

# LT3790

## 60V Four-Switch Synchronous Buck-Boost Controller

### DESCRIPTION

The DC2123B is a 60V four-switch synchronous buck-boost controller that demonstrates the high power capability of the [LT<sup>®</sup>3790](#). The output is 24V and the maximum output current is 5A. The switching frequency is 200kHz and efficiency is as high as 98% for a 24V input.

The LT3790 is capable of high power operation. DC2123B can be altered for increased output power with higher minimum input voltage. If  $V_{IN}$  remains always above 20V,  $I_{OUT}$  can be increased to 12A<sup>+</sup> (for 290W output) by changing RS2 to 4m $\Omega$ .

The operating input voltage range of DC2123B is from 8V to 56V. The output voltage, EN/UVLO, and OVLO are all programmed by resistor dividers. EN/UVLO is set so the circuit will turn off when the input voltage falls below 8V and will turn on when the input voltage rises above 9.6V. OVLO is set to engage for input voltages above 57V.

Current sense resistors program input and output current limits and also determine the monitoring voltages that indicate input and output current. IVINMON provides a 30mV/1A voltage that is used to monitor the input current. Input current limit occurs at 33.3A and is set by RIN1. ISMON provides a 160mV/1A voltage that is used to monitor the output current. The output current limit is 7.5A and is set by RS2.

The demo circuit features MOSFETs that compliment the 5V gate drive of the LT3790 to achieve high efficiency. 60V MOSFETs are used on the input side of the four-switch topology while 40V MOSFETs are used on the output side. Ceramic capacitors are used at both the circuit input and output because of their small size and high ripple current capability. In addition to ceramic capacitors, there is an aluminum polymer capacitor on the output that assures feedback loop stability, even at low temperatures. The input has an aluminum electrolytic capacitor in addition to ceramic capacitors. A two-stage L-C input filter can easily be added for electro-magnetic compatibility. The

pcb has large copper planes and extensive vias for thermal performance.

The CLKOUT output and the SYNC input can be used to synchronize switching between two or more DC2123B circuits. A resistor from SYNC to ground must be removed prior to using the SYNC input.

$\overline{SHORT}$  and  $\overline{C/10}$  are open-collector status flag outputs and are pulled up to the  $INTV_{CC}$  pin voltage. A resistor shorts the CCM pin to  $\overline{C/10}$  and causes the circuit to change to discontinuous conduction mode (DCM) when  $\overline{C/10}$  is active at light load currents. CCM can also be connected with a resistor to  $INTV_{CC}$  instead of  $\overline{C/10}$  for continuous conduction mode (CCM) operation over the entire load range.

The CTRL input is pulled up to the  $V_{REF}$  pin through a 0 $\Omega$  resistor to set the output current limit to its maximum, and an external voltage on CTRL can be used to lower the current limit if the resistor is removed. A capacitor at the SS pin programs soft-start and additionally SS is pulled up to the  $V_{REF}$  pin through a 100k resistor. The switching frequency is adjustable with a resistor.

The demo circuit is designed to be easily reconfigured to many other applications, including the example schematics in the data sheet. Consult the factory for assistance.

High power operation, four-switch buck-boost topology, fault protection and full monitoring make the LT3790 attractive for high power voltage regulator circuits and also circuits that require output current regulation such as battery chargers. The LT3790EFE is available in a thermally enhanced 38-lead TSSOP package. The LT3790 data sheet must be read in conjunction with this demo manual to properly use or modify demo circuit DC2123B.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC2123B>**

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## PERFORMANCE SUMMARY

Specifications are at  $T_A = 25^\circ\text{C}$

| PARAMETER                                                      | CONDITIONS                                                         | MIN  | TYP  | MAX  | UNITS |
|----------------------------------------------------------------|--------------------------------------------------------------------|------|------|------|-------|
| Minimum Input Voltage, $V_{PVIN}$                              | $V_{OUT} = 24\text{V}$ $I_{OUT} \leq 5\text{A}$                    |      | 8    |      | V     |
| Maximum Input Voltage, $V_{PVIN}$                              | $V_{OUT} = 24\text{V}$ $I_{OUT} \leq 5\text{A}$                    |      | 56   |      | V     |
| Maximum Output Current                                         | $8\text{V} < V_{PVIN} < 56\text{V}$ , $CTRL = V_{REF}$             | 5    |      |      | A     |
| Input EN Voltage, $V_{PVIN(EN)}$                               | $R3 = 88.7\text{k}$ , $R4 = 499\text{k}$ , $V_{PVIN}$ Rising       |      | 9.6  |      | V     |
| Input UVLO Voltage, $V_{PVIN(UVLO)}$                           | $R3 = 88.7\text{k}$ , $R4 = 499\text{k}$ , $V_{PVIN}$ Falling      |      | 8.0  |      | V     |
| Input OVLO Turn-Off Voltage, $V_{PVIN(OVLO \text{ turn-off})}$ | $R11 = 27.4\text{k}$ , $R1 = 499\text{k}$ , $V_{PVIN}$ Rising      |      | 57.6 |      | V     |
| Input OVLO Turn-On Voltage, $V_{PVIN(OVLO \text{ turn-on})}$   | $R11 = 27.4\text{k}$ , $R1 = 499\text{k}$ , $V_{PVIN}$ Falling     |      | 56.2 |      | V     |
| Output Voltage $V_{OUT}$                                       | $R19 = 71.5\text{k}$ , $R34 = 1.37\text{k}$ , $R20 = 3.83\text{k}$ | 23.5 |      | 24.5 | V     |
| Efficiency                                                     | $V_{PVIN} = 24\text{V}$ , $I_{OUT} = 5\text{A}$                    |      | 98   |      | %     |
| Switching Frequency                                            | $R18 = 147\text{k}$                                                |      | 200  |      | kHz   |
| Input Current Limit                                            | $RIN1 = 0.0015\Omega$                                              |      | 33   |      | A     |
| Output Current Limit                                           | $RS2 = 0.008\Omega$                                                |      | 7.5  |      | A     |

## QUICK START PROCEDURE

It is easy to set up demonstration circuit DC2123B to evaluate the performance of the LT3790. Refer to Figure 1 for the proper measurement equipment setup and follow the procedure below:

**NOTE:** Make sure that the voltage applied to  $PV_{IN}$  does not exceed the absolute maximum voltage rating of 60V for the LT3790.

1. Connect the EN/UVLO terminal to ground with a clip-on lead. Connect the power supply (with power off), load, and meters as shown.

2. After all connections are made, turn on the input power and verify that the input voltage is between 8V and 56V.
3. Remove the clip-on lead from EN/UVLO. Verify that the output voltage is 24V.

**NOTE:** If the output voltage is low, temporarily disconnect the load to make sure that it is not set too high.

4. Once the proper output voltage is established, adjust the input voltage and load within the operating ranges and observe the output voltage regulation, ripple voltage, efficiency and other parameters.



QUICK START PROCEDURE



Figure 3. Output Voltage Ripple at 5A Output Current, V<sub>OUT</sub> = 24V, 25MHz Bandwidth

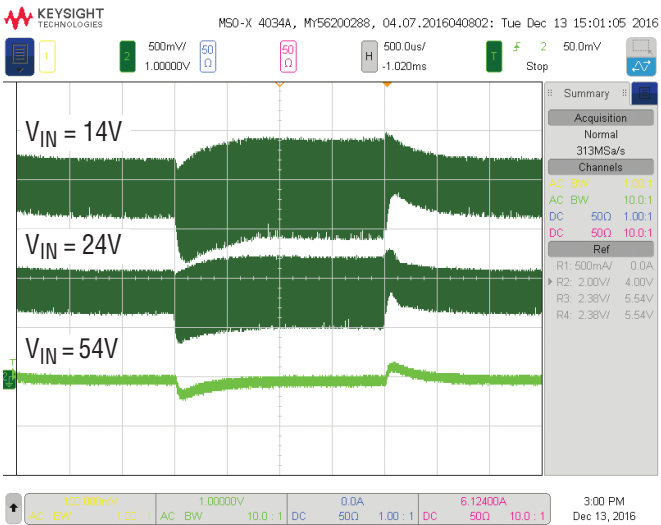


Figure 4. Output Voltage Load Transient Response, V<sub>OUT</sub> = 24V, I<sub>OUT</sub> = 2.5A to 5A to 2.5A, 25MHz Bandwidth

## QUICK START PROCEDURE

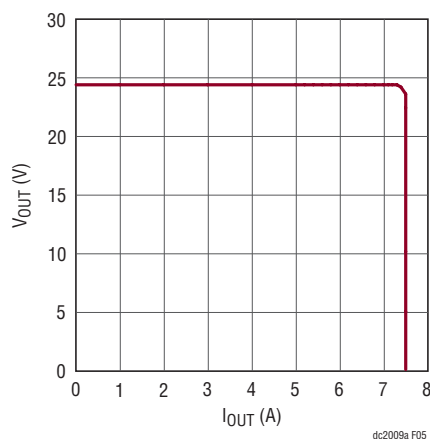


Figure 5.  $V_{OUT}$  in Current Limit,  $V_{IN} = 24V$

## DIFFERENCES BETWEEN LT3790 AND LT3791-1

The LT3790 is an improved version of the LT3791-1 and is recommended for use in new designs. Some external component values may change, but otherwise, the LT3790 is functionally equivalent to the LT3791-1. The differences between the two products are:

1. The LT3790 has a 60mV (typical) full-scale  $V_{(ISP-ISN)}$  current sense voltage, compared to 100mV (typical) for the LT3791-1. This change allows lower power current sense resistors to be used for most applications.
2. The LT3790 CTRL pin linear range is from 0V to 1.1V, and has a turn-off threshold of 50mV (typical), compared to a 200mV to 1.1V linear range and 175mV (typical) turn-off threshold for the LT3791-1. These changes make it easier to parallel two or more LT3790 ICs for higher power levels.
3. The LT3790  $\overline{C/10}$  pin pulls low when the  $V_{(ISP-ISN)}$  voltage is less than 1/10 full scale, compared to the LT3791-1, where  $\overline{C/10}$  pulls low when both  $V_{(ISP-ISN)}$  is less than 1/10 full scale and  $V_{FB}$  is greater than 1.15V (typical). Since the  $\overline{C/10}$  pin is used to allow DCM mode for some applications, this change ensures that negative current does not occur at light loads for a broader range of applications.

# DEMO MANUAL DC2123B

## PARTS LIST

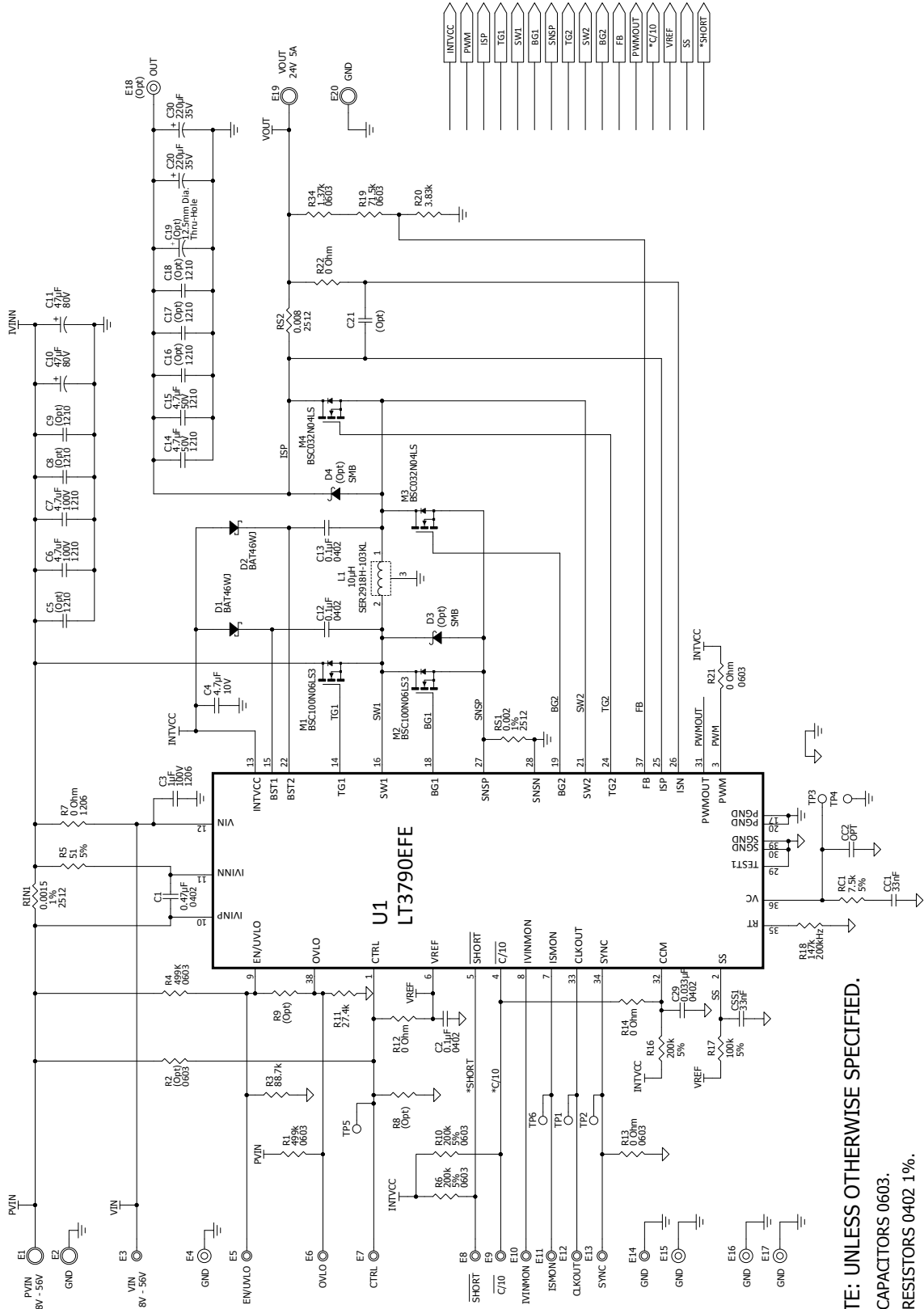
| ITEM                               | QTY | REFERENCE    | PART DESCRIPTION                               | MANUFACTURER/PART NUMBER            |
|------------------------------------|-----|--------------|------------------------------------------------|-------------------------------------|
| <b>Required Circuit Components</b> |     |              |                                                |                                     |
| 1                                  | 2   | CC1, CSS1    | CAP., X7R 33nF 25V 10% 0603                    | AVX 06033C333KAT1A                  |
| 2                                  | 1   | C1           | CAP., X5R 0.47 $\mu$ F 16V 20% 0402            | TDK C1005X5R1C474MT                 |
| 3                                  | 3   | C2, C12, C13 | CAP., X5R 0.1 $\mu$ F 16V 10% 0402             | TDK C1005X5R1C104KT                 |
| 4                                  | 1   | C3           | CAP., X5R 1 $\mu$ F 100V 10% 1206              | TAIYO YUDEN HMK316BJ105KL-T         |
| 5                                  | 1   | C4           | CAP., X5R 4.7 $\mu$ F 10V 10% 0603             | TAIYO YUDEN LMK107BJ475KA           |
| 6                                  | 2   | C6, C7       | CAP., X7S 4.7 $\mu$ F 100V 10% 1210            | TDK C3225X7S2A475K200AB             |
| 7                                  | 2   | C10, C11     | CAP., ALUM. ELECT. 47 $\mu$ F 80V $\pm$ 20%    | UNITED CHEMI-CON EMZA800ADA470MJA0G |
| 8                                  | 2   | C14, C15     | CAP., X5R 4.7 $\mu$ F 50V 20% 1210             | TAIYO YUDEN UMK325BJ475MM-T         |
| 9                                  | 2   | C20, C30     | CAP., HYBRID COND. POLYMER 220 $\mu$ F 35V 20% | SUN ELECTRONIC INDUSTRIES 35HVP220M |
| 10                                 | 1   | C29          | CAP., X7R 0.033 $\mu$ F 16V 10% 0402           | TDK C1005X7R1C333K                  |
| 11                                 | 2   | D1, D2       | SCHOTTKY BARRIER 100V SOD323(SC-90)            | NXP SEMI. BAT46WJ                   |
| 12                                 | 1   | L1           | INDUCTOR, 10 $\mu$ H SER2900                   | COILCRAFT, SER2918H-103KL           |
| 13                                 | 2   | M1, M2       | MOSFET-N CHANNEL, 60V, TDSO8                   | INFINEON, BSC100N06LS3 G            |
| 14                                 | 2   | M3, M4       | MOSFET-N CHANNEL, 40V, TDSO8                   | INFINEON, BSC032N04LS               |
| 15                                 | 1   | RC1          | RES., CHIP 7.5k 0.06W 5% 0402                  | VISHAY CRCW04027K50JNED             |
| 16                                 | 1   | RIN1         | RES., 0.0015 $\Omega$ 1W 1% 2512               | PANASONIC, ERJ-M1WTF1M5U            |
| 17                                 | 1   | RS1          | RES., 0.002 $\Omega$ 1W 1% 2512                | PANASONIC, ERJ-M1WTF2M0U            |
| 18                                 | 1   | RS2          | RES., 0.008 $\Omega$ 1W 1% 2512                | PANASONIC, ERJ-M1WSF8M0U            |
| 19                                 | 2   | R1, R4       | RES., CHIP 499k 0.06W 1% 0603                  | VISHAY CRCW0603499KFKEA             |
| 20                                 | 1   | R3           | RES., CHIP 88.7k 0.06W 1% 0402                 | VISHAY CRCW040288K7FKED             |
| 21                                 | 1   | R5           | RES., CHIP 51 $\Omega$ 0.06W 5% 0402           | NIC, NRC04F51R0TRF                  |
| 22                                 | 2   | R6, R10      | RES., CHIP 200k 0.06W 5% 0603                  | VISHAY CRCW0603200KJNEA             |
| 23                                 | 1   | R11          | RES., CHIP 27.4k 0.06W 1% 0402                 | VISHAY CRCW040227K4FKED             |
| 24                                 | 1   | R16          | RES., CHIP 200k 0.06W 5% 0402                  | VISHAY CRCW0402200KJNED             |
| 25                                 | 1   | R17          | RES., CHIP 100k 0.06W 5% 0402                  | VISHAY CRCW0402100KJNED             |
| 26                                 | 1   | R18          | RES., CHIP 147k 0.06W 1% 0402                  | VISHAY CRCW0402147KFKEA             |
| 27                                 | 1   | R19          | RES., CHIP 71.5k 0.06W 1% 0603                 | VISHAY CRCW060371K5FKEA             |
| 28                                 | 1   | R20          | RES., CHIP 3.83k 0.06W 1% 0402                 | VISHAY CRCW04023K83FKED             |
| 29                                 | 1   | U1           | I.C., 60V BUCK-BOOST VOLT. REG.                | LINEAR TECH. CORP. LT3790EFE#PBF    |

## PARTS LIST

| ITEM                                            | QTY | REFERENCE                                                 | PART DESCRIPTION               | MANUFACTURER/PART NUMBER         |
|-------------------------------------------------|-----|-----------------------------------------------------------|--------------------------------|----------------------------------|
| <b>Additional Demo Board Circuit Components</b> |     |                                                           |                                |                                  |
| 1                                               | 0   | C5, C8, C9, C16, C17, C18 (Opt)                           | CAP., 1210                     |                                  |
| 2                                               | 0   | C19 (Opt)                                                 | OPTIONAL                       |                                  |
| 3                                               | 0   | C21, C22, C28, CC2                                        | CAP., 0603                     |                                  |
| 4                                               | 0   | C23                                                       | OPTIONAL                       |                                  |
| 5                                               | 0   | C24, C25, C26, C27 (Opt)                                  | OPTIONAL                       |                                  |
| 6                                               | 0   | D3, D4 (Opt)                                              | SCHOTTKY DIODE, SMB            |                                  |
| 7                                               | 0   | D5, D6 (Opt)                                              | DIODE, SOD-123                 |                                  |
| 8                                               | 0   | D7 (Opt)                                                  | DIODE, SOD-523                 |                                  |
| 9                                               | 0   | L2, L3 (Opt)                                              | OPTIONAL                       |                                  |
| 10                                              | 0   | M5, M6, M7, M8, M12 (Opt)                                 | OPTIONAL                       |                                  |
| 11                                              | 0   | M9, M10, M11 (Opt)                                        | OPTIONAL                       |                                  |
| 12                                              | 0   | R2, R23, R24, R26-R32                                     | RES., 0603 OPTIONAL            |                                  |
| 13                                              | 1   | R7                                                        | RES., CHIP 0 $\Omega$ 1206     | YAGEO, RC1206FR-070RL            |
| 14                                              | 0   | R8, R9, R25                                               | Res., 0402 OPTIONAL            |                                  |
| 15                                              | 3   | R12, R14, R22                                             | RES., CHIP 0 $\Omega$ 0402     | VISHAY CRCW04020000Z0ED          |
| 16                                              | 2   | R13, R21                                                  | RES., CHIP 0 $\Omega$ 0603     | VISHAY CRCW06030000Z0EA          |
| 17                                              | 1   | R34                                                       | RES., CHIP 1.37k 0.06W 1% 0603 | PANASONIC ERJ-3EKF1371V          |
| <b>Hardware: For Demo Board Only</b>            |     |                                                           |                                |                                  |
| 1                                               | 4   | E1, E2, E19, E20                                          | CONNECTOR, BANANA JACK         | KEYSTONE 575-4                   |
| 2                                               | 13  | E3, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E21, E22 | TURRET, TESTPOINT              | MILL MAX 2308-2-00-80-00-00-07-0 |
| 3                                               | 5   | E4, E15, E16, E17, E24                                    | TURRET, TESTPOINT              | MILL MAX 2501-2-00-80-00-00-07-0 |
| 4                                               | 0   | E18 (Opt)                                                 | OPTIONAL                       |                                  |
| 5                                               | 0   | E23 (Opt)                                                 | OPTIONAL                       |                                  |
| 6                                               | 4   | MH1-MH4                                                   | STANDOFF, NYLON 0.50"          | KEYSTONE, 8833 (SNAP-ON)         |

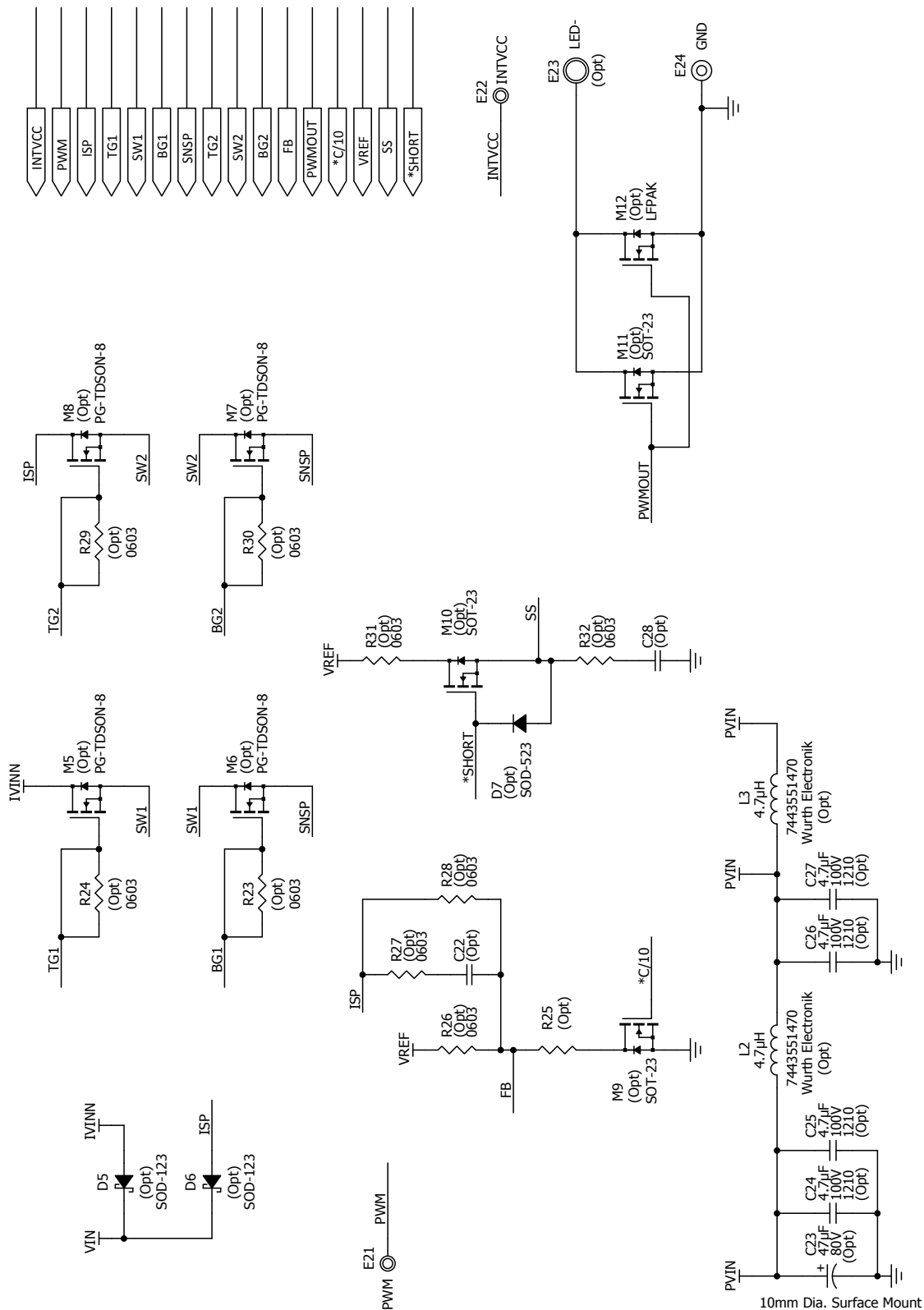
# DEMO MANUAL DC2123B

## SCHEMATIC DIAGRAM



NOTE: UNLESS OTHERWISE SPECIFIED.  
ALL CAPACITORS 0603.  
ALL RESISTORS 0402 1%.

## SCHEMATIC DIAGRAM



# DEMO MANUAL DC2123B

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