

STR-ECS640A-GEVB Rev. 4.5 Evaluation Board User's Manual

EVBUM2816/D

Description

This user guide provides practical guidelines for the new revision 4.5 evaluation board (EVB) using the **onsemi** ecoSpin motor controller ECS640A. The ECS640A device embedded features are Arm Cortex-M0+ microcontroller, 600 V power switch gate drivers, operational amplifiers and bootstrap diodes. This EVB module may be configured for the control of sinusoidal or trapezoidal shaped backemf motors and its default software enables basic motor movement when used with ecoSpin Trapezoidal or DTFC graphical user interface applications. An isolated J-link on-board circuit is available for the user.

The EVB was developed to support customers during their first steps designing applications with the ECS640A configurable motor control system. The design was tested as described in this document but not qualified regarding safety requirements or manufacturing and operation over the entire operating temperature range or lifetime. The EVB is intended for functional testing under laboratory conditions and by trained specialists only.

Features

- Single ECS640A Packaged Device, containing Logic Controller, Gate-drivers and Operational Amplifiers
- Output Power up to 650 W
- AC Mains Input Rectification enables DC Bus Configuration for 120 Vac (Voltage Doubler Rectifier) or 230 Vac (Full Wave Rectifier) Input Voltages
- Configurable Motor Control Methods for Trapezoidal or Vector-control (FOC and DTFC) Motor Applications
- Isolated J-link On-board
- Power Stage Inverter composed of 6 **onsemi** IGBTs (FGPF15N60UNDF)
- User-friendly GUI. ecoSpin Motor Controller Interface is a GUI designed to Fine Tune Motor Control Applications using Trapezoidal or "Direct Torque and Flux Control" (DTFC) Algorithms
- NCP10970 DC/DC Converter designed to provide both 15 VDC (Buck Topology) and 3.3 VDC (Embedded LDO)

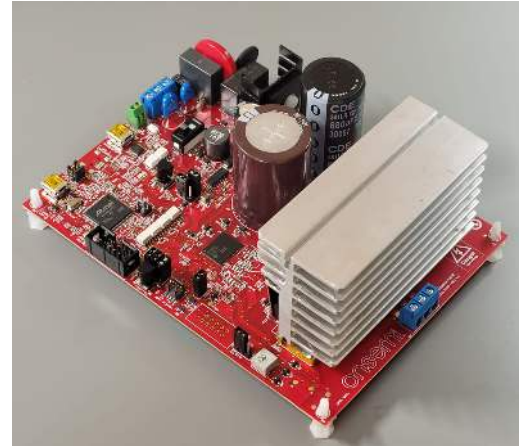


Figure 1. Evaluation Board Photo

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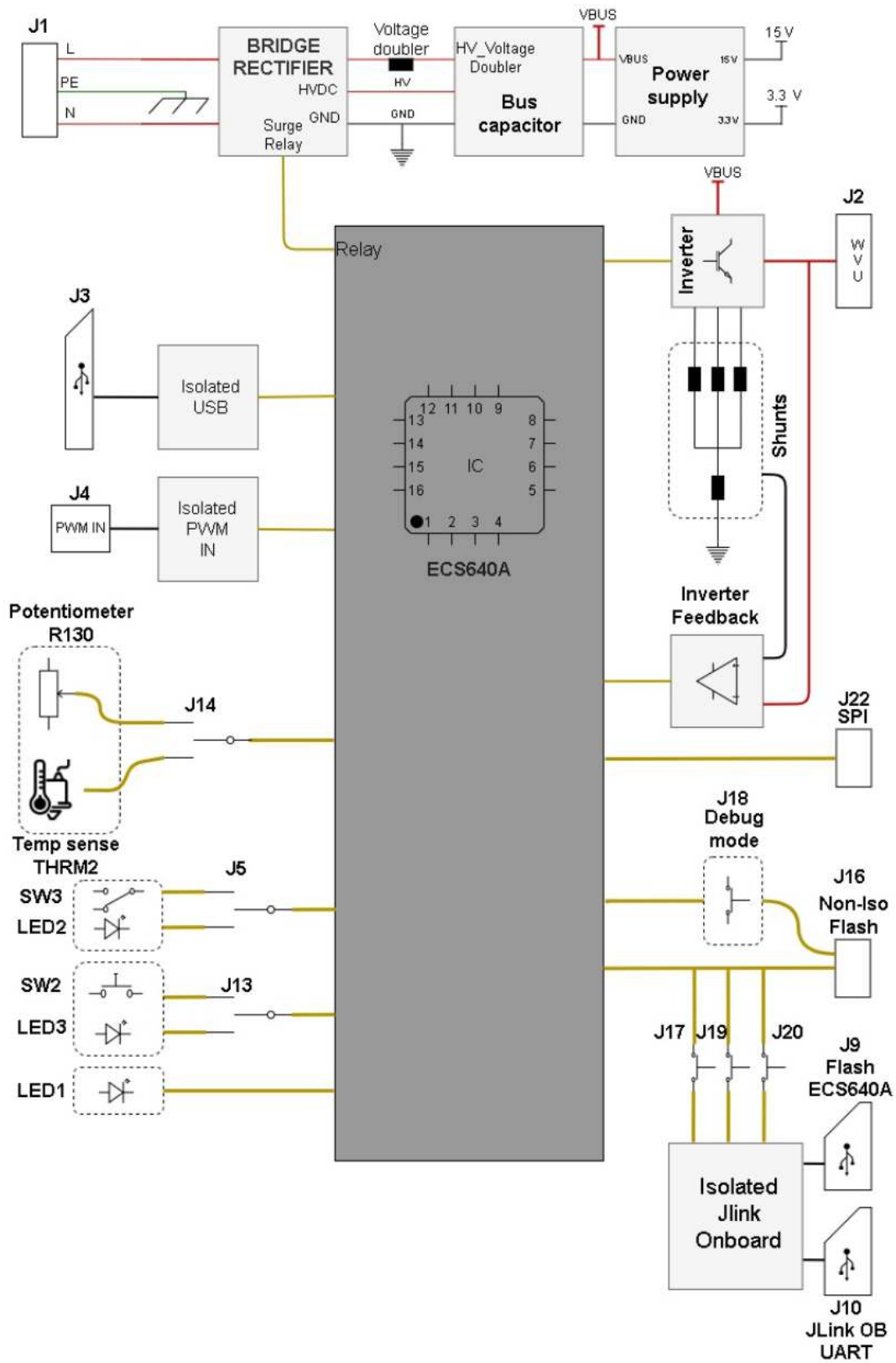


Figure 2. Simplified Block Diagram

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VOLTAGE MAP

Figure 3 identifies voltage potential per area of the STR-ECS640A-GEVB.

AREA 1

Voltage is up to 20 V with regards to the negative DC bus voltage potential (Low voltage non-isolated)

AREA 2

Voltage isolated from Area 1 GND reference. Maximum internal voltage drop of 5 V \pm 5%

AREA 3

Voltage isolated from Area 1 GND reference. Maximum internal voltage drop of 5 V \pm 5%

AREA 4

Voltage isolated from Area 1 GND reference. PWM_IN step is operational for supply signal from 5 V up to 12 V between its inputs.

AREA 5

High voltage non-isolated.

Areas 2, 3 and 4 do not share their reference signal necessarily, but it is strongly advised to not short the reference signal from Area 1 with any other Area since the others might carry Protective Earth, Line or Neutral signals.

Area 1 connectors: J15, J16, J22.

Area 2 connectors: J8, J9, J10.

Area 3 connectors: J3.

Area 4 connectors: J4.

Area 5 connectors: J1, J2.

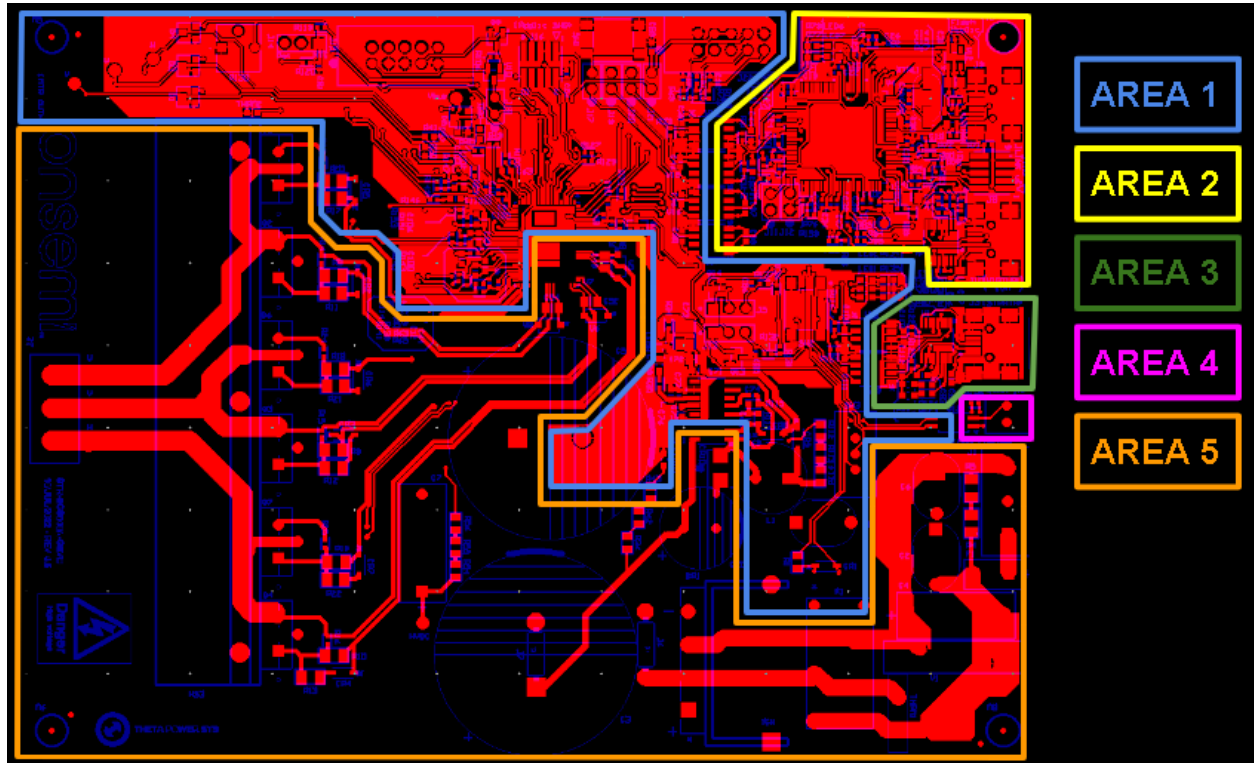











Figure 3. Voltage Map

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SAFETY PRECAUTIONS

It is **mandatory** to read the following precautions before manipulating the STR–ECS640A–GEVB.

| | |
|---|---|
|  | The ground potential of Areas 1 and 5 (see Voltage Map section) is biased to a negative DC bus voltage potential. When connecting an oscilloscope probe to these areas, the scope's ground needs to be isolated. Failure to do so may result in personal injury or death. |
|  | The connectors inside Areas 1 and 5 (see Voltage Map section) are NOT biased to an earth (PE) potential. It is recommended to isolate the signals before any connection is made to Area 1 and/or 5. |
|  | STR–ECS640A–GEVB system contains DC bus capacitors which take time to discharge after removal of the main supply. Before touching the module, wait ten minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. |
|  | Only personnel familiar with the drive and associated machinery should plan or implement the installation, start-up and subsequent maintenance of the system. Failure to comply may result in personal injury and/or equipment damage. |
|  | The surfaces of the heat sink may become hot, which may cause injury. |
|  | STR–ECS640A–GEVB system contains parts and assemblies that are sensitive to Electrostatic Discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing this assembly. ESD control procedures not followed may lead to component damage. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines. |
|  | A drive, incorrectly applied or installed, can result in component damage or reduction in product lifetime. Wiring or application errors such as under sizing the motor, supplying an incorrect or inadequate AC supply or excessive ambient temperatures may result in system malfunction. |
|  | Remove and lock out power from the drive before you disconnect or reconnect wires or perform service. Wait ten minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death. |
|  | Voltage doubler can be used only with 110 V rms power input, the use of the doubler when 220 V rms input may result in personal injury or death. |

MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|------------------------------|-----------|------------|-------------|
| Input Voltage Range (Note 1) | V_{in} | 230 | V_{ac} |
| Output Power | P_{out} | 650 | W |
| Current per Inverter Leg | I_{out} | 2.6 | A_{rms} |
| Overcurrent Protection | | 4 | A_{peak} |
| Operation Temperature | T_{max} | –20 to 105 | $^{\circ}C$ |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Refer to ELECTRICAL CHARACTERISTICS, RECOMMENDED OPERATING RANGES and/or APPLICATION INFORMATION for Safe Operating parameters.

RECOMMENDED OPERATING RANGES

| Rating | Symbol | Min | Max | Unit |
|---------------------|----------|-----|-----|-------------|
| Input Voltage | V_{in} | 24 | 230 | V_{ac} |
| Ambient Temperature | T_A | –20 | 60 | $^{\circ}C$ |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

USER CONFIGURATION

Control Types and Application

STR-ECS640A-GEVB is populated in a way to sample each inverter leg current separately as well as each output voltage and the high voltage DC bus. However, the user may leverage only what is fit for their application requirement and ignore additional data sampled by the remaining AD pins.

Current gain and offset are determined leveraging ECS640A embedded opamp. The outputs of these opamps are directly connected to the AD input pins of ECS640A internal Arm Cortex-M0+ microcontroller (Nebo-40-64). Externally to the ECS640A, these opamp output current signals feed the overcurrent protection circuit. The standard 3-leg current reading circuit is simplified in Figure 4.

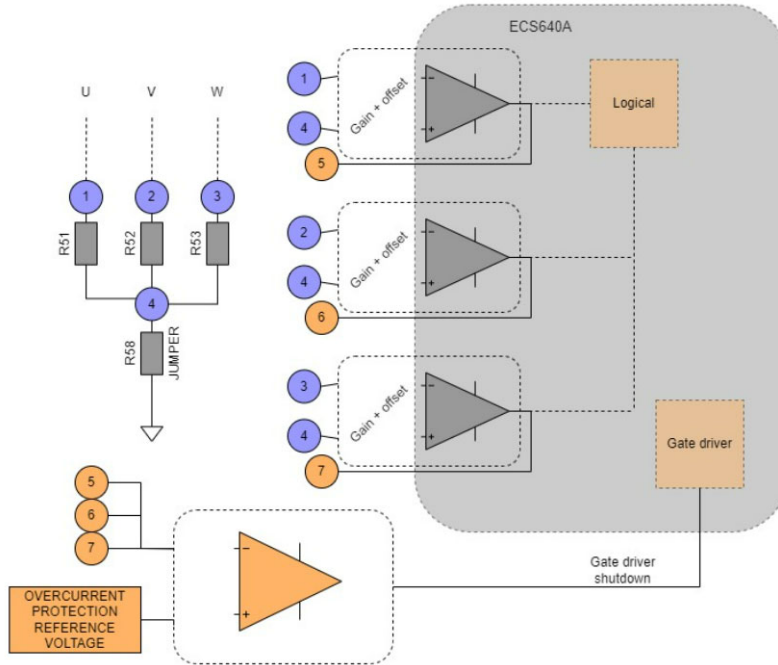


Figure 4. Three-Leg Current Reading Diagram

The user has access to the components that set the shunt values, as well as the gain, offset and the overcurrent protection setpoint, as these circuits are visible in STR-ECS640A-GEVB’s schematic.

WARNING: The user must be aware of the risks of manual operation in replacing electronic parts from this module, which may not have the intended effect due to shorts or cold solder joints as well as several other failure modes that may occur because of this interaction. The application software must also be updated to reflect the changes in hardware.

STR-ECS640A-GEVB has a dedicated overcurrent circuit for applications that consider the sum of the currents method instead of sensing the current from each inverter leg separately. If single shunt bus overcurrent method is preferred, then shunts topology must be changed and the 4th opamp circuit is available with its own gain and offset provided, as well as a dedicated overcurrent protection setpoint. This case is represented in Figure 5.

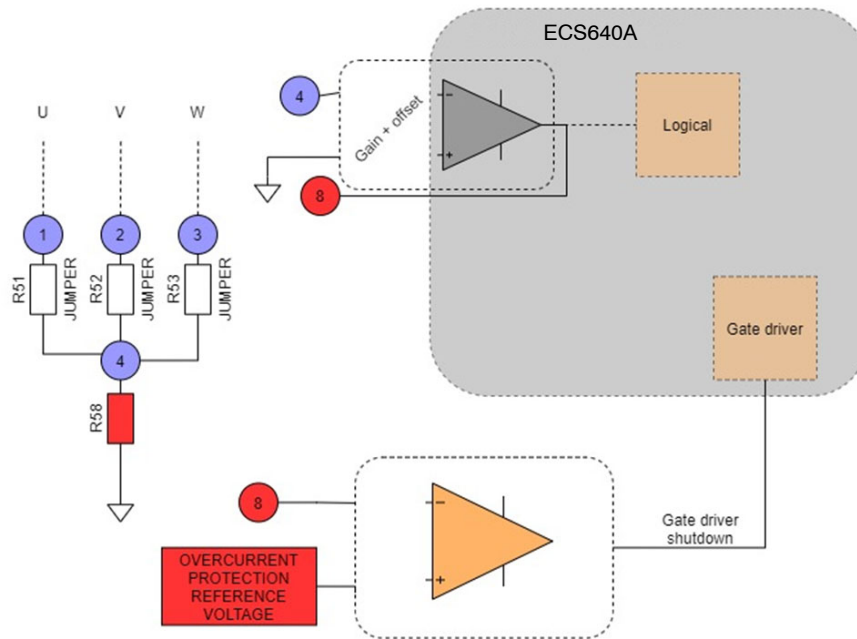


Figure 5. Bus Current Reading Diagram

Voltage Input and Motor Connection

Figure 6 shows the connections for the high voltage non isolated signals that can be attached to the STR-ECS640A-GEVB.

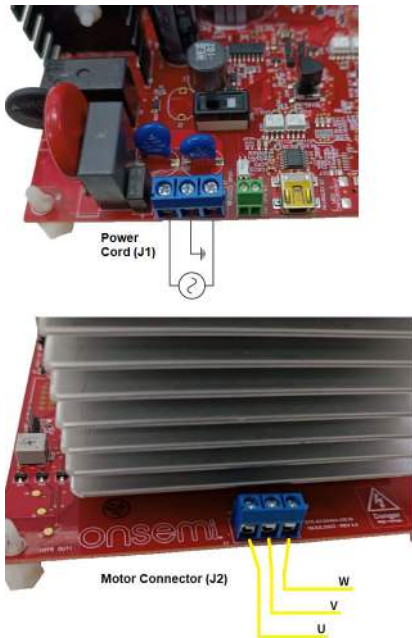


Figure 6. Voltage Input and Motor Connection

AC Rectifier: Voltage Doubler or Full Wave Topology

Voltage doubler topology (120AC input) should have jumper J6 populated and capacitor C3 mounted. Full wave topology (230VA input) should have J6 jumper and C3

capacitor depopulated and a J7 jumper added to C3 footprint location.

WARNING: Do not use voltage doubler topology with 230 VAC input: it will result in serious damage. Figure 7 shows both configurations. When using voltage doubler topology the high voltage DC bus is roughly twice the input peak voltage.

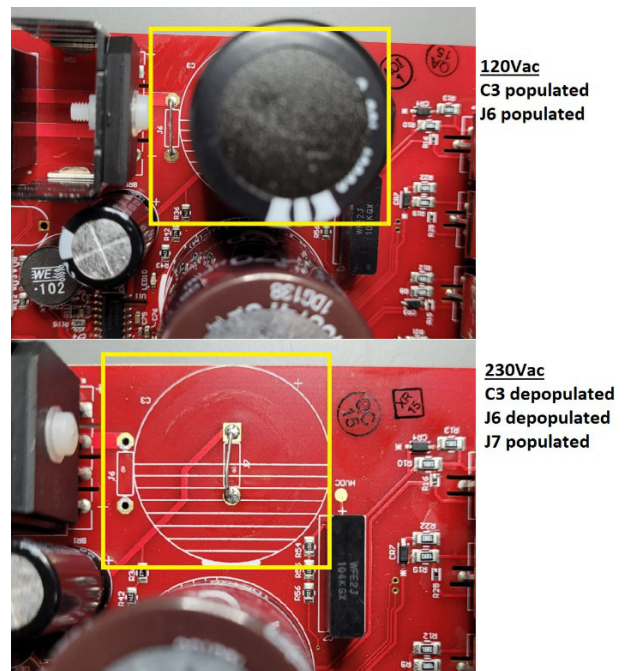


Figure 7. AC Rectifier – 120 V or 230 V Configurations

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GENERAL FEATURES

STR-ECS640A-GEVB has different options and features, which are shown in Figure 8.

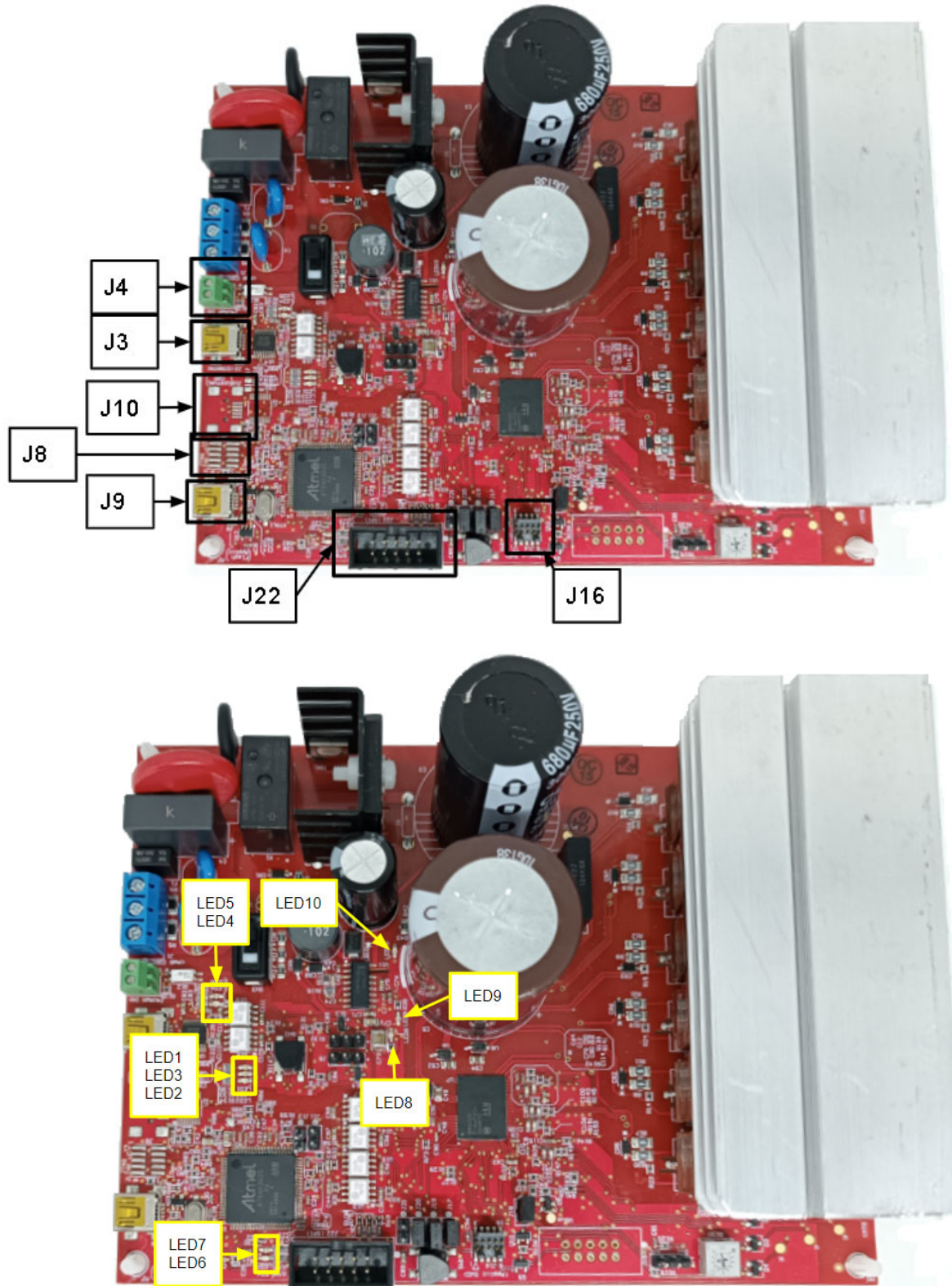


Figure 8. Evaluation Board Features

Table 1.

| Component | PCB Designator | Comment / Function |
|--|----------------|---|
| USER INPUT CONFIGURATION | | |
| Potentiometer | R130 | Function to be defined by user's custom software |
| Button | SW2 | Function to be defined by user's custom software |
| Slide switch | SW3 | Function to be defined by user's custom software |
| LED'S CONFIGURATION | | |
| J-link on-board led communication | LED 6, 7 | Visual feedback for Jlink operation (flashing, debugging, etc.) |
| ECS640A USB-UART LED communication | LED 4, 5 | Visual feedback for ECS640A J3 USB-UART communication |
| User interface LEDs | LED 1, 2, 3 | Function to be defined by user's custom software |
| DC Supply LEDs | LED 8 | 15 VDC supply status |
| | LED 9 | 3.3 VDC supply status |
| | LED 10 | HVDC bus supply status |
| USER'S CONNECTION FOR PROGRAMMING AND DEBUG | | |
| Non-isolated external J-link | J15, J16 | Non-isolated option for external J-link connection |
| SPI | J22 | Optional SPI or Hall sensor connection |
| Isolated J-link on board | J9 | Isolated J-link onboard USB connection to flash ECS640A |
| Program J-link firmware | J8 | To update or reset J-link onboard firmware |
| J-link onboard UART | J10 | Function to be defined by user's custom software |
| ECS640A USB-UART connector | J3 | Enables ecoSpin DTFC or Trapezoidal graphical interface app communication |
| Isolated PWM input | J4 | Function available to user's custom software |

Jumper Configuration

Many configurations are available by switching the jumper connections on the STR-ECS640A-GEVB. These configurations are shown in Figure 9 to Figure 11.

The NTC or potentiometer can be selected by changing the J14 connection configuration as shown in Figure 9.

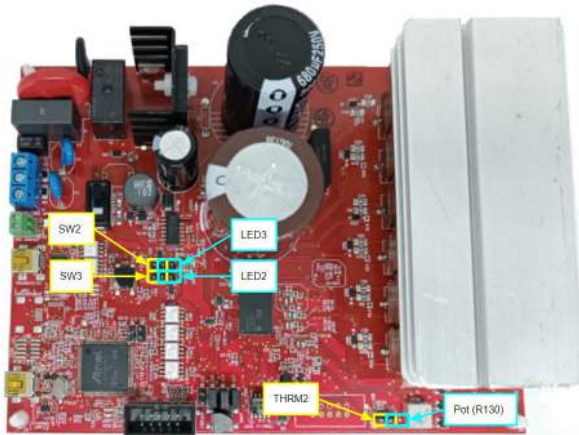


Figure 9. J5, J13, J14 Jumpers Selection

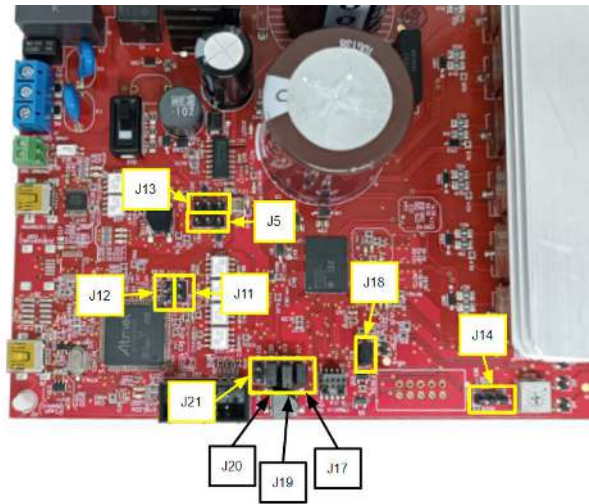


Figure 10. Jumpers Location

The STR-ECS640A-GEVB has a NTC thermistor to indirectly monitor the heat sink's temperature, shown in Figure 11.

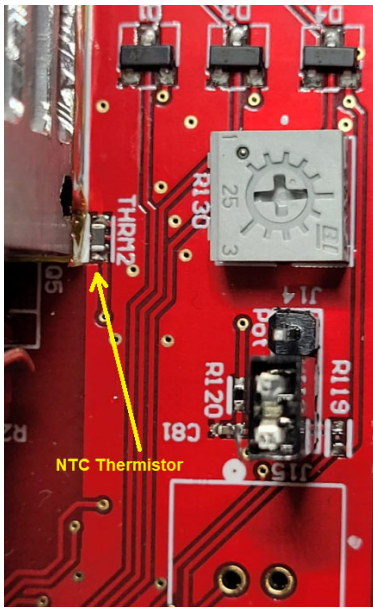


Figure 11. NTC Thermistor Location

Table 2.

| Component | PCB Designator | Comment / Function |
|--------------------------------------|----------------|---|
| JUMPER SELECTOR CONFIGURATION | | |
| LED2 or SW3 switch selector | J5 | Allows user to manage an extra LED or a switch via custom software |
| LED3 or SW2 switch selector | J13 | Allows user to manage an extra LED or a switch via custom software |
| Potentiometer or thermistor selector | J14 | Allows user to manage an AD input from either the potentiometer or the thermistor |
| JUMPER ENABLE CONFIGURATION | | |
| SPI VCC configuration | J21 | Optional VCC connection to SPI connector to facilitate some debugging tools |
| UC_SWDIO | J20 | If shorted, J-link onboard is used instead of an external tool |
| UC_CLK | J19 | If shorted, J-link onboard is used instead of an external tool |
| DBG_EN | J18 | If shorted, enables ECS640A Nebo debug mode |
| UC_RST | J17 | If shorted, J-link onboard is used instead of an external J-link (see J16, J15) |
| JTAG Disable | J12 | If shorted, J-link onboard disables JTAG |
| CDC Enable | J11 | If shorted, J-link onboard enables CDC |

EVBUM2816/D

EVB BILL OF MATERIALS

| Item # | Quantity | Description | Designator | Manufacturer | Part Number |
|--------|----------|--|--|------------------------------------|----------------------|
| 1 | 1 | Bridge Rectifiers 8A | BR1 | Micro Commercial Co | GBU8K-BP |
| 2 | 2 | Safety Capacitors 2200pF 20% Y5U | C2, C6 | Vishay Beyschlag/Draloric/BC | WYO222MCMBF0KR |
| 3 | 1 | 680uF 250V low ESR | C3 | Cornell Dubilier | 381LR681M250K032 |
| 4 | 1 | CAP FILM 0.33UF 10% 630VDC RAD | C4 | Würth Elektronik | 890334025034CS |
| 5 | 1 | 680uF 450V low ESR | C5 | United Chemi-Con | EKHS451VSN681MR50S |
| 6 | 1 | CAP FILM 0.1UF 10% 630VDC RADIAL | C7 | Panasonic Electronic Components | ECW-FE2J104K |
| 7 | 1 | CAP MLCC - 1812 .1UF 1KV 10% | C117 | KEMET | C1812X104KDRACTU |
| 8 | 3 | CAP MLCC - 1812 .01UF 1KV 10% | C118, C119, C120 | KEMET | CKC18C103JDGACAUTO |
| 9 | 32 | CAP CER 0.1UF 10V X7R 0402 | C11, C12, C13, C15, C18, C19, C20, C21, C22, C23, C24, C25, C27, C30, C31, C33, C34, C35, C36, C39, C40, C48, C50, C51, C58, C66, C67, C77, C78, C81, C85, C86 | Würth Elektronik | 885012205018 |
| 10 | 0 | CAP CER 0.1UF 10V X7R 0402 | C16, C93 | Yageo | CC0402JRX7R6BB104 |
| 11 | 7 | CAP CER 10UF 25V X5R 0805 | C14, C41, C42, C61, C62, C72, C108 | Samsung Electro-Mechanics | CL21A106KAYNNNG |
| 12 | 0 | CAP CER 10UF 25V X5R 0805 | C17 | Samsung Electro-Mechanics | CL21A106KAYNNNG |
| 13 | 3 | CAP CER 22UF 25V X5R 0805 | C49, C52, C54 | TDK Corporation | C2012JB1E226M125AC |
| 14 | 1 | CAP CER 10PF 50V NP0 0402 | C26 | Murata Electronics | GCM1555C1H100JA16J |
| 15 | 2 | CAP CER 22PF 50V NP0 0402 | C28, C29 | Würth Elektronik | 885012005057 |
| 16 | 7 | CAP CER 20PF 50V NP0 0402 | C32, C37, C43, C47, C53, C55, C56 | Yageo | CC0402GRNP09BN200 |
| 17 | 23 | CAP CER 1UF 25V X5R 0603 | C38, C44, C46, C57, C63, C71, C76, C82, C83, C87, C89, C96, C97, C98, C99, C109, C110, C111, C112, C113, C114, C115, C116 | Würth Elektronik | 885012106022 |
| 18 | 1 | CAP CER 10000PF 16V X5R 0402 | C45 | Würth Elektronik | 885012205031 |
| 19 | 6 | CAP CER 100PF 50V NP0 0402 | C59, C84, C88, C90, C91, C92 | Murata Electronics | GCM1555C1H101JA16D |
| 20 | 1 | CAP CER 4.7UF 25V X6S 0805 | C60 | TDK Corporation | C2012X6S1H475K125AC |
| 21 | 6 | CAP CER 0.033UF 25V X7R 0402 | C8, C9, C10, C64, C65, C74 | TDK Corporation | CGA2B3X7R1H333K050BB |
| 22 | 1 | CAP CER 0.01UF 25V X5R 0603 | C68 | Würth Elektronik | 885012206065 |
| 23 | 1 | CAP CER 0.22UF 35V X5R 0402 | C69 | Murata Electronics | GRT155R6YA224KE01D |
| 24 | 1 | CAP ALUM 22UF 20% 450V RADIAL | C70 | Nichicon | UVY2W220MHD |

EVBUM2816/D

EVB BILL OF MATERIALS (continued)

| Item # | Quantity | Description | Designator | Manufacturer | Part Number |
|--------|----------|--|--|---|-----------------------|
| 25 | 1 | CAP CER 47UF 25V X5R 1210 | C73 | Taiyo Yuden | TMK325ABJ476MM-P |
| 26 | 1 | CAP CER 22UF 10V X5R 0603 | C75 | Murata Electronics | GRM187R61A226ME15D |
| 27 | 4 | CAP CER 4.7PF 100V NPO 0603 | C94, C101, C104, C107 | Vishay | VJ0603D4R7CXPBJ |
| 28 | 8 | CAP CER 10PF 50V NPO 0603 | C79, C80, C95, C100, C102, C103, C105, C106 | AVX Corporation | 06035C100KAT2A |
| 29 | 7 | DIODE GEN PURP 75V 250MA SOD123 | CR1, CR2, CR3, CR4, CR5, CR6, CR7 | Micro Commercial Co | 1N4448W-TP |
| 30 | 2 | DIODE GEN PURP 600V 1A SOD123F | CR8, CR9 | onsemi | ES1JFL |
| 31 | 1 | DIODE GP 600V 3A SMB | CR10 | onsemi | S3JB |
| 32 | 4 | DIODE ARRAY 100V 215MA SOT23-3 | D1, D3, D4, D5 | onsemi | BAV99LT1G |
| 33 | 1 | FUSE BRD MNT 10A 350VAC 72VDC | F1 | Bel Fuse Inc. | 0697H9100-02 |
| 34 | 1 | HEATSINK TO-220 TABS BLACK | HS1 | Aavid, Thermal Division of Boyd Corporation | 6021BG |
| 35 | 1 | HEATSINK PROFILE 87.5MM | HS3 | Aavid, Thermal Division of Boyd Corporation | 78075 |
| 36 | 2 | TERM BLK 3POS SIDE ENTRY 5MM PCB | J1, J2 | Würth Elektronik | 691102710003 |
| 37 | 2 | Mini USB,R/A,SMT,B Type,pbFree | J3, J9 | Würth Elektronik | 65100516121 |
| 38 | 0 | Mini USB,R/A,SMT,B Type,pbFree | J10 | Würth Elektronik | 65100516121 |
| 39 | 1 | TERMI-BLOK PCB MOUNT, 90 2P. | J4 | Würth Elektronik | 691210910002 |
| 40 | 3 | CONN HEADER VERT 3POS 2.54MM | J5, J13, J14 | Würth Elektronik | 61300311121 |
| 41 | 1 | Bridge 0R 10mm | J6 | Stackpole Electronics Inc | JW60ZT0R00 |
| 42 | 0 | Bridge 0R 10mm | J7 | Stackpole Electronics Inc | JW60ZT0R00 |
| 43 | 2 | CONN HEADER SMD 10POS 1.27MM | J8, J16 | Samtec Inc. | FTSH-105-01-L-DV-K-TR |
| 44 | 7 | CONN HEADER VERT 2POS 2.54MM | J11, J12, J17, J18, J19, J20, J21 | Würth Elektronik | 61300211121 |
| 45 | 1 | CONN HEADER VERT 10POS 2.54MM | J22 | Würth Elektronik | 61201021621 |
| 46 | 1 | RELAY GEN PURPOSE SPST 10A 12V | K1 | Omron Electronics Inc-EMC Div | G5Q-1A4 DC12 |
| 47 | 1 | FIXED IND 1MH 600MA 1.5 OHM TH | L1 | Würth Elektronik | 7447471102 |

EVBUM2816/D

EVB BILL OF MATERIALS (continued)

| Item # | Quantity | Description | Designator | Manufacturer | Part Number |
|--------|--------------|--|---|------------------------------------|------------------|
| 48 | 5 | LED GREEN DIFFUSED 0603 SMD | LED1, LED3, LED5, LED7, LED9 | Würth Elektronik | 150060VS55040 |
| 49 | 1 | LED AMBAR DIFFUSED 0603 SMD | LED8 | Würth Elektronik | 150060AS75003 |
| 50 | 4 | LED RED CLEAR 0603 SMD | LED2, LED4, LED6, LED10 | Würth Elektronik | 150060SS75000 |
| 51 | 4 | SNAP-ON SPACER SCREW MOUNT 9,6 M | M5, M6, M7, M8 | Würth Elektronik | 709952000 |
| 52 | 1 | PAN PHILLIPS SCREW, NATURAL, NYL | M1 | Essentra | 50M030050P010 |
| 53 | 0.00000 1 | THERMAL TRANSFER COMPOUND | M2, M18 | Electrolube | HTC100T |
| 54 | 1 | WASHER FLAT M3 NYLON | M3 | Essentra | MFW030A |
| 55 | 1 | PLASTIC HEXAGON NUT M3 | M4 | Essentra | 04M030050HN |
| 56 | 3 | PAN PHILLIPS SCREW, NATURAL, NYL | M9, M13, M14 | Essentra | 50M030050P006 |
| 57 | 6 | Heat Sinks Max Clip System for TO-220, MAX-220 Thin Components, 12mm Width, 0.6mm Thickness, 40N Force | M10, M11, M12, M15, M16, M17 | Aavid | MAX10NG |
| 58 | 5 | TRANS PREBIAS NPN 50V SOT23-3 | Q1, Q9, Q13, Q14, Q15 | onsemi | MMUN2233LT1G |
| 59 | 6 | IGBT 600V 30A 42W TO-220F | Q2, Q3, Q4, Q5, Q6, Q7 | onsemi | FGPF15N60UNDF |
| 60 | 1 | OPTOISO 3.75KV TRANS 4-MINI-FLAT | Q12 | onsemi | FODM8801A |
| 61 | 1 | RES SMD 91 OHM 5% 1/2W 0805 | R1 | Panasonic Electronic Components | ERJ-P06J910V |
| 62 | 4 | RES SMD 1M OHM 5% 1/4W 1206 | R2, R3, R6, R7 | Bourns Inc. | CR1206-JW-105ELF |
| 63 | 2 | RES SMD 560K OHM 5% 1/4W 1206 | R4, R5 | Vishay Dale | CRCW1206560KJNEA |
| 64 | 12 | RES SMD 18 OHM 1% 1/4W 1206 | R8, R9, R10, R11, R12, R13, R17, R18, R19, R20, R21, R22 | Panasonic Electronic Components | ERJ-8ENF18R0V |
| 65 | 29 | RES SMD 10K OHM 5% 1/10W 0402 | R23, R24, R25, R32, R34, R65, R85, R88, R91, R94, R96, R100, R101, R104, R106, R109, R122, R131, R136, R139, R140, R143, R144, R147, R148, R151, R152, R158, R159 | Panasonic Electronic Components | ERJ-2GEJ103X |
| 66 | 3 | RES SMD 100K OHM 5% 1/10W 0402 | R14, R15, R16 | Panasonic Electronic Components | ERJ-2GEJ104X |

EVBUM2816/D

EVB BILL OF MATERIALS (continued)

| Item # | Quantity | Description | Designator | Manufacturer | Part Number |
|--------|----------|---------------------------------------|---|------------------------------------|------------------|
| 67 | 15 | RES SMD 150K OHM 1% 1/8W 0805 | R26, R27, R28, R37, R38, R39, R46, R47, R48, R54, R55, R56, R112, R113, R114 | TE Connectivity Passive Product | CRGCQ0805F150K |
| 68 | 4 | RES SMD 3.3K OHM 1% 1/10W 0603 | R30, R41, R50, R57 | Panasonic Electronic Components | ERJ-3EKF3301V |
| 69 | 6 | RES SMD 470 OHM 1% 1/10W 0402 | R31, R33, R69, R73, R75, R108 | TE Connectivity Passive Product | CRGCQ0402F470R |
| 70 | 3 | RED SMD 270K OHM 5% 1/8W 0805 | R36, R42, R43 | Yageo | RC0805JR-07270KL |
| 71 | 3 | RES SMD 0.1 OHM 1% 2W 2512 | R51, R52, R53 | Stackpole Electronics Inc | CSRN2512FTR100 |
| 72 | 1 | RES SMD JUMPER 1W 2512 | R58 | Yageo | AC2512JK-070RL |
| 73 | 2 | RES SMD 10.5K OHM 1% 1/10W 0402 | R59, R64 | Panasonic Electronic Components | ERJ-2RKF1052X |
| 74 | 3 | RES SMD 39K OHM 1% 1/10W 0402 | R60, R66, R119 | Panasonic Electronic Components | ERJ-U02F3902X |
| 75 | 5 | RES SMD 4.7K OHM 5% 1/10W 0402 | R61, R71, R78, R83, R89 | Panasonic Electronic Components | RK73B1ETTP472J |
| 76 | 5 | RES SMD 51K OHM 5% 1/10W 0402 | R62, R138, R142, R146, R150 | Panasonic Electronic Components | ERJ-U02J513X |
| 77 | 1 | RES SMD 10 OHM 5% 1/10W 0402 | R63 | Panasonic Electronic Components | ERJ-2GEJ100X |
| 78 | 2 | RES SMD 39 OHM 1% 1/10W 0402 | R67, R68 | Panasonic Electronic Components | ERJ-U02F39R0X |
| 79 | 4 | RES SMD 150 OHM 5% 1/10W 0402 | R70, R74, R76, R81 | Panasonic Electronic Components | ERJ-2GEJ151X |
| 80 | 14 | RES SMD 100 OHM 5% 1/10W 0402 | R72, R80, R84, R86, R87, R90, R92, R93, R95, R97, R99, R102, R107, R120 | KOA Speer Electronics, Inc. | RK73B1ETTP101J |
| 81 | 2 | RES SMD 220 OHM 5% 1/10W 0603 | R77, R79 | Panasonic Electronic Components | ERJ-3GEYJ221V |
| 82 | 1 | RES SMD 6.8K OHM 5% 1/10W 0402 | R82 | Panasonic Electronic Components | ERJ-2GEJ682X |
| 83 | 11 | RES SMD 1K OHM 5% 1/10W 0402 | R29, R35, R40, R49, R98, R103, R105, R110, R129, R132, R137 | Panasonic Electronic Components | ERJ-2GEJ102X |
| 84 | 1 | RES SMD 200K OHM 1% 1/10W 0603 | R111 | Vishay Dale | CRCW0603200KFKEA |
| 85 | 1 | RES SMD 56K OHM 1% 1/10W 0603 | R115 | Yageo | RC0603FR-0756KL |
| 86 | 5 | RES SMD 2.7K OHM 5% 1/10W 0402 | R116, R124, R125, R127, R128 | Panasonic Electronic Components | ERJ-2GEJ272X |
| 87 | 5 | RES SMD 2.7K OHM 5% 1/10W 0603 | R123, R126, R133, R134, R135 | Panasonic Electronic Components | ERJ-3GEYJ272V |
| 88 | 1 | TRIMMER 10K OHM 0.5W PC PIN TOP | R130 | Nidec Copal Electronics | CT6ECT-6ER103 |

EVBUM2816/D

EVB BILL OF MATERIALS (continued)

| Item # | Quantity | Description | Designator | Manufacturer | Part Number |
|--------|----------|--|--|------------------------------------|------------------------|
| 89 | 4 | RES SMD 5.1K OHM 1% 1/10W 0402 | R141, R145, R149, R153 | Panasonic Electronic Components | ERJ-U02F5101X |
| 90 | 2 | SWITCH TACTILE SPST-NO 0.05A 24V | SW1, SW2 | Omron Electronics Inc-EMC Div | B3FS-1050 |
| 91 | 2 | KEY CAP BLACK | M19, M20 | Omron Electronics Inc-EMC Div | B32-2110 |
| 92 | 1 | SWITCH SLIDE SPDT 4A 125V | SW3 | APEM Inc. | 25139NAH |
| 93 | 1 | ICL 15 OHM 20% 3A 15MM | THRM1 | EPCOS - TDK Electronics | B57237S0150M051 |
| 94 | 1 | THERMISTOR NTC 15KOHM 3950K 0603 | THRM2 | Murata Electronics | NCP18XW153J03RB |
| 95 | 1 | Analog Comparators 3-36V Qud Comparator Commercial Temp | U1 | onsemi | LM339DR2G |
| 96 | 1 | USB Interface IC USB to Basic Serial UART IC SSOP-16 | U14 | FTDI | FT230XS-R |
| 97 | 0 | USB Interface IC USB to Basic Serial UART IC SSOP-16 | U2 | FTDI | FT230XS-R |
| 98 | 1 | TVS DIODE 5.5VWM SOT143B | U3 | Würth Elektronik | 8240026 |
| 99 | 1 | ARM Microcontrollers - MCU 256K Flash, 52K SRAM 32-bit ARM Cortex M3 | U4 | Microchip Technology / Atmel | ATSAM3U2CA-AU |
| 100 | 4 | MMSZ5251BT1G | U5, U6, U8, U9 | onsemi | MMSZ5251BT1G |
| 101 | 1 | ECS640A | U7 | onsemi | NFMECS640A0 |
| 102 | 2 | BJT SOT-23 45V 800MA | U10, Q8 | Diotec Semiconductor | BC807-40 |
| 103 | 1 | DUAL OUTPUT HV BUCK SWITCHER 3.3 | U11 | onsemi | NCP10970A1DR2G |
| 104 | 1 | IC REG LINEAR 3.3V 250MA SOT23-5 | U12 | onsemi | NCP163ASN330T1G |
| 105 | 6 | OPTOISO 3.75KV PUSH PULL 8SO | U13, U15, U16, U17, U18, U19 | onsemi | FOD0720 |
| 106 | 1 | VARISTOR 620V 8KA DISC 20MM | V1 | Würth Elektronik | 820523811B |
| 107 | 1 | CRYSTAL 12.0000MHZ 18PF SMD | XTAL1 | Abracon LLC | ABLS7M-12.000MHZ-B-2-T |
| 108 | 10 | Headers & Wire Housings 2P SOCKET C-GRID III | M21, M22, M23, M24, M25, M26, M27, M28, M29, M30 | TE Connectivity AMP Connectors | 4-530153-1 |

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