J6, J7	PCB Banana Female 1 row, 1 pos., Thru Vert.	Keystone	575-8
34	1	J90	Header Male 100 mil 1 row, 2 pos., Thru Vert.	Tyco	4-103185-0-02
35	1	J800	Header 100 mil 5 pos. Right Angle	Wurth	61300511021
36	1	JP1	50 mil Jumper Red with Handle	Harwin Inc	M50-2020005
37	1	L1	FIXED IND 10 μH 21 MΩ	TDK	SPM10065Vt-100M-D
38	1	L720	10 μH	CoilCraft	LPS4012-103MRB
39	1	L920	FIXED IND 68 μH 540 MA 840 MΩ	Wurth	74404042680
40	2	Q1, Q2	100 V 13.5 mΩ 8.2 A	EPC	EPC2052
41	1	Q60	100 V 330 0 mΩ 0.5 A	EPC	EPC2038
42	3	R1, R2, R755	RES SMD 20 Ω 0.5% 1/16 W 0402	Yageo	RT0402DRE0720RL
43	1	R3	RES SMD 180 K Ω 0.1% 1/10 W 0603	Panasonic	ERA-3AEB184V
44	1	R4	RES SMD 31 K Ω 0.1% 1/10 W 0603	Panasonic	ERA-3AEB3162V
45	1	R5	RES SMD 9.1 K Ω 0.1% 1/5 W 0603	Panasonic	ERJ-PB3B9101V
46	1	R6	RES SMD 2.7 K Ω 0.1% 1/10 W 0603		ERA-3AEB272V

Table 2: Bill of Materials (continued)

Item	Qty	Reference	Part Description	Manufacturer	Part #
47	1	R7	RES 0.001 Ω 1W 0805 WIDE	Susumo	KRL2012E-M-R001-J-T5
48	2	R8, R922	RES SMD 100 K Ω 1% 1/16 W 0402	Yageo	RT0402FRE07100KL
49	1	R62	RES SMD 27 K Ω 5% 1/10 W 0402	Panasonic	ERJ-2GEJ273X
50	1	R63	RES 20 Ω 5% 1/16W 0402	Stackpole	RMCF0402JT20R0
51	2	R70, R75	RES SMD 2.2 Ω 5% 1/10 W 0402	Panasonic	ERJ-2GEJ2R2X
52	3	R71, R76, R510	RES SMD 10 K Ω 1% 1/16 W 0402	Yageo	RC0402FR-0710KL
53	3	R77, R81, R83	RES 0 Ω JUMPER 1/16 W 0402	Stackpole	RMCF0402ZT0R00
54	3	R78, R551, R920	RES SMD 0 Ω JUMPER 1/10 W 0603	Panasonic	ERJ-3GEY0R00V
55	3	R80, R82, R750	RES SMD 1 Ω 1% 1/16 W 0402	Yageo	RC0402FR-071RL
56	1	R501	RES SMD 4.7 K Ω 1% 1/10 W 0402	Panasonic	ERJ-2RKF4701X
57	2	R502, R503	RES SMD 15 Ω 1% 1/10 W 0402	Panasonic	ERJ-2RKF15R0X
58	2	R530, R531	RES SMD 270 Ω 1% 1/10 W 0402	Panasonic	ERJ-2RKF2700X
59	4	R720, R724, R752, R754	RES SMD 0 Ω JUMPER 1/10 W 0402	Panasonic	ERJ-2GE0R00X
60	3	R721, R800, R801	RES SMD 10 K Ω 5% 1/16 W 0402	Yageo	RC0402JR-0710KL
61	1	R722	RES SMD 90.9 K Ω 0.1% 1/16 W 0402	Panasonic	ERA-2AEB9092X
62	2	R723, R923	RES SMD 31.6 K Ω 1% 1/16 W 0402	Yageo	RC0402FR-0731K6L
63	1	R921	RES SMD 1 K Ω 5% 1/16 W 0402	Yageo	RC0402JR-071KL
64	4	SO1, SO2, SO3, SO4	8834 Nylon Standoff	Keystone	8834
65	4	TP1, TP2, TP3, TP4	HookUP SMD	Keystone	5015
66	1	U80	80 V Half Bridge eGaN Driver	Upi	uP1966E
67	1	U720	Buck Switching Regulator IC REG BUCK ADJ 500 MA 10 WSON	Texas Instruments	TPS62175DQCR
68	1	U750	Current Sense Amplifier SOT-23-6, gain 50	MicroChip	MCP6C02T-50E/CHY
69	1	U800	100 MHz 16-bit, 28-pin, 32 kB	MicroChip	DSPIC33CK32MP102-I/2N
70	1	U920	Synchronous Buck Regulator Adjustable (3-65)V _{in} , (150 mA I _{out})	Texas Instruments	LM5165DRCT

Table 3: Optional Components

Item	Qty	Reference	Part Description	Manufacturer	Part #
1	2	C70, C75	CAP CER 100 pF 50 V X7R 0402	Yageo	CC0402KRX7R9BB101
2	1	C805	CAP CER 51 pF 50 V COG/NP0 0402	Samsung	CL05C510JB5NNNC
3	2	D1, D2	DIODE SCHOTTKY 100 V 2 A DO220AA	Vishay	SS2PH10-M3
4	1	D77	DIODE SCHOTTKY 40 V 300 mA SOD523	ST Microelectronics	BAT54KFILM
5	3	J1, J2, J750	Header Male 50 mil 1 row, 2 pos., Thru Vert.	Sullins	GRPB021VWVN-RC
6	1	R60	RES SMD 4.7 Ω 5% 1/10 W 0402	Panasonic	ERJ-2GEJ4R7X
7	4	R520, R521, R534, R535	RES SMD 4.7K Ω 1% 1/10 W 0402	Panasonic	ERJ-2RKF4701X
8	1	R751	RES SMD 0 Ω JUMPER 1/10 W 0402	Panasonic	ERJ-2GE0R00X
9	1	L500	CMC 550 MA 2LN 90 Ω SMD	Würth	744230900
10	1	U510	USB to I2C and UART	MicroChip	MCP2221A-I/ML
11	1	U520	Bi-directional Digital Isolator	Analog Devices	ADuM1201CR
12	1	J500	USB Micro Thru RightAngle	Amphenol	10118194-0001LF
13	3	R532, R533, R552	RES SMD 0 Ω JUMPER 1/10 W 0603	Panasonic	ERJ-3GEY0R00V

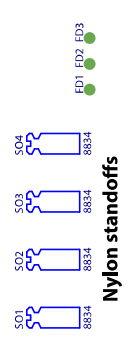
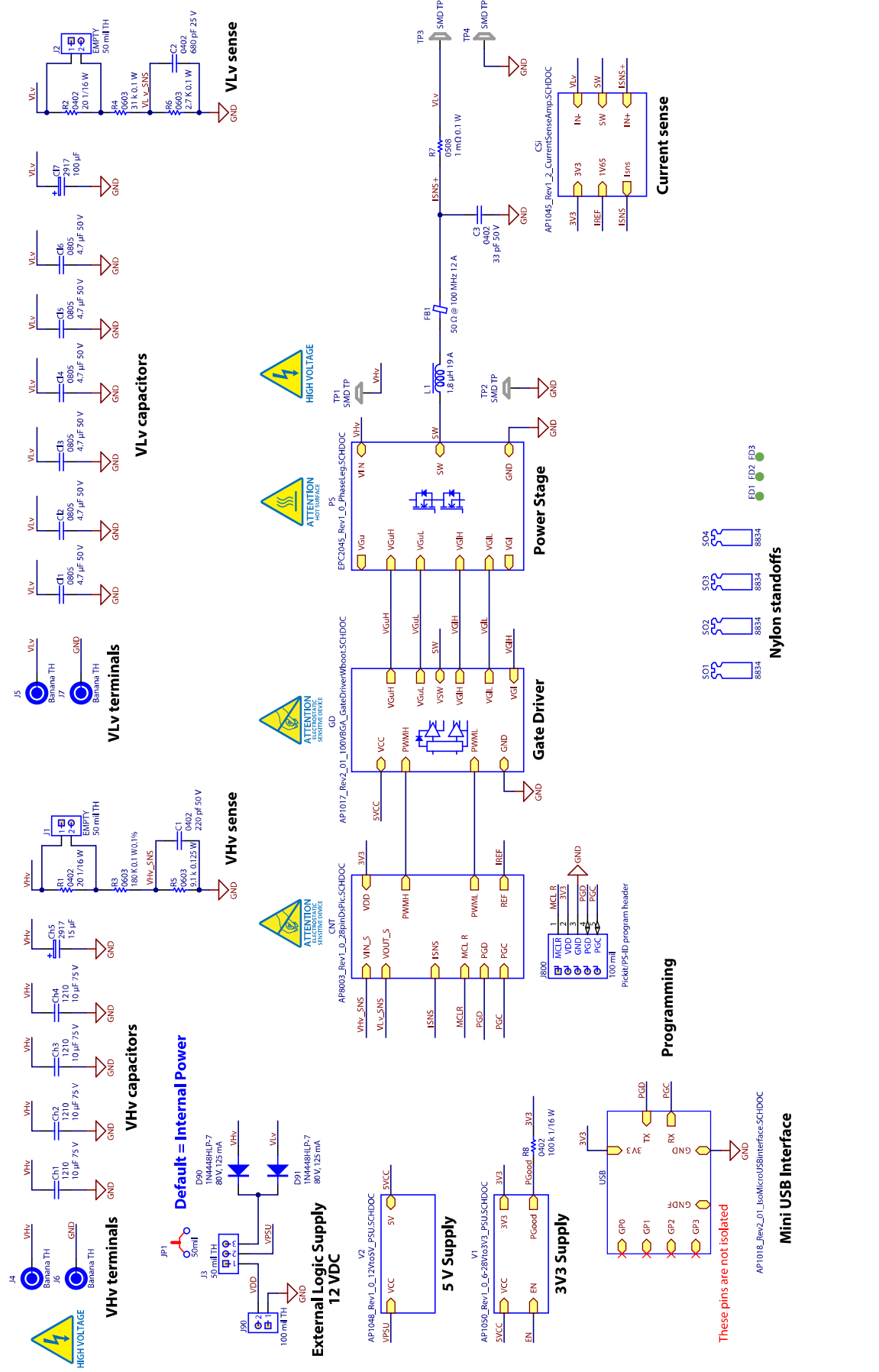


Figure 13: EPC9162 Main schematic

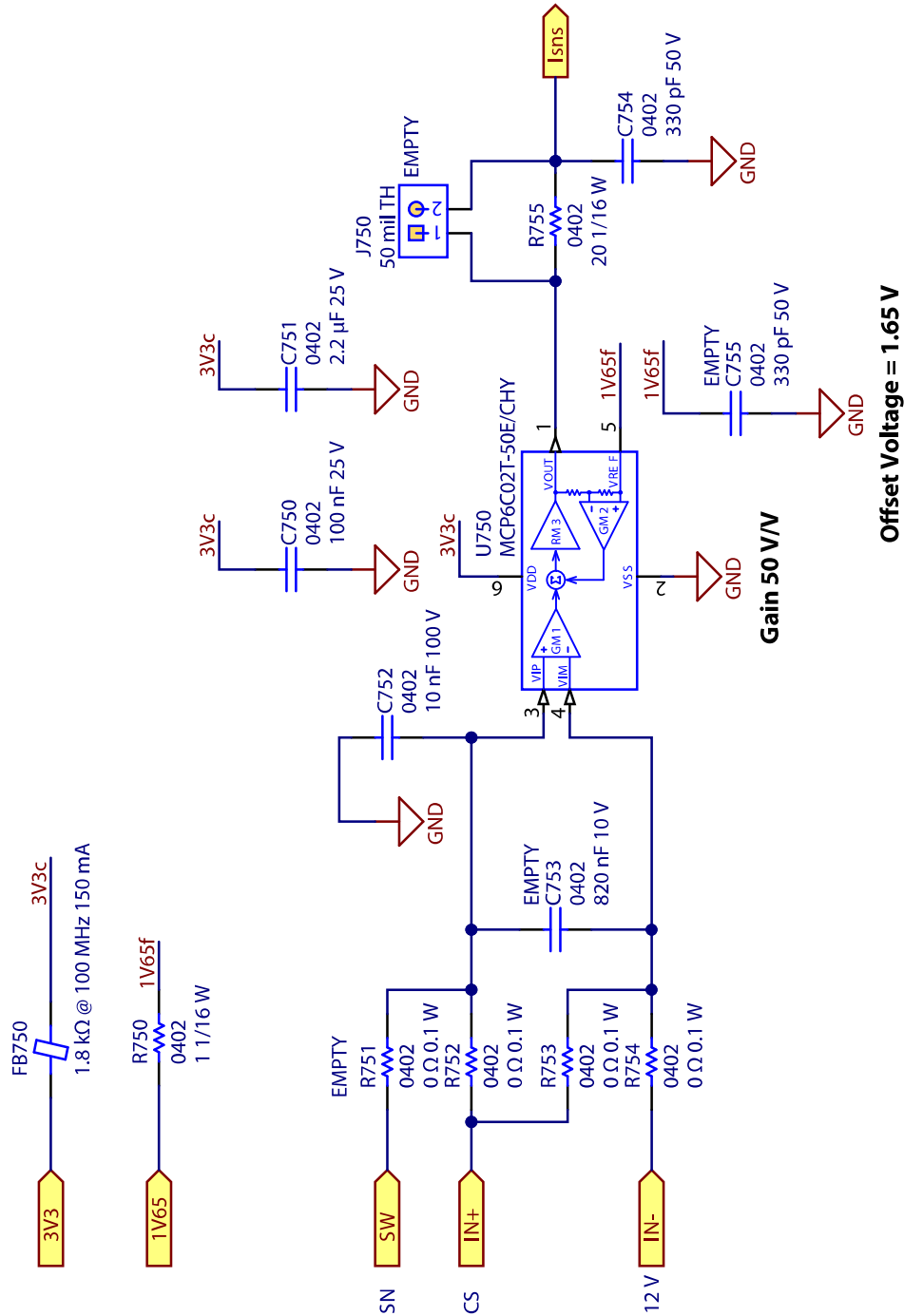


Figure 15: Bi-Directional 65 V Current Sense Amplifier schematic

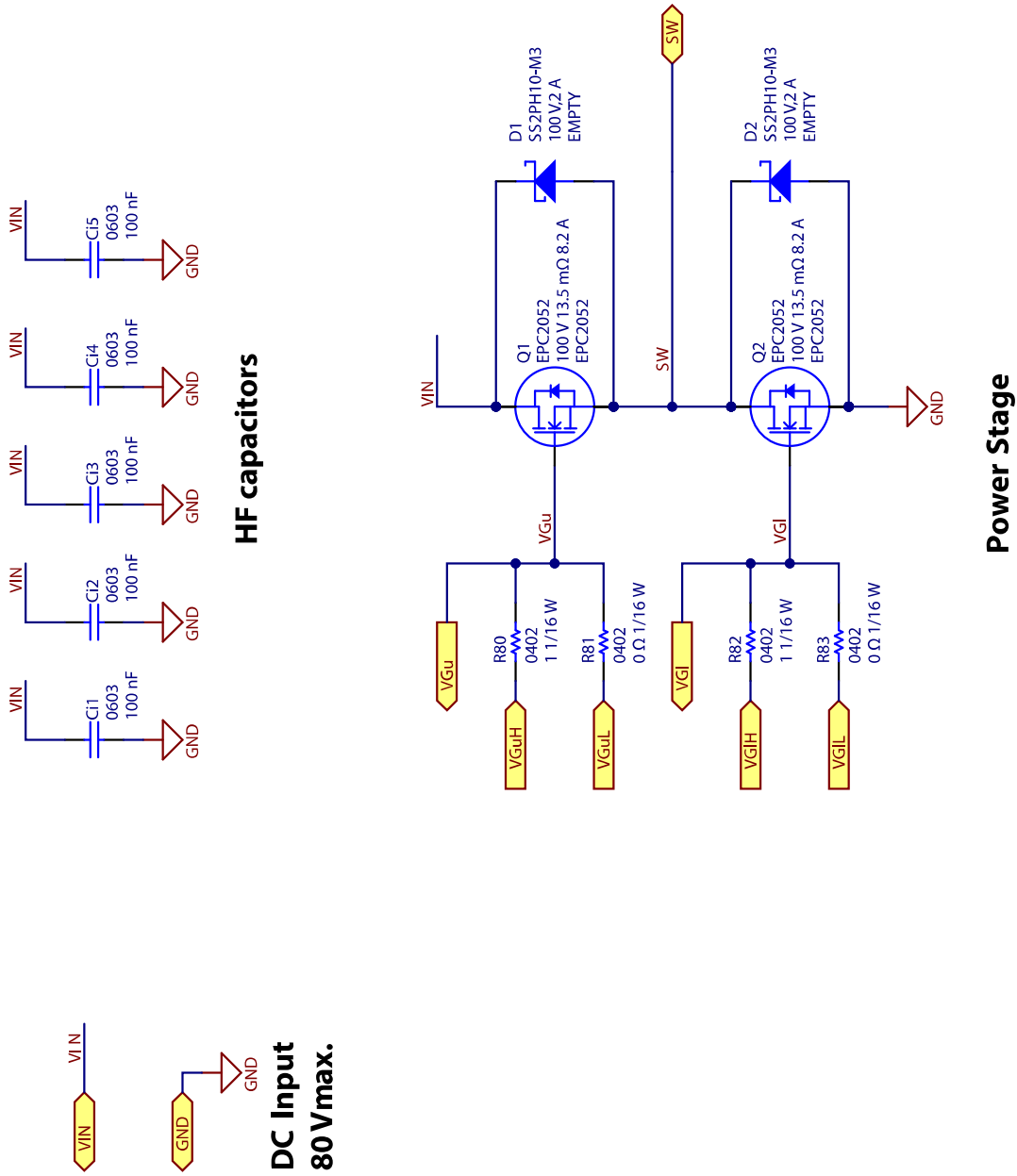
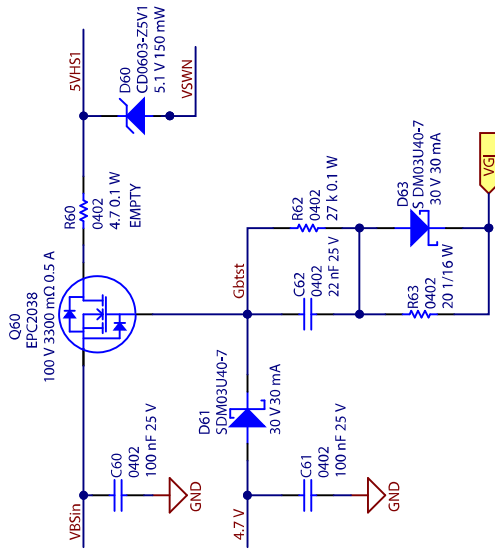


Figure 16: EPC2052 Phase leg schematic

Sync Boot = Install R60 and D77, remove R77
 No Sync Boot = Install R77, remove R60 and D77
 Default = No Sync Boot



Synchronous Bootstrap Power Supply

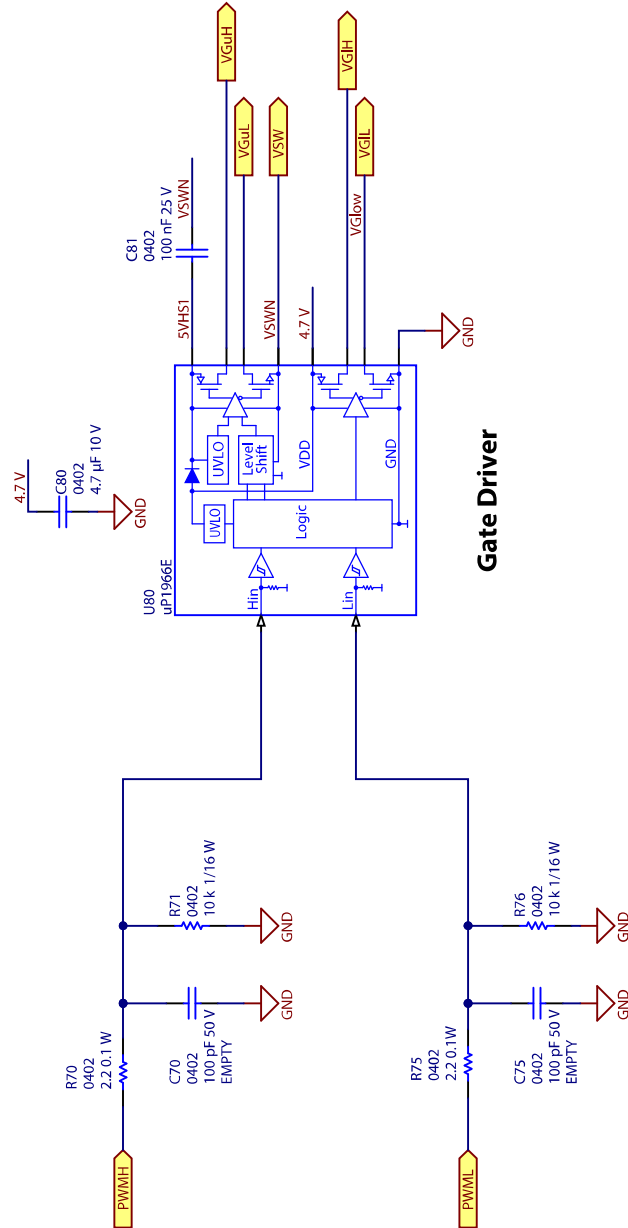
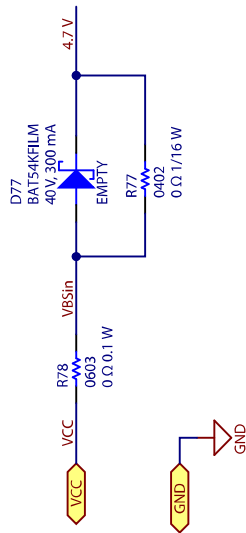


Figure 17. . 100V Gate Driver with Bootstrap schematic

6 V min. to 28 V max.



PSU disconnect

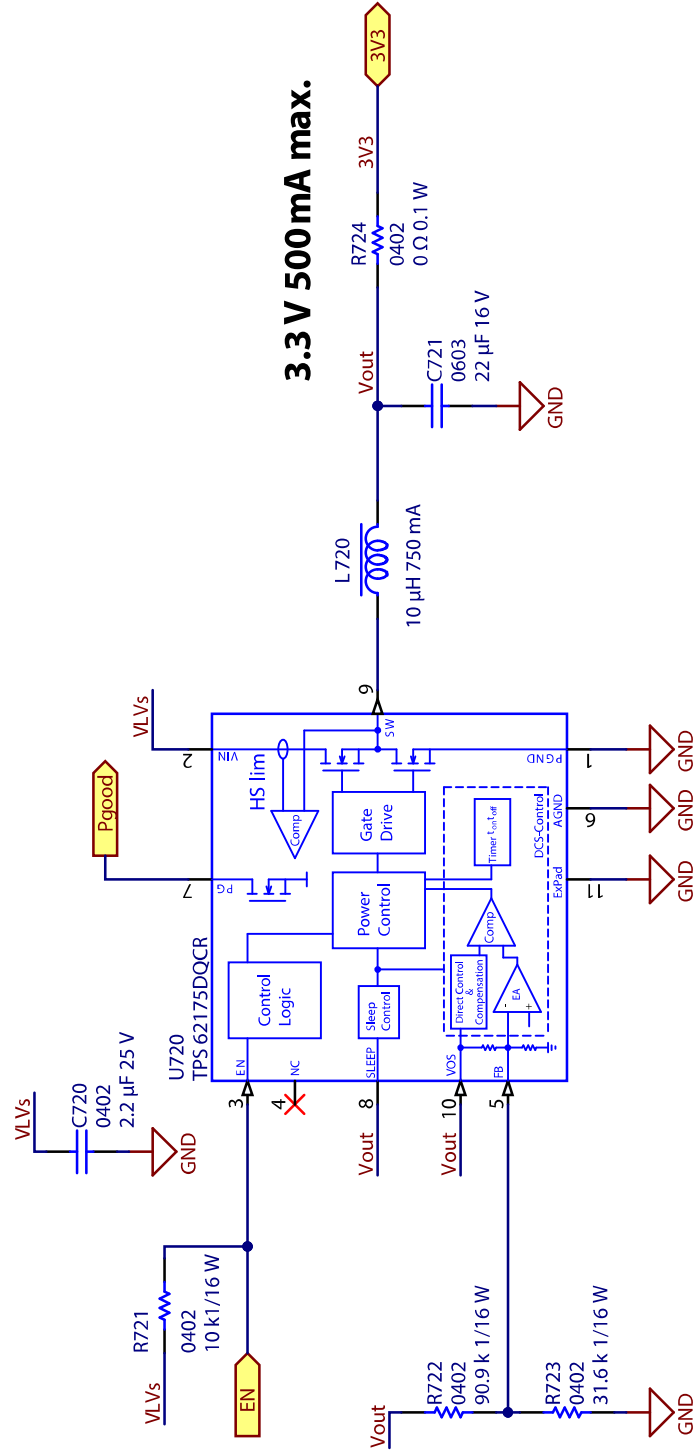


Figure 18: 6V-28V to 3.3V Housekeeping Power Supply schematic

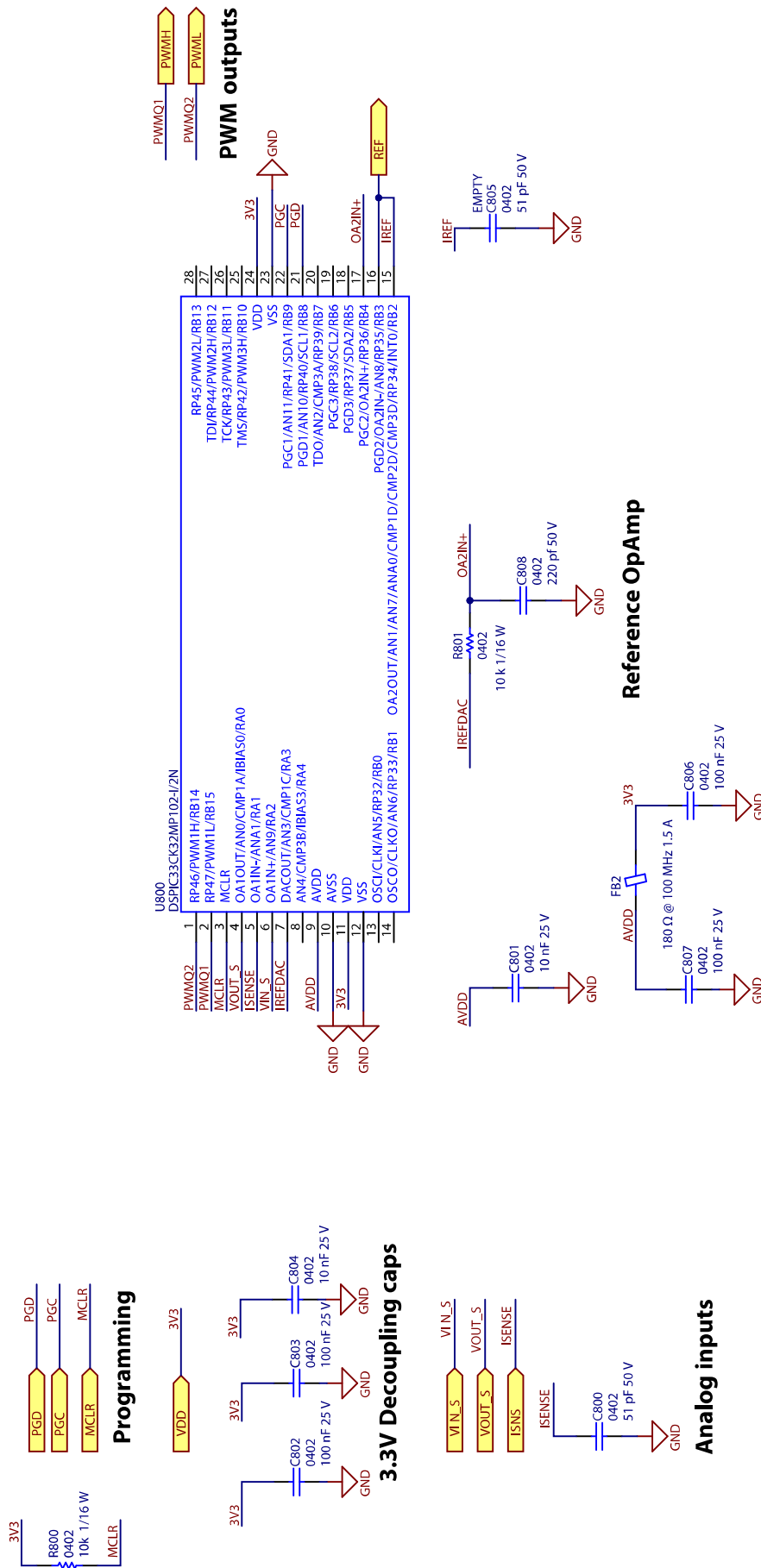
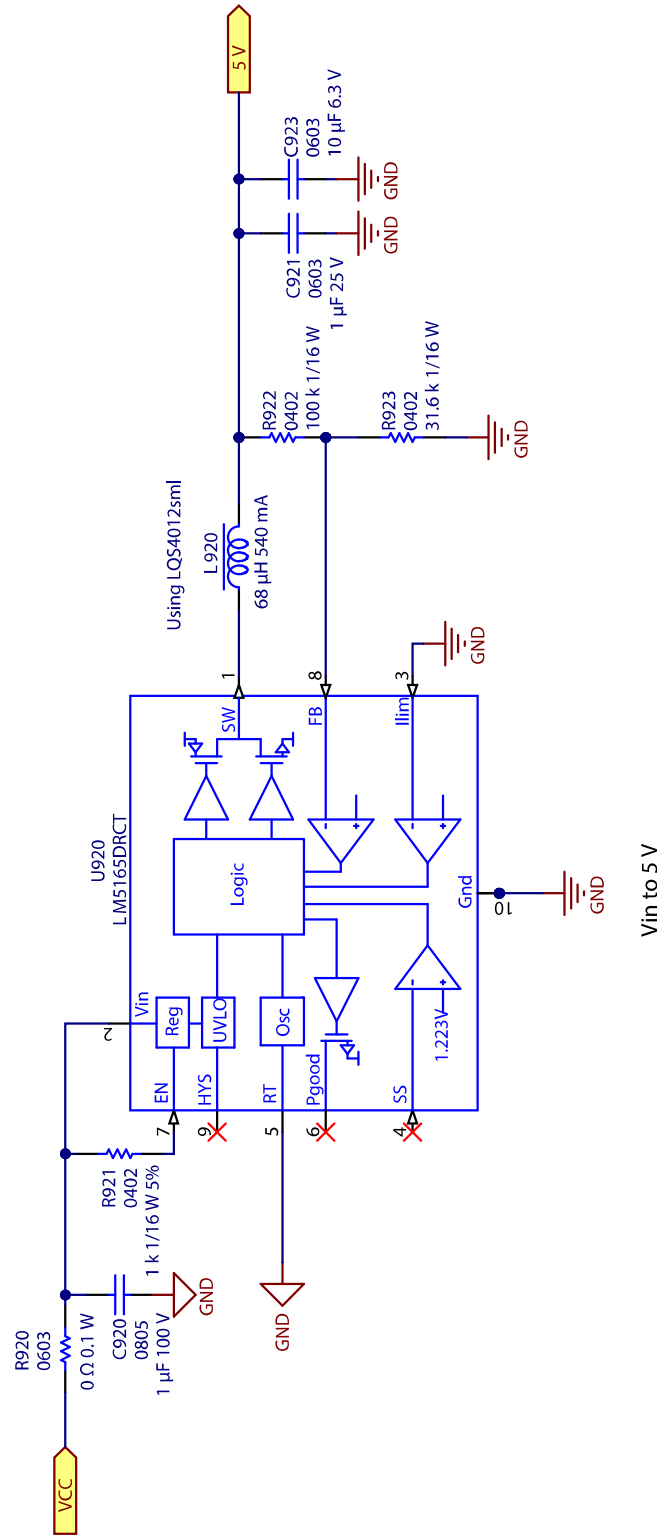


Figure 19: 28-pin 6X6 DsPic controller schematic



Housekeeping power supply

Figure 20: 6V-65V to 5V Housekeeping Power Supply schematic



EPC would like to acknowledge Microchip Technology Inc. (www.microchip.com) for their support of this project.

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The EPC9162 system features the [dsPIC33CK32MP102](#) 16-Bit Digital Signal Controller with High-Speed ADC, Op Amps, Comparators and High-Resolution PWM. Learn more at www.microchip.com.

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Demonstration Board Notification

The EPC9162 board is intended for product evaluation purposes only. It is not intended for commercial use nor is it FCC approved for resale. Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Quick Start Guide. Contact an authorized EPC representative with any questions. This board is intended to be used by certified professionals, in a lab environment, following proper safety procedures. Use at your own risk.

As an evaluation tool, this board is not designed for compliance with the European Union directive on electromagnetic compatibility or any other such directives or regulations. As board builds are at times subject to product availability, it is possible that boards may contain components or assembly materials that are not RoHS compliant. Efficient Power Conversion Corporation (EPC) makes no guarantee that the purchased board is 100% RoHS compliant.

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