

Negative Input Synchronous Multi-Topology DC/DC Controller

DESCRIPTION

Demonstration circuit 2148A features the **LT[®]8709**, a negative input synchronous multi-topology DC/DC controller designed for negative input power supplies where the highest input supply voltage is ground. Examples of these circuits include negative buck, negative boost, negative buck-boost and negative inverting. The DC2148A is a negative buck-boost with an operating input voltage range from -4.5V to -38V and an output voltage of -12V , however this demo circuit can be easily reconfigured for other negative input topologies. The maximum output current for DC2148A is 5A, the switching frequency is 400kHz and the maximum efficiency with a -12V input is 91%.

The output voltage is programmed with a single resistor R7 and a -4.22V turn-on threshold is programmed with resistor divider R3 and R4. Current sense resistor R1 programs the switch current limit and current sense resistor R2 programs an output current limit. Filters can be added to the switch and output current sense resistors using component placeholders on the PCB. The I_{MON} output voltage is proportional to output current and a $0.1\mu\text{F}$ capacitor C17 filters I_{MON} .

This demo circuit uses logic-level 60V NMOS and PMOS that operate down to a -4.5V input voltage. Diode D1 is in parallel with the PMOS to improve efficiency. Resistors can be added to the gate drives of both NMOS and PMOS. There are placeholders so the NMOS and PMOS can be paralleled.

Ceramic capacitors are used at both the circuit input and output because of their small size and high ripple current capability. The input has an aluminum electrolytic capacitor in addition to the ceramic capacitors and there is a placeholder to add an electrolytic capacitor at the output.

The MODE input is pulled up to INTV_{CC} by 100k resistor R14 which allows discontinuous conduction mode (DCM) and pulse-skipping operation. There is a placeholder that can be used to connect MODE to $-V_{\text{IN}}$ instead of INTV_{CC} for continuous conduction mode (CCM) switching.

The switching frequency is adjustable using resistor R5. The SYNC input can be used to synchronize the switching frequency. Zero ohm jumper R16 from SYNC to $-V_{\text{IN}}$ must be removed prior to using the SYNC input. Feedback loop compensation can be optimized using components R6, C7 and C8.

Capacitor C14 at the SS pin programs soft-start. PG is an open-collector status flag output and is pulled up to the INTV_{CC} pin voltage by the 100k resistor R23.

There are placeholders to add level shifting circuitry for EN/FBIN, SYNC and PG signals. In addition, the demo circuit is designed to be easily reconfigured to many other applications, including the example schematics in the data sheet. The PCB has extensive vias for thermal performance.

Synchronous switching and negative input operation make the LT8709 attractive for negative input, high-power voltage regulator circuits. The LT8709EFE is available in a thermally enhanced 20-lead TSSOP package. The LT8709 data sheet must be read in conjunction with this demo manual to properly use or modify DC2148A.

Design files for this circuit board are available at <http://www.linear.com/demo/DC2148A>

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DEMO MANUAL DC2148A

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

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|--|-------|-------|-------|-------|
| Minimum Input Voltage, V_{-VIN} | | -4.5 | | | V |
| Maximum Input Voltage, V_{-VIN} | | | | -38 | V |
| Maximum Output Current (See Figure 2), I_{OUT} | $-12\text{V} > V_{-VIN} > -38\text{V}$ $V_{-VIN} = -4.5\text{V}$ | 5 | | | A |
| | | 2.5 | | | A |
| Input EN/FBIN Turn-On Voltage, V_{-VIN} | $R3 = 13.3\text{k}$, $R4 = 10\text{k}$ 1%, $V_{GND,-VIN} = \text{Rising}$ | | -4.22 | | V |
| Output Voltage, V_{OUT} | $R7 = 130\text{k}$ | -12.5 | | -11.7 | V |
| Efficiency | $V_{-VIN} = -12\text{V}$, $I_{OUT} = 2.5\text{A}$ | | 91 | | % |
| Switching Frequency | $R5 = 88.7\text{k}$ | | 400 | | kHz |
| Output Current Limit | $R2 = 0.006\Omega$, 1% | | 8.3 | | A |

QUICK START PROCEDURE

To use DC2148A to evaluate the performance of the LT8709, refer to Figure 1 for the proper measurement equipment setup, Figure 2 for the maximum output current versus input voltage and then follow the procedure:

NOTE: Make sure that the voltage applied to $-V_{IN}$ does exceed $-38V$. A GND to $-V_{IN}$ voltage that is greater than $38V$ may cause voltage spikes that occur during switching to exceed the voltage ratings at the drains of the NMOS and PMOS.

NOTE: When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly to terminals across the $-V_{IN}$ or V_{OUT} capacitors. See Figure 3 for proper scope probe technique.

1. Connect the EN/FBIN terminal to $-V_{IN}$ with a clip-on lead. Connect the power supply (with power off), load, and meters as shown in Figure 1.
2. After all connections are made, turn on the input power and verify that the input voltage is between $-4.5V$ and $-38V$.
3. Remove the clip-on lead from EN/FBIN. Verify that the output voltage is $-12V$.

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

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.

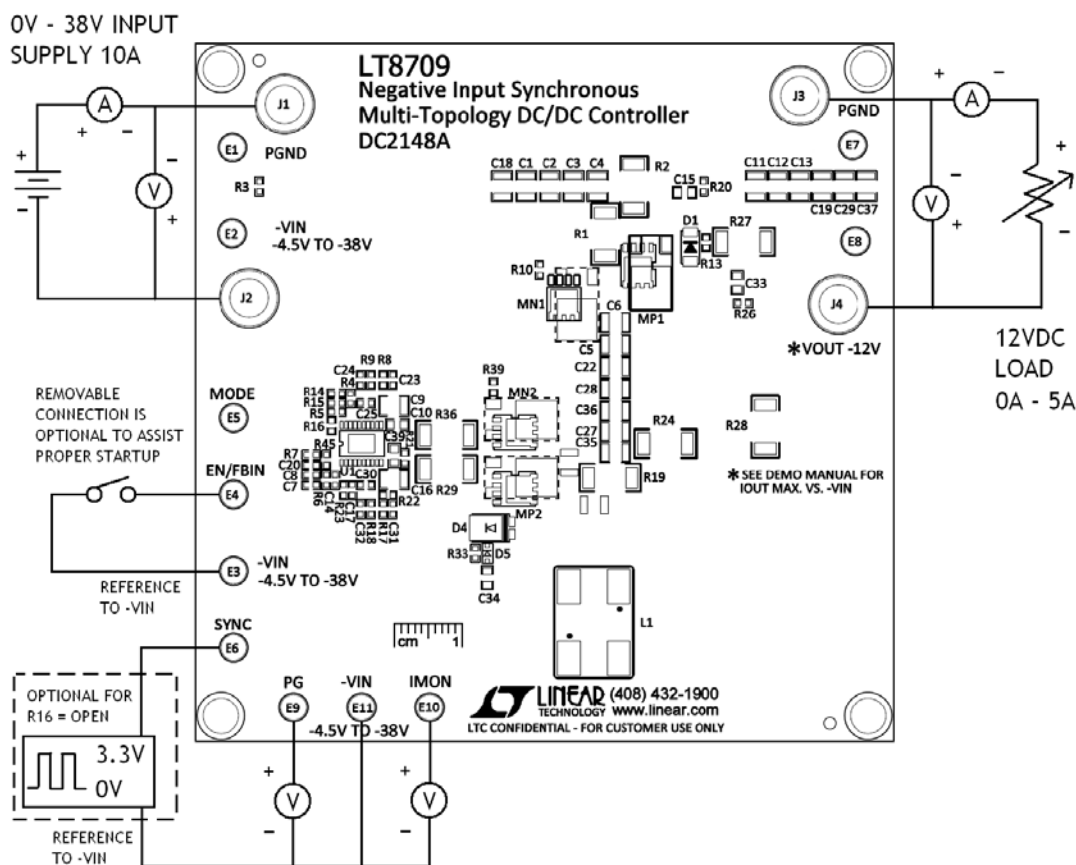


Figure 1. Proper Measurement Equipment Setup for DC2148A

QUICK START PROCEDURE

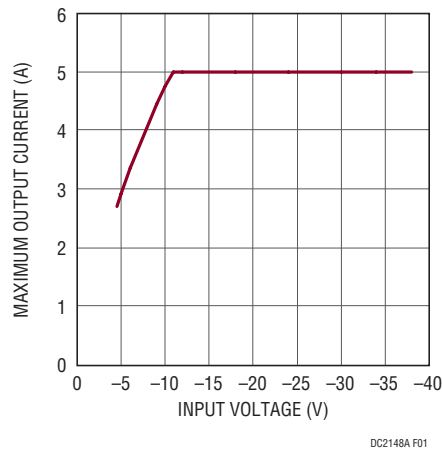


Figure 2. Maximum Output Current vs Input Voltage

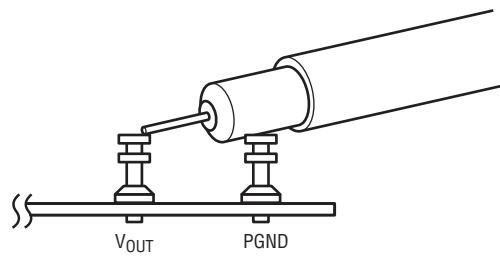


Figure 3. Proper Scope Probe Technique

QUICK START PROCEDURE

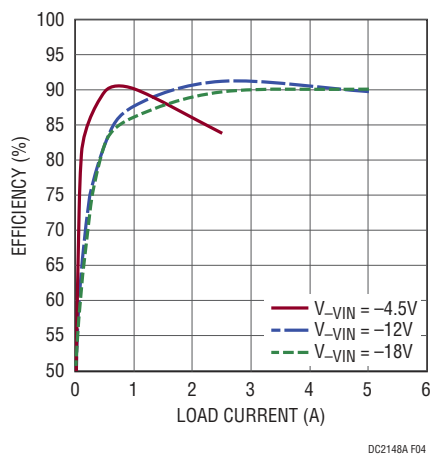


Figure 4. Efficiency

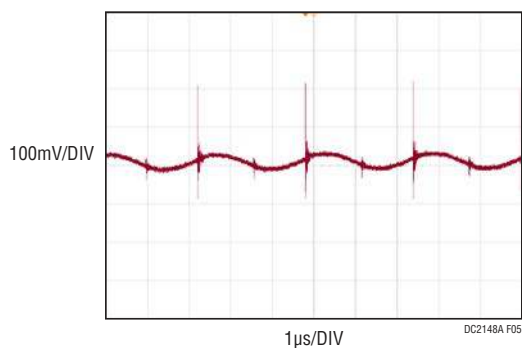


Figure 5. Output Voltage Ripple at 5A Output Current, $V_{-VIN} = -12V$, $V_{OUT} = -12V$

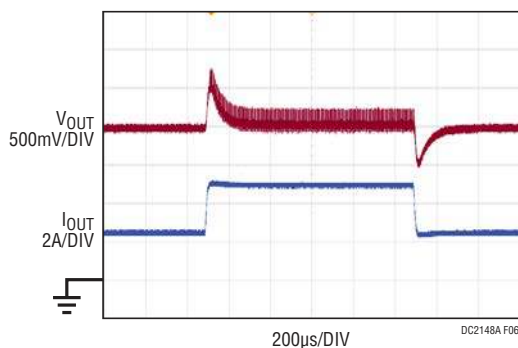


Figure 6. Output Voltage Load Transient Response, $V_{-VIN} = -12V$, $V_{OUT} = -12V$, $I_{OUT} = 2.5A$ to $5A$ to $2.5A$

DEMO MANUAL DC2148A

PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|-----|---|--|------------------------------|
| Required Circuit Components | | | | |
| 1 | 5 | C1, C2, C3, C4, C18 | Cap., X5R 10 μ F 50V 10% 1210 | MURATA GRM32ER61H106KA12L |
| 2 | 5 | C5, C6, C11, C12, C13 | Cap., X5R 22 μ F 16V 20% 1210 | TDK C3225X5R1C226M |
| 3 | 1 | C7 | Cap., X7R 4.7nF 25V 10% 0603 | AVX 06033C472KAT2A |
| 4 | 1 | C8 | Cap., NPO 47pF 25V 10% 0603 | AVX 06033A470KAT2A |
| 5 | 2 | C9, C16 | Cap., X7R 2.2 μ F 100V 10% 1210 | Murata GRM32ER72A225KA35L |
| 6 | 2 | C10, C15 | Cap., X7R 2.2 μ F 16V 20% 0805 | Taiyo Yuden EMK212BJ225MG |
| 7 | 1 | C14 | Cap., X5R 0.22 μ F 50V 20% 0603 | TDK C1608X5R1H224M |
| 8 | 1 | C17 | Cap., X7R 0.1 μ F 25V 10% 0603 | AVX 06033C104KAT2A |
| 9 | 1 | D1 | Diode Schottky, 60V/3Amp SOD-128 | Philips(NXP) PMEG6030EP |
| 10 | 1 | L1 | Inductor, 3.5 μ H \pm 20% | Würth Elektronik 74485540350 |
| 11 | 1 | MN1 | MOSFET, Single N-Channel 22A/60V Power 56 | Fairchild Semi. FDMS86520L |
| 12 | 1 | MP1 | MOSFET, Single P-Channel 60V DPAK | Vishay SUD19P06-60-E3 |
| 13 | 1 | R1 | Res., 0.002 2W 1% 2512 | Vishay WSL-2512-2L000-F-EA |
| 14 | 1 | R2 | Res., 0.006 1W 1% 2512 | Vishay WSL-2512-6L000-F-EA |
| 15 | 1 | R3 | Res., Chip 13.3k 0.06W 1% 0603 | Vishay CRCW060313K3FKEA |
| 16 | 1 | R4 | Res., Chip 10.0k 0.06W 1% 0603 | Vishay CRCW060310K0FKEA |
| 17 | 1 | R5 | Res., Chip 88.7k 0.06W 1% 0603 | Vishay CRCW060388K7FKEA |
| 18 | 1 | R6 | Res., Chip 10k 0.06W 5% 0603 | Vishay CRCW060310K0JNEA |
| 19 | 1 | R7 | Res., Chip 130k 0.06W 1% 0603 | Vishay CRCW0603130KFKEA |
| 20 | 1 | U1 | I.C., Volt. Reg. TSSOP20-FE/CB | Linear Tech. Corp. LT8709EFE |
| Additional Demo Board Circuit Components | | | | |
| 1 | 0 | C20, C23, C24, C25, C30, C31, C32 (Opt) | Cap., 0603 | |
| 2 | 1 | C21 | Cap., Alum 220 μ F 50V 20% 10mm Dia. SMD | Sun Elect. 50CE220AX |
| 3 | 0 | C19, C22, C27, C28, C29, C35, C36, C37 (Opt) | Cap., 1210 | |
| 4 | 0 | C26 (Opt) | Cap., 8mm Dia. SMD | |
| 5 | 0 | C33, C34, C39 (Opt) | Cap., 0805 | |
| 6 | 0 | C38 (Opt) | Cap., X7R 0.1 μ F 100V 10% 1206 | AVX 12061C104KAT2A |
| 7 | 0 | D2, D3 (Opt) | Schottky Barrier 100V SOD323 | NXP Semi. BAT46WJ |
| 8 | 0 | D4 (Opt) | Schottky Diode PowerDi5 | |
| 9 | 0 | D5 (Opt) | Diode, SOD-323 | |
| 10 | 0 | MN2 (Opt) | MOSFET, Single N-Channel 60V PowerPAK SO8 | |
| 11 | 0 | MP2 (Opt) | MOSFET, Single P-Channel PowerPAK SO8 | |
| 12 | 0 | Q1 (Opt) | Trans., PNP SOT23 | Zetex FMMT593 |
| 13 | 0 | Q2 (Opt) | XSTR, NPN SOT-23 | Diode Inc. MMBT2222A |
| 14 | 0 | R8, R9, R10, R11, R12, R13, R15, R17, R18, R21, R22, R25, R26, R31, R32, R33, R34, R37, R38, R39, R45 (Opt) | Res., 0603 | |

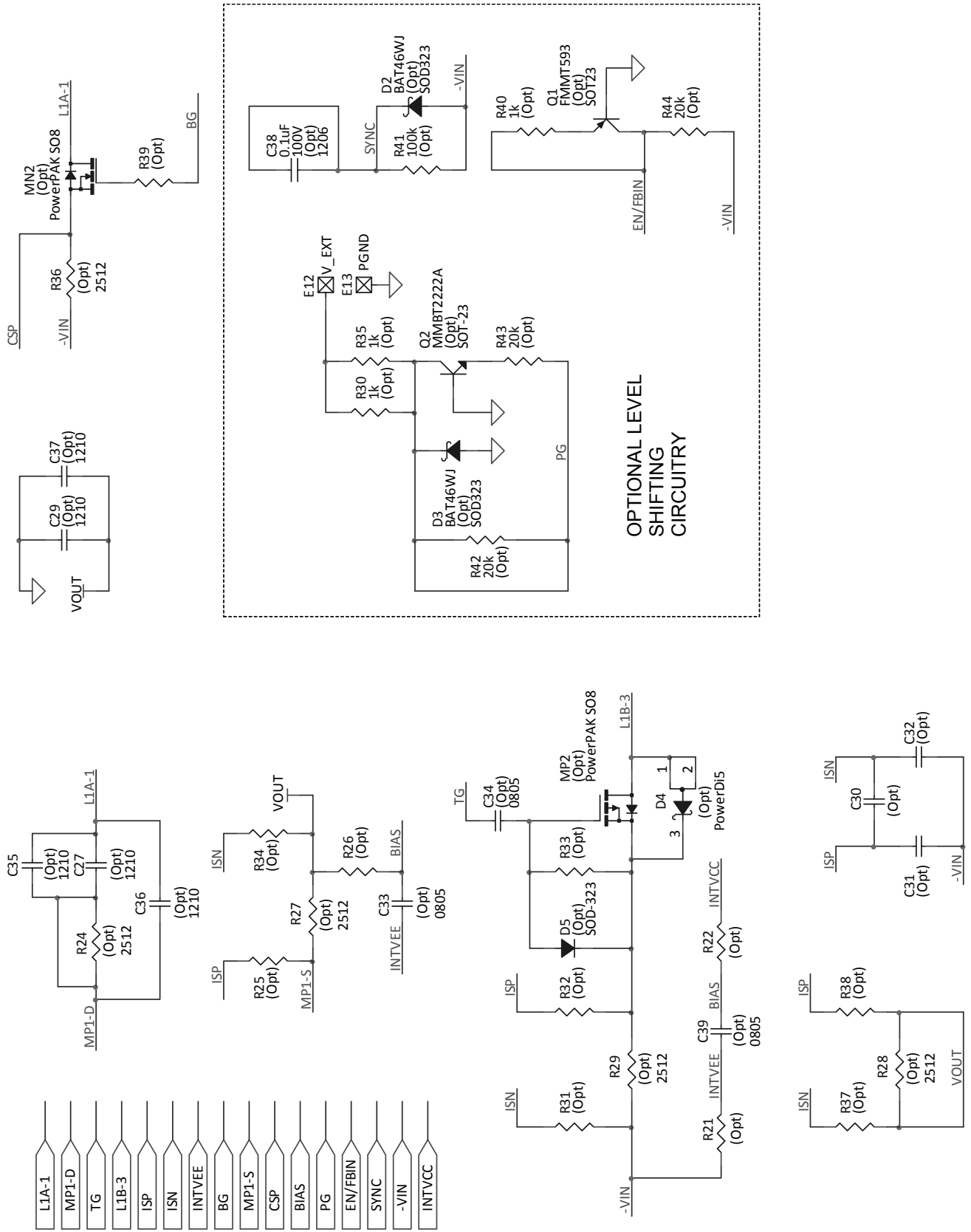
PARTS LIST

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|------|-----|-------------------------------|---|--------------------------|
| 15 | 2 | R14, R23 | Res., Chip 100k 0.06W 5% 0603 | Vishay CRCW0603100KJNEA |
| 16 | 2 | R16, R20 | Res/Jumper, Chip 0 Ω 0.25W 5A 0603 | Vishay CRCW06030000Z0EA |
| 17 | 1 | R19 | Res/Jumper, Chip 0 Ω 1.5W 16A 2512 | Vishay CRCW25120000Z0EA |
| 18 | 0 | R24, R27, R28, R29, R36 (Opt) | Res., 2512 | |
| 19 | 0 | R30, R35, R40 (Opt) | Res., Chip 1k 0.06W 5% 0603 | Vishay CRCW06031K00JNEA |
| 20 | 0 | R41 (Opt) | Res., Chip 100k 0.06W 5% 0603 | Vishay CRCW0603100KJNEA |
| 21 | 0 | R42, R43, R44 (Opt) | Res., Chip 20k 0.06W 5% 0603 | Vishay CRCW060320K0JNEA |

Hardware: For Demo Board Only

| | | | | |
|---|----|--|---------------------------------------|----------------------------------|
| 1 | 11 | E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11 | Turret, Testpoint | Mill Max 2501-2-00-80-00-00-07-0 |
| 2 | 4 | J1, J2, J3, J4 | Connector, Banana Jack | Keystone 575-4 |
| 3 | 4 | MH1-MH4 | STAND-OFF, NYLON 0.50" Tall (SNAP ON) | Keystone 8833 |

SCHEMATIC DIAGRAM



DEMO MANUAL DC2148A

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