

LTC3376

20V, 4-Channel Buck DC/DC with 8x Configurable 1.5A Power Stages (Configuration CFG(3:0) = 0000)

DESCRIPTION

Demonstration Circuit DC2966A shows the [LTC®3376](#) 4-channel configurable buck regulator operating in configuration CFG[3:0] = 0000. This sets the LTC3376 to operate as a quad buck with all four possible outputs, each capable of 3A. By default, outputs 1-4 are set at 5V, 3.3V, 2.5V, and 1.8V, respectively.

Outputs can be enabled, disabled, or sequenced individually. By default, all channel inputs are separate but the board can be configured to power all or some channels from a

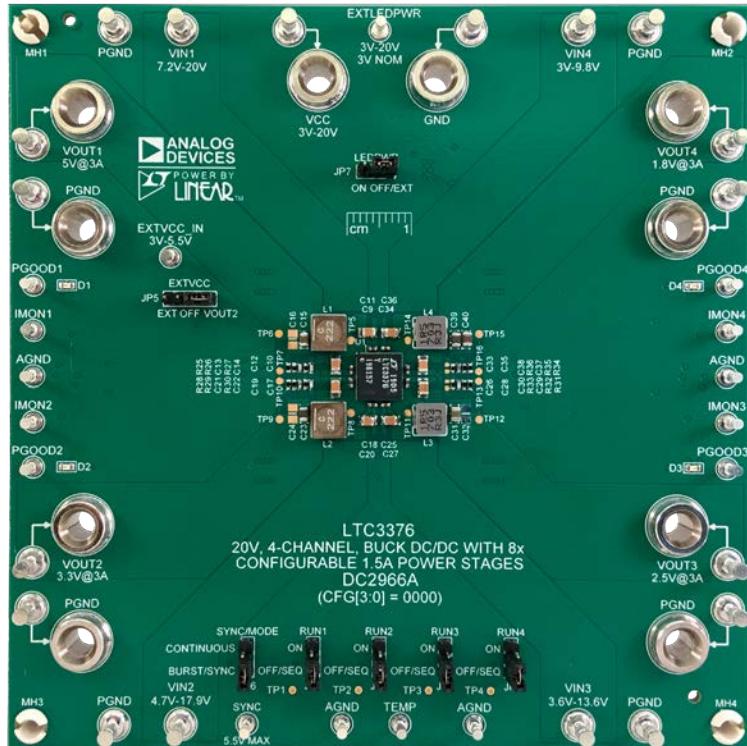
common input. Each channel has a PGOOD LED indicator to show that its output is regulating within the desired range. Switching operation can allow burst mode for high-efficiency operation at low load currents but can also be forced to continuous PWM for more deterministic EMI.

The PCB is laid out on 6 layers and the demonstration circuit provides access to all features of the LTC3376.

[Design files for this circuit board are available.](#)

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BOARD PHOTO



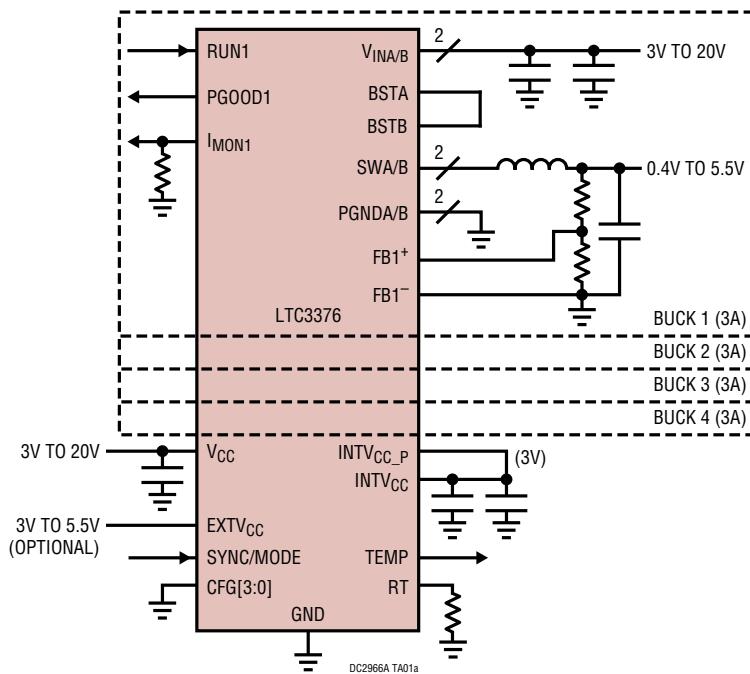
DEMO MANUAL DC2966A

PERFORMANCE SUMMARY

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

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------|--------------------------------|--|-----|------|------|-------|
| V_{CC} | LTC3376 Power Voltage Range | R39-R42 not installed (default) R39-R42 installed | 3 | 20 | 9.8 | V |
| CHANNEL 1 | | | | | | |
| V_{IN1} | Channel 1 Input Voltage Range | Default V_{OUT1} Voltage (5V) | 7.2 | 20 | 20 | V |
| V_{OUT1} | Channel 1 Output Voltage | Default FB Resistor Values | | 5 | | V |
| I_{OUT1} | Channel 1 Output Current Limit | | | 3 | | A |
| CHANNEL 2 | | | | | | |
| V_{IN2} | Channel 2 Input Voltage Range | Default V_{OUT2} Voltage (3.3V) | 4.7 | 17.9 | 17.9 | V |
| V_{OUT2} | Channel 2 Output Voltage | Default FB Resistor Values | | 3.3 | | V |
| I_{OUT2} | Channel 2 Output Current Limit | | | 3 | | A |
| CHANNEL 3 | | | | | | |
| V_{IN3} | Channel 3 Input Voltage Range | Default V_{OUT3} Voltage (2.5V) | 3.6 | 13.6 | 13.6 | V |
| V_{OUT3} | Channel 3 Output Voltage | Default FB Resistor Values | | 2.5 | | V |
| I_{OUT3} | Channel 3 Output Current Limit | | | 3 | | A |
| CHANNEL 4 | | | | | | |
| V_{IN4} | Channel 4 Input Voltage Range | Default V_{OUT4} Voltage (1.8V) | 3 | 9.8 | 9.8 | V |
| V_{OUT4} | Channel 4 Output Voltage | Default FB Resistor Values | | 1.8 | | V |
| I_{OUT4} | Channel 4 Output Current Limit | | | 3 | | A |

TYPICAL APPLICATION



QUICK START PROCEDURE

Follow the procedure below to familiarize yourself with the DC2966A.

1. Configure the board as follows:

JP1-JP4 OFF

JP5 OFF

JP6 BURST/SYNC

JP7 ON

R39-R42 not installed

2. Choose one of the four channels to test and connect test equipment to that channel based on Figure 1. Figure 1 is configured to test channel 1 but moving the lab equipment respectively to other outputs (or all outputs) allows those to be tested instead.

For your chosen channel, x, PS1 should be on V_{INx} and V_{M1} / LD1 should be on V_{OUTx} . Adjust the PS1 voltage to any voltage in the range shown on the chosen V_{INx} input turret.

3. Enable power from PS2 & PS1 and note that V_{M1} reads 0V.

4. Put the jumper of JP1-JP4 relevant to your chosen channel in the ON position to enable the relevant RUNx pin. Note that V_{M1} reads your chosen output voltage:

V_{OUT1} 5V

V_{OUT2} 3.3V

V_{OUT3} 2.5V

V_{OUT4} 1.8V

Also note that the PGOODx LED corresponding to your chosen output is now lit.

5. Enable LD1 and observe that V_{OUTx} maintains regulation and V_{M1} reads the same output voltage.

6. Optional: try cascading bucks; connect V_{OUT1} to V_{IN2} and V_{OUT2} to V_{IN4} , set RUN1, RUN2, and RUN4 to ON, then measure 1.8V on V_{OUT4} . Also, consider repeating this procedure with other outputs or with multiple outputs running simultaneously.

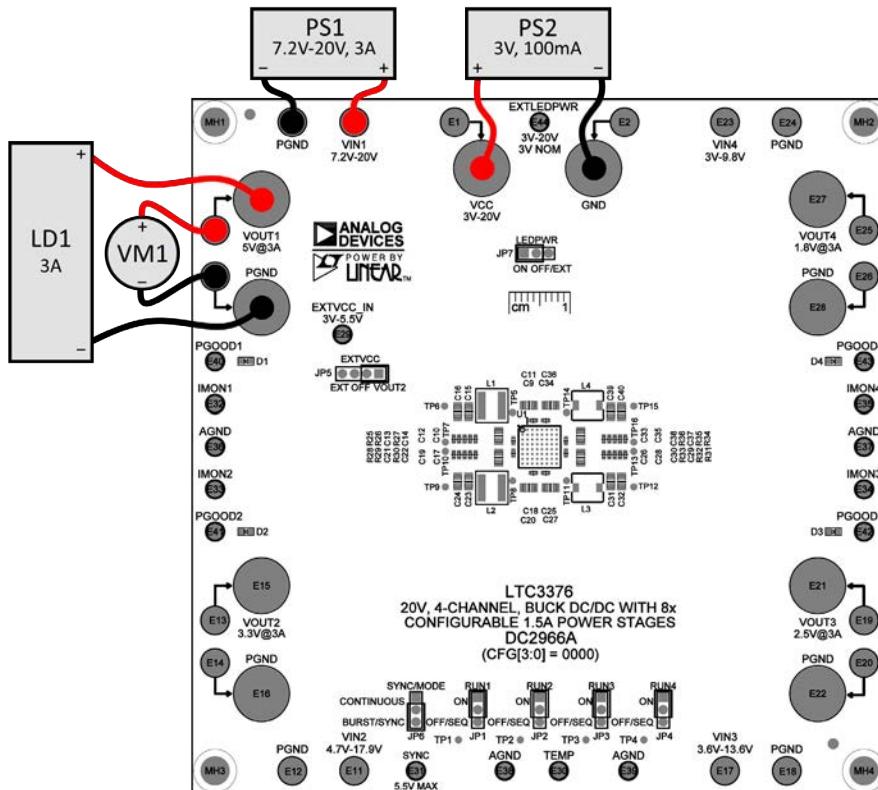


Figure 1. Quick Start Setup for the DC2966A Demo Circuit

DEMO MANUAL DC2966A

JUMPER DESCRIPTIONS

Table 1. Jumper Function Descriptions

| JUMPER | NAME | FUNCTION | POSITIONS | POSITION DESCRIPTION |
|---------|--------------------|--------------------------------------|-------------------|--|
| JP1-JP4 | RUN1-RUN4 | Enables outputs 1-4 respectively | ON | Output enabled |
| | | | OFF/SEQ | Output disabled or sequenced (see Sequencing section) |
| JP5 | EXTV _{CC} | Determines EXTV _{CC} source | V _{OUT2} | EXTV _{CC} powered by the LTC3376's V _{OUT2} output (3.3V default) turret |
| | | | OFF | EXTV _{CC} not powered externally |
| | | | EXT | EXTV _{CC} powered by a source connected to EXTV _{CC_IN} |
| JP6 | SYNC/MODE | Sets continuous, burst, or sync mode | CONTINUOUS | Forced continuous PWM operation |
| | | | BURST/SYNC | Burst mode allowed, will sync to a PWM input on SYNC turret |
| JP7 | LEDPWR | Determines LED power source | ON | LEDs powered from V _{CC} |
| | | | OFF/EXT | LEDs powered by a source connected to EXTLEDPWR turret |

DEMO CIRCUIT OPERATION

Introduction to the DC2966A

The DC2966A demonstration circuit features the LTC3376, a step-down multi-output monolithic buck regulator. This demo circuit puts the LTC3376 into configuration CFG[3:0] = 0000. As such, LTC3376 will utilize all four possible outputs, each with a current limit of 3A. V_{OUT1}-V_{OUT4} have default output voltages of 5V, 3.3V, 2.5V, and 1.8V, respectively. These voltages are configured using voltage dividers on the FB pins and can be changed by the user.

Each output of the LTC3376 has its own separate input and these must be supplied separately by default on the demo circuit. Optionally, R39-R42 can be installed to power all outputs from the V_{CC} input, therefore requiring only one supply to operate the board (refer to Ganging Inputs Section).

All LTC3376 monitoring pins are accessible through small turrets near the edges of the board. Configurable options (except for the CFG[3:0] pins) can be modified using jumpers. Refer to the Jumper Descriptions section of this demo manual for further information.

Demo Circuit Layout

The CFG[3:0] pins are hard-tied to their positions due to the fact that the board layout is highly dependent on the configuration. In different configurations, the inputs and

outputs must be connected differently, making the layout for each CFG[3:0] setting unique.

The design is done on a 6-layer PCB with most power routing on the top and bottom layers. Separate analog ground (AGND) and power ground (PGND) planes are used to isolate sensitive signals from switching noise and high currents. These AGND/PGND nodes meet at the V_{CC} input's GND connection.

When laying out a custom board, it is recommended that the power routing sections of this layout are studied thoroughly and copied as much as is relevant to the custom design. Also, be sure to follow all guidelines given in the PCB Considerations section of the LTC3376 datasheet.

Ganging Inputs

If it is desired to power some or all inputs from the same supply, R39-R42 can be installed to tie V_{IN} nodes to V_{CC}. A 0Ω resistor jumper, thick wire, or solder bridge across the R39-R42 footprints is valid for this purpose. Multiple outputs can then be powered by a single supply to the V_{CC} input, but note that the V_{IN} range for all inputs must then be respected by the V_{CC} input. For this board, that means the new V_{CC} input range is 7.2V-9.8V for proper operation with R39-R42 installed.

Note that ganging inputs may increase the switching jitter.

DEMO CIRCUIT OPERATION

EXTV_{CC} Input

The EXTV_{CC} function allows for a 3V-5.5V source to be input into the EXTV_{CC} pin to bypass an internal linear regulator that outputs 3V to EXTV_{CC}. By using another power source such as V_{OUT1}-V_{OUT4}, this EXTV_{CC} can be driven by a more efficient switching regulator output, therefore using less power.

In the JP5 = V_{OUT2} position, V_{OUT2} (3.3V default) is routed to EXTV_{CC}. Note that if V_{OUT2} is changed to a voltage that is not 3V-5.5V, this option should not be used. In the JP5 = EXT position, any valid supply can be input to the EXTV_{CC_IN} turret to perform this function. In the JP5 = OFF position, the internal linear regulator is used.

SYNC Input

With JP6 = BURST/SYNC, the SYNC turret can be used to synchronize switching to an externally-generated clock. For more information, refer to the Synchronizing the Oscillator to an External Clock section of the LTC3376 datasheet.

Sequencing

The DC2966A includes provisions to easily sequence the order of output enabling. This is achieved by making the RUNx pin voltage dependent on the level of some other voltage. On DC2966A, R3-R10 create voltage dividers with the outputs on each RUNx input. With the corre-

sponding jumper JP1-JP4 set to the OFF/SEQ position, a voltage on TP1-TP4 can enable RUN1-RUN4 at a desired input voltage, depending on the voltage divider ratio.

Figure 2 illustrates the V_{OUTX} voltages when RUN1 = ON while RUN2-RUN4 = OFF/SEQ and are driven by PGOOD1-PGOOD3 respectively. The result is that each buck is enabled when the previous buck reaches regulation.

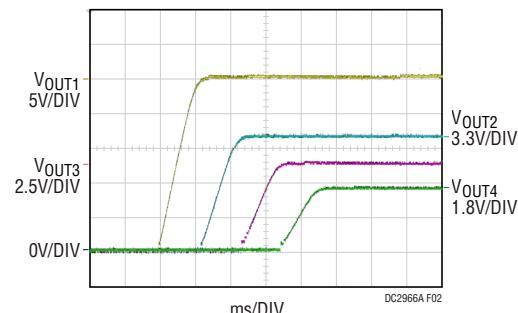


Figure 2. Sequencing V_{OUT1}-V_{OUT4} in Order

PGOODx LEDs

Each PGOODx signal can drive an LED for a visual indication that its respective output is within a valid regulation range. If JP7 = ON, the LED power is drawn from V_{CC} and will increase the current drawn from that input. When evaluating the low power consumption of the LTC3376, it may be helpful to set JP7 = OFF/EXT. In this position, LED power can optionally be supplied from an external 3V-20V source connected to the EXTLEDPWR turret.

PARTS LIST

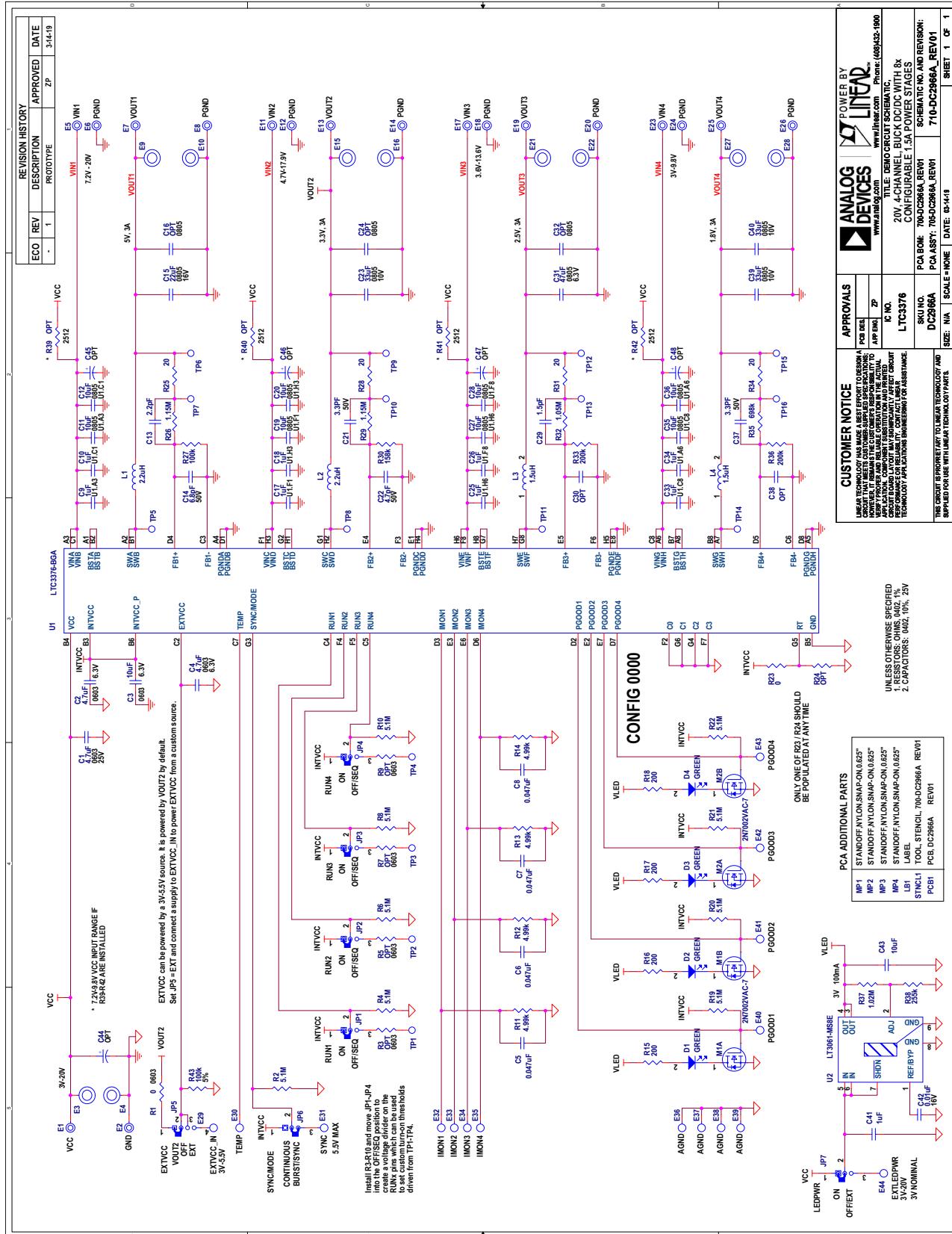
| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|-----------------------------|-----|--|--|----------------------------|
| Required Circuit Components | | | | |
| 1 | 1 | C1 | CAP, 4.7uF, X5R, 25V, 20%, 0603 | MURATA, GRM188R61E475ME11D |
| 2 | 2 | C2, C4 | CAP, 4.7uF, X5R, 6.3V, 10%, 0603 | KEMET, C0603C475K9PACTU |
| 3 | 1 | C3 | CAP, 10uF, X5R, 6.3V, 10%, 0603 | AVX, 06036D106KAT2A |
| 4 | 4 | C5-C8 | CAP, 0.047uF, X7R, 25V, 10%, 0402 | TDK, C1005X7R1E473K050BC |
| 5 | 8 | C9, C10, C17, C18, C25, C26, C33, C34 | CAP, 1uF, X5R, 25V, 10%, 0402, AEC-Q200 | MURATA, GRT155R61E105KE01D |
| 6 | 8 | C11, C12, C19, C20, C27, C28, C35, C36 | CAP, 10uF, X5R, 25V, 10%, 0805 | TDK, C2012X5R1E106K085AC |
| 7 | 1 | C13 | CAP, 2.2pF, C0G, 25V, +/-0.1pF, 0402 | MURATA, GRM1555C1E2R2BA01D |
| 8 | 1 | C14 | CAP, 6.8pF, C0G/NP0, 50V, +/-0.5pF, 0402 | AVX, 04025A6R8DAT2A |
| 9 | 1 | C15 | CAP, 22uF, X5R, 16V, 10%, 0805 | TDK, C2012X5R1C226K125AC |

DEMO MANUAL DC2966A

PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------|-----|---|--|-----------------------------------|
| 10 | 2 | C21, C37 | CAP, 3.3pF, COG, 50V, 0.25pF, 0402 | AVX, 04025A3R3CAT2A |
| 11 | 1 | C22 | CAP, 4.7pF, COG, 50V, 0.5pF, 0402 | AVX, 04025A4R7DAT2A |
| 12 | 3 | C23, C39, C40 | CAP, 33uF, X5R, 10V, 20%, 0805 | TDK, C2012X5R1A336M125AC |
| 13 | 1 | C29 | CAP, 1.5pF, NPO, 25V, +/-0.5pF, 0402 | WURTH ELEKTRONIK, 885012005035 |
| 14 | 1 | C31 | CAP, 47uF, X5R, 6.3V, 20%, 0805 | TAIYO YUDEN, JMK212BBJ476MG-T |
| 15 | 1 | C41 | CAP, 1uF, X5R, 25V, 10%, 0603 | AVX, 06033D105KAT2A |
| 16 | 1 | C42 | CAP, 0.01uF, X7R, 16V, 10%, 0402 | KEMET, C0402C103K4RAC7867 |
| 17 | 1 | C43 | CAP, 10uF, X5R, 10V, 20%, 0603 | AVX, 0603ZD106MAT2A |
| 18 | 4 | D1-D4 | LED, GREEN, WATER-CLEAR, 0603, NO SUBS. ALLOWED | LITE-ON, LTST-C193KGKT-5A |
| 19 | 18 | E1, E2, E5-E8, E11-E14, E17-E20, E23-E26 | TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THICK | MILL-MAX, 2501-2-00-80-00-00-07-0 |
| 20 | 10 | E3, E4, E9, E10, E15, E16, E21, E22, E27, E28 | CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE, 0.218" | KEYSTONE, 575-4 |
| 21 | 16 | E29-E44 | TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062" THICK | MILL-MAX, 2308-2-00-80-00-00-07-0 |
| 22 | 6 | JP1-JP4, JP6, JP7 | CONN., HDR, MALE, 1x3, 2mm, VERT, STR, THT, NO SUBS. ALLOWED | WURTH ELEKTRONIK, 62000311121 |
| 23 | 1 | JP5 | CONN., HDR, MALE, 1x4, 2mm, VERT, STR, THT | WURTH ELEKTRONIK, 62000411121 |
| 24 | 2 | L1, L2 | IND., 2.2uH, PWR, 20%, 9.2A, 14.5mOHMS, 5.48mmX5.28mm, XAL5030, AEC-Q200 | COILCRAFT, XAL5030-222MEB |
| 25 | 2 | L3, L4 | FIXED IND 1.5UH 6A 20 MOHM SMD | SUSUMU, PCMB053T-1R5MS |
| 26 | 2 | M1, M2 | XSTR., MOSFET, DUAL N-CH, 0.28A, SOT-563 | DIODES INC., 2N7002VAC-7 |
| 27 | 4 | MP1-MP4 | STANDOFF, NYLON, SNAP-ON, 0.625" | KEYSTONE, 8834 |
| 28 | 1 | PCB1 | PCB, DC2966A | ANALOG DEVICES, 600-DC2966A |
| 29 | 2 | R1, R23 | RES., 0 OHM, 1/10W, 0603, AEC-Q200 | VISHAY, CRCW06030000Z0EA |
| 30 | 9 | R2, R4, R6, R8, R10, R19-R22 | RES., 5.1M OHMS, 5%, 1/16W, 0402 | PANASONIC, ERJ2GEJ515X |
| 31 | 4 | R11-R14 | RES., 4.99k OHMS, 1%, 1/16W, 0402 | NIC, NRC04F4991TRF |
| 32 | 4 | R15-R18 | RES., 200 OHMS, 1%, 1/10W, 0603 | VISHAY, CRCW0603200RFKEA |
| 33 | 4 | R25, R28, R31, R34 | RES., 20 OHMS, 1%, 1/16W, 0402, AEC-Q200 | NIC, NRC04F20R0TRF |
| 34 | 2 | R26, R29 | RES., 1.15M OHMS, 1%, 1/16W, 0402 | VISHAY, CRCW04021M15FKED |
| 35 | 1 | R27 | RES., 100k OHMS, 1%, 1/16W, 0402, AEC-Q200 | VISHAY, CRCW0402100KFKED |
| 36 | 1 | R30 | RES., 158k OHMS, 1%, 1/16W, 0402 | VISHAY, CRCW0402158KFKED |
| 37 | 1 | R32 | RES., 1.05M OHMS, 1%, 1/16W, 0402, AEC-Q200 | VISHAY, CRCW04021M05FKED |
| 38 | 2 | R33, R36 | RES., 200k OHMS, 1%, 1/16W, 0402 | PANASONIC, ERJ2RKF2003X |
| 39 | 1 | R35 | RES., 698k OHMS, 1%, 1/16W, 0402, AEC-Q200 | VISHAY, CRCW0402698KFKED |
| 40 | 1 | R37 | RES., 1.02M OHMS, 1%, 1/16W, 0402, AEC-Q200 | VISHAY, CRCW04021M02FKED |
| 41 | 1 | R38 | RES., 255k OHMS, 1%, 1/16W, 0402 | VISHAY, CRCW0402255KFKED |
| 42 | 1 | R43 | RES., 100k OHMS, 5%, 1/16W, 0402 | ROHM, MCR01MZPJ104 |
| 43 | 1 | U1 | IC, 20V Monolithic Four Channel 12A Configurable Synchronous Buck DC-DC | ANALOG DEVICES, LTC3376EY#PBF |
| 44 | 1 | U2 | IC REG LIN POS ADJ 100MA 8MSOP | ANALOG DEVICES, LT3061EMS8E#PBF |
| 45 | 7 | XJP1-XJP7 | CONN., SHUNT, FEMALE, 2 POS, 2mm | WURTH ELEKTRONIK, 60800213421 |

SCHEMATIC DIAGRAM



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