

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)

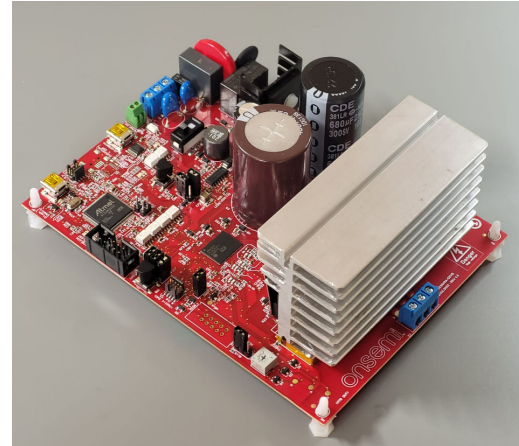


Figure 1. Evaluation Board Photo



Figure 2. Simplified Block Diagram

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.

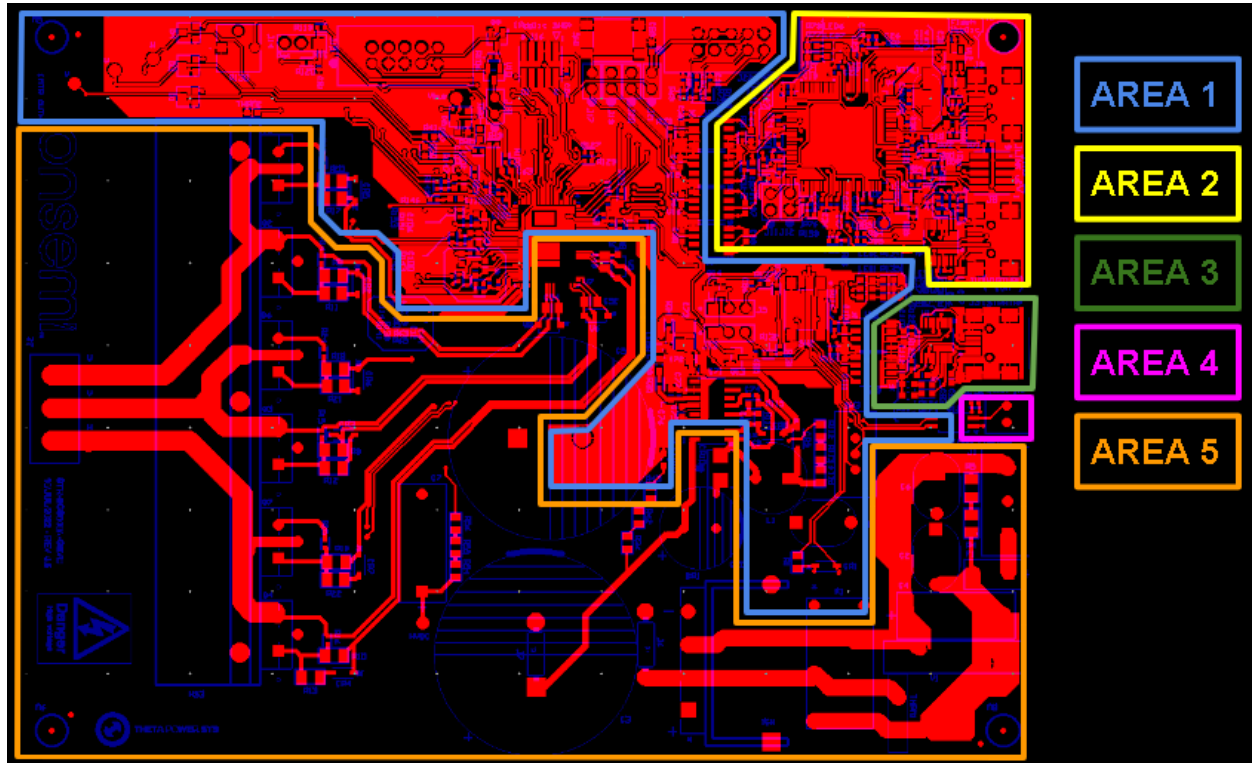


Figure 3. Voltage Map

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.

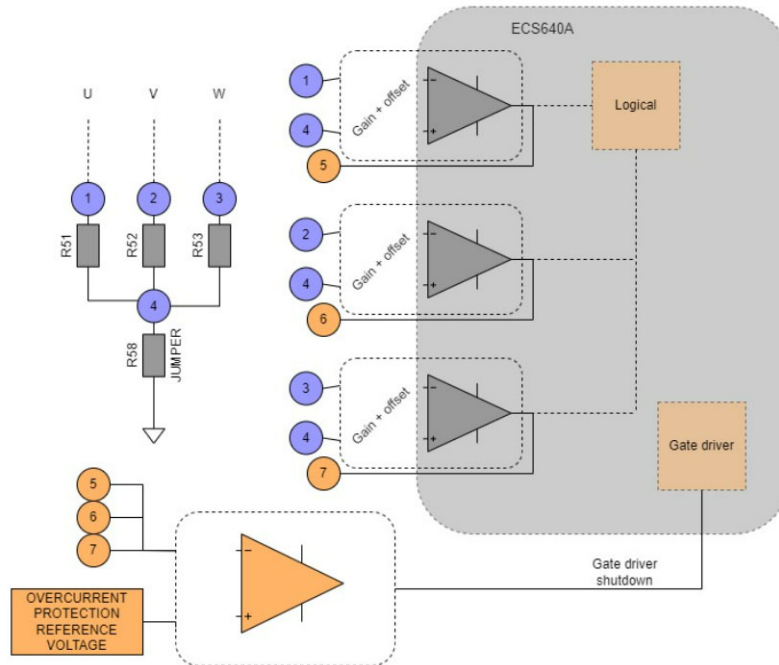


Figure 4. Three-Leg Current Reading Diagram

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.

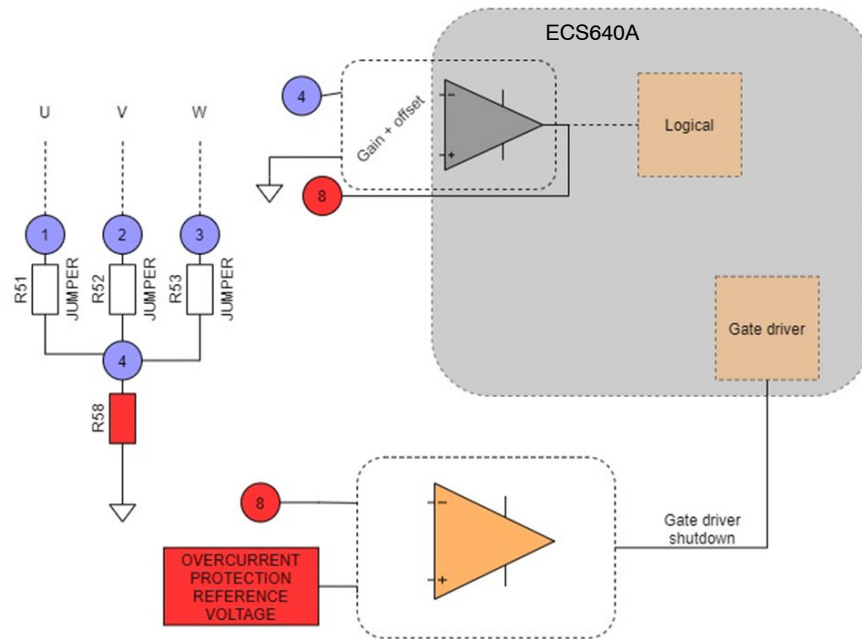


Figure 5. Bus Current Reading Diagram

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.

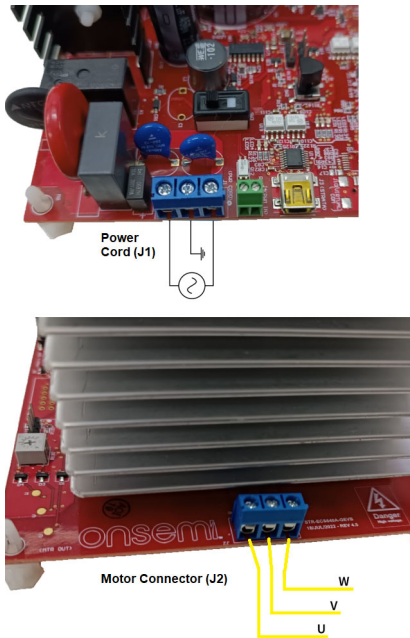


Figure 6. Voltage Input and Motor Connection

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.

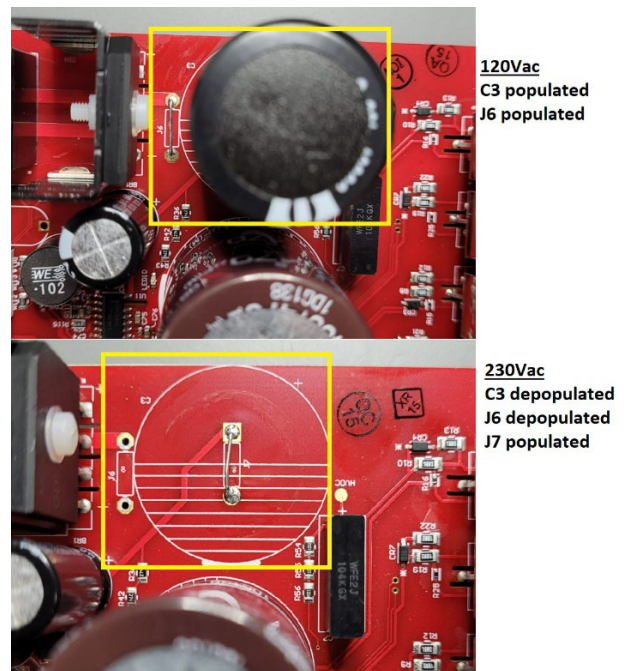


Figure 7. AC Rectifier – 120 V or 230 V Configurations

GENERAL FEATURES

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

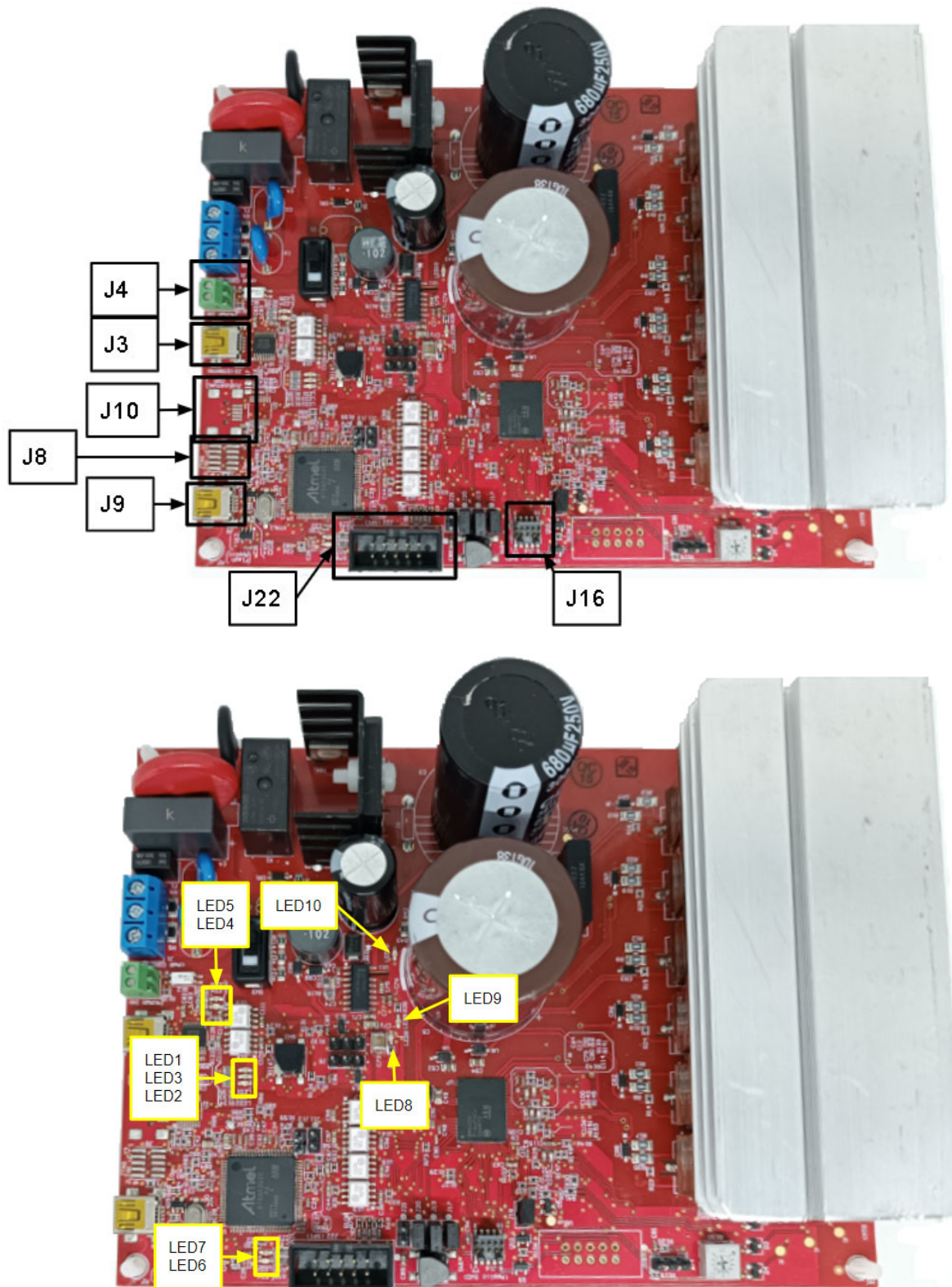


Figure 8. Evaluation Board Features

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.

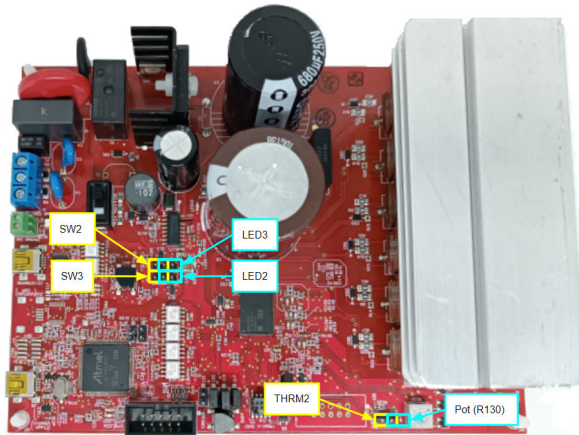


Figure 9. J5, J13, J14 Jumpers Selection

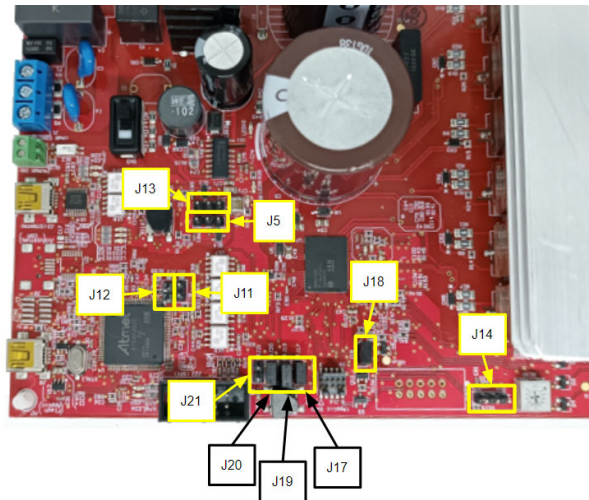


Figure 10. Jumpers Location

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

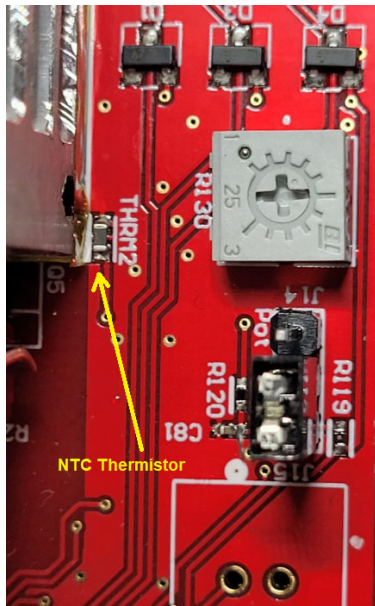


Figure 11. NTC Thermistor Location

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

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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

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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 NP0 0603	C94, C101, C104, C107	Vishay	VJ0603D4R7CXPBJ
28	8	CAP CER 10PF 50V NP0 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

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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	MFV030A
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

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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

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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	Diodec 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 12.000MHZ 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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