Repair procedure
for
old e-max scooter 1500 and 2000 controller

Foreword:

This procedure describes the repair of the controller. There are 4 different models of controller was made. The principal function is each case the same but the design is a little bit different. An engineer should be able to repair all models. If not you can ask me.

All works on it has to make very carefully because there are a high current, up to 60 amps!

Principal function of the controller

The battery voltage for the controller comes from the big relay after the key switch is turned on.

A switched power supply (on the left corner near cable input) reduced the battery voltage to 15 VDC. This 15 VDC are used for the IC U1 to U4 and U9 only. The voltage regulator Q8 reduced this 15 VDC to 6 VDC for the IC U11 and for the hall sensors. The operating voltage for the IC U5 to U8 and U12 comes from the U4 pin 7.

If you turn the accelerator a voltage between 0 – 6VDC on pin 9 of the U4 (MC33033DW) starts the DC brushless controller IC. Immediately the control signal to the 3 pcs. U1, U2 and U3 (IR2110) will open these IC and open the MOSFET's and the motor runs. At the same time the 3 hallsensors of the motor give the controller IC U4 the information in which direction the motor is turning and which rpm it has.
All other IC's are for input signal (brake switch) and amplifiers.

The MOSFET's switched the winding of the motor to battery voltage and to ground alternating.

Needed tools:

- screwdriver PH2
- Cutter small (for capacitors and MOSFET) and cutter very small for IC
- Solder station min. 80W with 3 different tips (very small for the small IC, medium for diodes and capacitors, big for MOSFET and big capacitors). We recommended a Weller solder station type WD 1000 or better WD 2 from Weller.
- Resolder station WDD81V from Weller (don't use a resolder pump!!)
- Some tweezers for IC and SMD parts
- Resolder copper for cleaning the pads of IC and SMD parts
- Solder Sinn 0.3mm, 0.5mm and 1mm diameter
- Power Supply 0-40 VDC, 6 amps.
- Oscilloscope up to 20MHZ or better
- Digital Multimeter to measure DC, Resistance

Opening of the controller

- Remove the controller from the scooter
- Disconnect all cables
- Remove all screws of the cover and open it
- Remove all screws of the MOSFET
- Lift up the PCB carefully and remove the screw of the temperature sensor

Test procedure

a) Visual inspection

Control the PCB and the MOSFET for broken points. If one MOSFET broken or the type of the MOSFET is not IRFP2907 cut of all MOSFET.

b) Measurement of some resistance

- Check on each MOSFET (U1A – U12A) if between the 3 lead (G, S, D) a short. If at one MOSFET a short circuit cut of all MOSFET. Also the control IC (IR2110) for the MOSFET which has the short has to be cut off and must be exchanged.

- Check over the 3 resistors (Gate-Resistor) of each MOSFET (U1A – U12A) if there is a resistance of 18 Ohm $\pm$2 Ohm. If no resistance or a short cut of all MOSFET. Also the control IC (IR2110) for the MOSFET which resistors are not correct has to be exchanged.

- Check the fuses. It should be measured a short over it

c) Check of the voltages (15 VDC, 6 VDC, 6.3 VDC reference).

For all following tests are necessary to connect the controller to power supply which is set to 40 VDC.
For the normal controller connect the single thin red wire to plus and the single big black cable to the minus of the power supply.
For the very old one (no single thin red wire) connect the single big red wire to plus and the single big black cable to the minus of the power supply.

Connect the minus lead of the DVM with the minus pole of the power supply.

15 VDC
- on the cathode of diode (black) close to the transformer a voltage of + 15.5VDC $\pm$0.7VDC.
  If not turn of the power and measure, if there is a short. If there is a short please check the IC (see in the description of principal function which one). If not all components of the Power Supply has to be exchanged. (D1, black diode, R20, Q1, TO220 transistor, both elco's near transformer). This is more efficiency than to find out which of the parts are broken. It's a loop system.

6 VDC
- on pin 8 of U11 (MC33039) must be +6 VDC ±0.3 VDC.
  If not U11 or Q8 are defect.

6.3 VDC reference of U4 (MC33033) pin 7
- on pin 7 of U4 (MC33033) must be +6.3 VDC ±0.3 VDC.
  If not, one of the IC U5 to U8 or U12 are defect.

d) Function test of the controller

Connect all cables of the controller to the scooter. Turn on the power by using key switch of the scooter. Look if there is no short or smoke from the open controller.

Battery Test switch
Press the battery test switch. The indicator should move slowly and stay in the green range of the scale if the battery is full.

Function of Hall sensors
It is very important to check the hall sensor function before you use the accelerator!! Reason is: if no hall sensor signal there or not correct the controller will immediately destroy!!
Connect the tip probe of the oscilloscope to pin 1 of U1. If you turn the rear wheel a little bit the polarity of the DC-Level should change (from 0 to 6 VDC, or in other direction). Repeat this procedure for U2 and U3.
If no DC-Level changes on U1, U2 or U3, measure at U9 pin 2, 4 and 6.
For example if the signal is there, one of the IR2110 is broken.
If no DC-Level changes on U9 pin 2, 4 and 6, measure at U4 pin 1, 2 and 20.
For example if the signal is there, the U9 is broken.
If no DC-Level changes on U4 pin 1, 2 and 20, measure at U4 pin 4, 5 and 6.
For example if the signal is not there, one of the Opto coupler on the backside of the PCB, or a cable or connector of the Hall sensor, or one of the Hall sensor inside the motor is broken. Or the 6 VDC is missing (can measured on the Hall sensor connector with DVM between red and black cable).

If all tests and signal are ok, turn slightly the accelerator. The motor must start. It makes no sense to rise up the accelerator to full speed. If the motor didn't start check the brake switch function or remove the connector of the brake switches.

If the motor running, listen for strange noise and watch the controller. Check each motor signal with the oscilloscope (be careful 48VDC and a lot of ampere). It should be always the same, when the motor is full running. The period change in relation to the setting of the accelerator.

Check if the motor stops by using the brakes.
If not a switch or cable is broken.

e) Final test

Test all functions. Also test the booster function.

Spare part list for the controller:

Following spare parts are for one controller needed, red marked parts are necessary for stock:

No of device	Qty.	Type	Description	Remarks
U1A to U12A	12	IRFP2907PBF	MOS-FET	If one of them is defect exchange also all MOS-FET, check the corresponding diode D2, D4 or D6 and resistors 56Ohm. Also change for safety the corresponding capacitor C3, C4 or C5 and U1, U2, U3
U1, U2, U3	3	IRS2110S	MOS-FET driver	If one of them is defect exchange also all MOS-FET, check the corresponding diode D2, D4 or D6 and resistors 56Ohm. Also change for safety the corresponding capacitor C3, C4 or C5.
U4	1	MC33033DW	Motor control IC	
U5, U6, U8	3	LM358M	Op	
U7	1	NE555	Timer	Is for booster signal activation of 1 minute
U9	1	CD4069 Or HEF4069UBT	4 inverter	
U10, Q5, 3x backside	5	TLP-521-1	Opto coupler	
U11	1	MC33039P	Motor control IC	
U12	1	LM393M	Op	
Q1	1	MMBT3904LT1 Or ZXTN2038F	NPN-Transistor	For the 15V DC-DC Converter
Q3	1	MJE13005	NPN-Transistor	For the 15V DC-DC Converter
Q8	1	78L06	6 VDC Voltage regulator	Voltage for Hall sensors and MC33039
R1-R6 R11-R16 R59-R62 R69-R85 R87-R89	36	51Ohm, 1%,		And all other resistor for the Gate of MOS-FET.
R20	1	100Ohm, 1%,		For the 15V DC-DC Converter
C3, C5, C6	3	4,7uF, 63V	Capacitor	Close to IR2110
C7, C9,C28, C101	4	1000uF, 63V	Capacitor	Big capacitor
C10	1	220uF, 63V	Capacitor	For the 15V DC-DC Converter
C15	1	470uF, 25V	Capacitor	For the 15V DC-DC Converter
D1	1	BZV85-C15 1.0W	Zener diode	For the 15V DC-DC Converter
D2, D4, D8	3	SS16	Shottky diode SMBJ15	
D3	1	HER107	Fast recovery diode	For the 15V DC-DC Converter

Recommended minimum Spare parts for one controller

No of device	Qty.	Type	Description	Order No Farnell	Price / Pcs.
U1A to U12A	12	IRFP2907PBF	MOS-FET TO-247	864-9316	7.15
U1, U2, U3	3	IRS2110S	MOS-FET driver 16 SOIC	Must be ordered by Buerklin 40S8567	2.88
U4	1	MC33033DW	Motor control IC 20 SOIC	Must be ordered by Spoerle	unknown
U5, U6, U8	3	LM358M	Op 8 SOIC	948-6828	0.585
U7	1	NE555	Timer 8 SOIC	958-9880	0.37
U9	1	CD4069 Or HEF4069UBT	4 inverter 14 SOIC	120-1295	0.717
U10, Q5, 3x backside	5	TLP-521-1	Opto coupler 4 DIP	122-5859	0.261
U11	1	MC33039P	Motor control IC 8 DIP	114-7795	Unknown
U12	1	LM393M	Op 8 SOIC	229-4229	0.403
Q1	1	MMBT3904LT1 Or ZXTN2038F	NPN-Transistor SOT-23	125-1226	0.27
Q3	1	MJE13005	NPN-Transistor TO-220	929-4171	1.15
Q8	1	78L06	6 VDC Voltage regulator TO-92	123-6592	0.137
R1-R6 R11-R16 R59-R62 R69-R85 R87-R89	36	51Ohm, 1%,	Resistor 0805	933-3355	0,031
R20	1	100Ohm, 1%,	Resistor 1206	933-5749	0.031
C3, C5, C6	3	4,7uF, 63V	Capacitor 5x11, RM 2.5	945-1471	0.036
C7, C9,C28, C101	4	1000uF, 63V	Capacitor 16x25, RM 7.5	969-3076	1.75
C10	1	220uF, 63V	Capacitor 10x16, RM 5	969-3041	0.724
C15	1	470uF, 25V	Capacitor 10x12.5, RM 5	121-9470	0.44
D1	1	BZV85-C15 1.0W	Zener diode 15V	109-7251	0.257
D2, D4, D8	3	SS16	Shottky diode SMBJ15	955-1298	0.387
D3	1	HER107	Fast recovery diode 1A, 800V	956-5191	0.46