

## Roger Stockton's Notes on the EV-1 SCR DC Motor Controller

There are different EV-1 models depending on voltage. There is a 48-84V model. Some will accept up to 144V (typically these were used in on-road conversions at 96-120V (e.g. Jet Electrica 007 @ 120V, etc.). Here are the connections.

All of these left terminal strip points connect to pack +ve via some combination of switches:

L1, L2 = no connection on PCB

L3 = PBAT (pack voltage to the controller logic, via key switch and max 10A fuse) R54 (22k) to pack sensing?, T5 (K of SCR1)

L4 = ITN (Ignore True Neutral input) 22K to L5

L5 = TN (True Neutral input) 100k to C6/diodes voltage protection B-, U12/pin4 (1 in+)

L6 = (not used, but goes to the circuit)

L7 = SEAT (seat switch input) 27k to voltage protection diodes,

L8 = (Not used, Two resistors in voltage divide to B-) 56k +10k with track to Q19 & SW1 3, 5.)

L9 = F (forward direction command input) 27k to protection

L10 = R (reverse direction command input) 27k

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All of the right terminal strip connections return to pack -ve:

R1 = P8REF (8.2V reference output, referred to pack -ve; not generally used)

R2 = I (current output; provides a voltage signal proportional to the motor current: 1.8V= 0A, 3.3V=500A ('B' model controller; other models may have other current limits)

R3 = PMT (Pulse Monitor Trip output; this energises either the forward or reverse contactor via a driver module, and allows the controller to drop out the direction contactor should it detect a commutation failure or other dangerous condition)

R4 = COM (common return for throttle pot and 1A bypass switch) (Not connected on 1H9, external connection to B-)

R5 = SPEED (throttle pot input from pot wiper, wiper connected to one end of 5K pot, other end connects to COM; NOTE: 0 ohms = FULL speed; 5K=stop - this is the reverse of Curtis operation!)

R6 = 1ASW (1A bypass switch input, if present, 1A switch is part of potbox assembly and connects to COM when throttle is floored)

R7 = PCTON (Percent On output; 2V= 0%, 6V=max % duty cycle)

R8 = 1A (1A bypass contactor output; pulls in the bypass contactor via a driver module)

R9 = FS (field shunt contactor output; pulls in the field shunt/weakening contactor via a driver module)

R10 = PLUG (plug braking output)

The 5 main power connections are:

P = battery +ve

T2 = motor field

A1 = common connection between motor armature and field

A2 = remaining motor armature connection

N = battery -ve

Field shunting is an optional feature that is not present on all controller models. If present, you would connect the field shunting contactor in series with the field shunting resistor, and this combination would connect across the field.

If forward and reverse operation are electrically achieved, then the forward and reverse contactors are single-pole double-throw types, each connected such that the NO contact connects to T2, the NC connects to A1, and the COM of one connects to one end of the field while the COM of the other connects to the other end of the field. Energizing one results in motor current flowing from T2 through the NO contact of the energized contactor, through the field, through the NC contact of the other contactor, and then through the motor armature to A2 (and then through the controller's internal shunt to battery -ve at N).

Energizing the other direction contactor results in the current flowing through the field in the reverse direction.

The 1A bypass contactor is normally open and connects between P and T2. When it closes, it applies full battery voltage directly to the motor at the T2 connection. This bypasses the SCR control and allows 100% duty cycle (the SCR only hits a max of about 90-95%), which provides an opportunity for the SCR to cool.

If you look closely at the control card housing (black plastic rectangle on top of the controller), you will notice that there is a flap that you can lift. Under this flap is a series of holes through which you can adjust various pots:

1A Bypass Time: delay from hitting full throttle until bypass contactor closes

C/L: current limit

C/A: acceleration rate (current ramp)

CREEP: creep speed

PLUG: plug braking current limit

1A0: 1A bypass dropout current

PU: field shunt pick up

DO: field shunt drop out

There shouldn't be a surge on the logic supply at startup due to the 1C charge check since the charge current is actually drawn via the power terminal P.

My literature states that the OSC card closes the FWD or REV contactor (MAIN, in our case, but PMT output either way) and then fires 2REC so that 1C can charge (connected through the motor to pack negative, N). When 2REC commutates off, if 1C is charged, then the gates to 5REC and 1REC are unlocked.

I checked all of the EV1's I have on hand:

EV-1C in my Suzuki (originally from a 1980-vintage 007): 84-144V, OSC1E5, rev 0. PCB 1C3641BCHE5.

The logic power supply is on a separate PCB mounted to the underside of the logic card top cover. PCB 1C3C41BPS5A5. 3 leads connecting it to the OSC PCB: one marked 'B 12', one 'W COM', and one 'R IN'. I assume that the 'B', 'W', and 'R' refer to wire colours Black, White, and Red (even though all three are white in this sample).

Pack voltage appears to go from OSC terminal L3 to the supply PCB via 'IN', through an inductor and shortly thereafter sees a 250V 5uF cap. There are 3 metal can transistors: one 2N5416 and two Motorola parts marked 7657-1 913 and a handful of plastic transistors, etc.

EV-1C from my 96V Omni: 84-144V, OSC1E5. Did not open.

EV-1C spare: 84-144V? OSC1E4C.

The logic supply on this 1E4 is still on the main logic PCB. Seems similar in general concept to the separate supply in the 1E5, but the cap near the battery voltage input is a 150V 4.7uF part.

The series pass power transistor is a Motorola part marked 44A7100 66-001 8026. Battery voltage goes from terminal L3 through a filter inductor, then through a 2W resistor and a diode before reaching the 150V cap.

EV-1B: 24-84V, 1C3645OSC5H9, R09. Did not open. Panel is marked 1C3645SCR1H9BOXAAF\* GE-S-SCR EV1B

The underside of the OSC housing bears a GE sticker dated 30 Aug 96 listing test results @ 48V: current limit 212.1 battery amps @ 50%, 1A dropout 499.3 motor amps, plug current limit 447.7 motor amps.

Both the EV-1Cs and the EV-1B use 250WVDC rated commutating cap(s) for 1C. The EV-1B part is a single 150uF 250WVDC part; the 'C's use a pair of what appear to be the same caps. This is important since the 1C cap gets charged to an amount **greater** than battery voltage depending on the current going through the motor (which is one reason why the current limit a panel can support depends on the voltage it runs at).

So, battery voltage connections to the OSC card:

All L terminals are generally referred to battery positive while all R terminals are generally referred to battery negative.

L3 (PBAT) is the input to the logic power supply. The power supply outputs a crudely regulated (11-15V) 12V supply that powers the SCR gate drive circuits and is the input to the precisely regulated 8.2V reference supply (available on terminal R1).

The other L terminals are inputs from the various interlock, etc. switches, and need to be supplied from the same source as L3.

The other voltage inputs of interest are between the power panel and the OSC card. These are made via the harness that connects to the underside of the OSC card with a largish plug.

Viewed from the top of the OSC card (so same as viewing the male pins in the harness connector after removing it from the socket), the pinout is:

T1	T2	T3	T4	T5	
	T6	T7	T8	T9	
T10		T11	T12	T13	T14

T1: red/wht wire from P terminal (n/c at OSC on the 1A4A diagrams, nor on the 1E5 card I examined)

T2, 3: white & red pair to gate & cathode of 2REC

T4, 5: white/black & black pair to gate & cathode of 1REC

T6: blue wire from N terminal

T7: white wire from side of 1C opposite pack positive (P) connection (cap voltage sense)

T8, 9: white & red pair to gate & cathode of 5REC

T10: violet wire from T2 terminal (motor voltage sense)

T11: brown wire from temp sensor (connected to T6 in OSC)

T12: orange wire from temp sensor

T13: green wire from load side of shunt

T14: yellow wire from battery (N) side of shunt

Don't take the wire colours as gospel since the schematic is 1974/75 vintage for the 1C3641BCHA4A (i.e. OSC1A4), 48-84V logic. For instance, I noticed that the wire between 1C and T7 is labeled as grey rather than white on a later GE wiring diagram.

Also, I notice that GE wiring diagrams for more recent models seem to suggest that the gate drive connections to 2REC and 5REC may have been swapped (i.e. T2&3 feed 5REC and T8&9 feed 2REC)? Fortunately, this change isn't of great interest to us, so I haven't taken the time to look closely enough to determine if there really was a change or if it was just getting too late in the evening for me ;^>

The outputs to drive the gates of each SCR are isolated from the logic by pulse transformers (the 3 little black bobbins along the top edge of the OSC PCB should you open the housing).

The significant connections are:

T5: this is the connection between the pulse transformer and the cathode of the main SCR (1REC). This connection is used by the OSC logic to sense the voltage on the SCR for the purposes of pulse monitor trip (PMT) logic, etc. (i.e. determining if the SCR has turned off when it is supposed to). You would need to trace the circuitry from T5 on your OSC PCB to identify where this signal goes, and take steps to reduce its level as appropriate. On the A4A schematic, this voltage is used in a couple of places and feeds a couple of voltage dividers, so simply cutting the track and inserting a voltage divider between T5 and the circuits using this voltage may not work unless you also provide a buffer. On the other hand, if you trace the circuitry thoroughly, it would likely be possible to identify the appropriate resistor(s) in the divider(s) for replacement with appropriate new values (or pots...) to get the levels back in range.

T7: this is the input used to sense the voltage on the 1C commutating cap. This may be used by the logic for other purposes, but its main use is so the logic can determine that the cap has charged above some \*minimum\* fraction of the battery voltage. If you run the card from lower than full battery voltage, then this condition is pretty much guaranteed; which means you may largely lose the safety benefits afforded by this check. Provided the logic circuits aren't going to fry from the higher voltage level, you could leave this one alone, but on the other hand, it should be pretty simple to place a voltage divider between the cap terminal and pack negative (N) (T6 should you wish to implement the divider at the harness plug or socket) to drop the voltage appropriately.

T10: this is the input used to sense the motor voltage. This input may be used for other purposes as well, but one thing this signal is used by the logic for is to disable the 1A bypass if the motor voltage is low (i.e. motor speed too low?). If the logic circuits can tolerate the higher voltage, then nothing needs to be done to scale this input, however, this will defeat the safety afforded by this feature and allow 1A bypass to be activated regardless of motor voltage/speed. Of course, I think this feature may have been removed in later revisions anyway due to the addition of the 1A 'on demand' pickup feature (i.e. if you mat the throttle so the 1A/WOT switch is activated, then after an adjustable delay the 1A bypass activates regardless of motor volts or speed, I think). It should be straightforward to scale this input with a divider or perhaps just a series resistor (see below), so not worth avoiding, IMHO.

Given that the OSC logic uses an 8.2V reference, I expect these battery level voltages are all divided down to about that level before being presented to the logic, so you may have to take some care that the impedance of your divider does not interact undesirably with the internal divider impedance. It seems a possible strategy might be place a pot in series between the cap terminal and T7, then connect a safe battery voltage to power up the OSC card and measure the voltage at the OSC side of T7 while adjusting the pot until the voltage seen by the OSC is the desired fraction of the actual voltage at the cap terminal. Then simply substitute a fixed resistor of the appropriate value in place of the pot. The same technique should work for the T5 voltage sense input (unfortunately you would need to locate and cut the appropriate PCB track so that the series resistor can be inserted between the logic and T5 without being in series with the pulse transformer output), and the T10 motor voltage sense input.

It may not be necessary to power up the OSC card while determining the series resistor values, however, since these various dividers ultimately feed GE's custom logic ICs and we (I anyway) don't know how they load the external circuitry, it seems safest to make the adjustments with the logic powered.

Driver modules: the 1A4A documentation states that each of the driver outputs is capable of driving one 1C3641BRDB (or ...BRDA) relay driver boards (which I assume is what is potted into the driver modules). It states that a BRDB is capable of sinking 1.5A max, and at 48V only a BRDA may sink up to 3A max.

The 84-144V OSC1E5 that was in my 96V Omni used a 1C3645CPM1RDB2 driver module, so we know it will tolerate a fully charged 96V pack. There was also a 1C3645CPM1LEK5 module installed that appears identical to the DB2, which I assume also accepted 96V.

The GE service/troubleshooting instructions appear to treat the DA@ and DB2 modules identically and describe testing at 24/36/48V using a 4K7 2W resistor between the battery and terminal 1, and testing at 72V using an 8K2 2W resistor between the battery and terminal 1, suggesting that either module is usable up to at least 72V (perhaps at least 84V, since the instructions covers both 24-48V and 48-84V models?).

I don't know if it is safe to assume that a DA2 driver contains a BDRA (1.5A max) board and a DB2 contains a BRDB (3A max @ 48V) board.