❸ ESC Motor Drive Signals

The Phantom 3-phase motor drive signals are the three motor wires soldered to the ESC board and labeled A–B–C. Only two of the three phases are energized at a time to step the motor in the proper direction (CW or CCW) and desired power. The MPU firmware converts the input PWM motor control signals into the 3–phase motor drive signals. These low-current 3v MPU drive signals are applied to an array of six MOSFETs to deliver the battery+11v high-current pulses required by the motor windings.

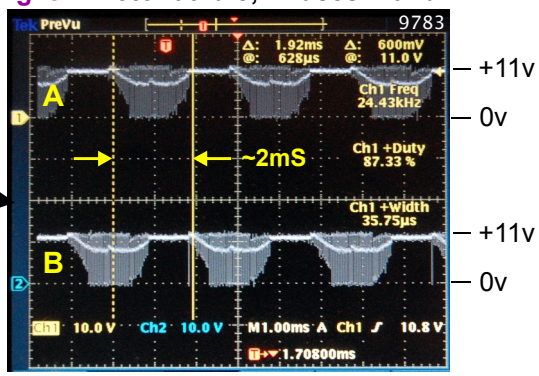
A MOSFET is basically a semiconductor switch; ideally, it is either ON for full current flow, or OFF for no current flow. They precisely deliver the appropriate power to the motor for the desired speed. Pulses are used to energize the motor windings. Thus, each motor drive signal (A–B–C) are "bursts" consisting of narrow pulses for precise speed control. It is important to note that each MOSFET drive burst powers the rotor to the next stator winding. Motors consist of 12 stator windings and 14 rotor magnetic poles. It takes 14 motor drive bursts per winding to complete one motor revolution.

1) **O-scope setup**: Ch.1 10v/div; Ch.2 10v/div; sweep 1mS/div; trigger: Ch.1
   Ch.1 to motor drive wire "A" (black) for the reference phase.
2) Turn on motor to idle. Observe 11v drive bursts on Ch. 1 (motor drive A)
3) Place Ch.2 probe on motor drive B channel (**Fig. 8**), then motor drive C (**Fig. 9**)
4) Observe proper phase sequencing between phases A–B and A–C; should be 120° (1mS at idle) apart.
5) Observe proper 3-phase sequencing at higher motor speeds.

NOTE: Since motor speed is constantly changing, triggering may be difficult. Try single sweep to capture waveforms.
FAIL: No drive burst on one or more motor drive lines is likely failed MOSFETs associated with the bad channel.
Blown MOSFETs are the main failure item on the ESC boards. A blown MOSFET is usually visibly destroyed.

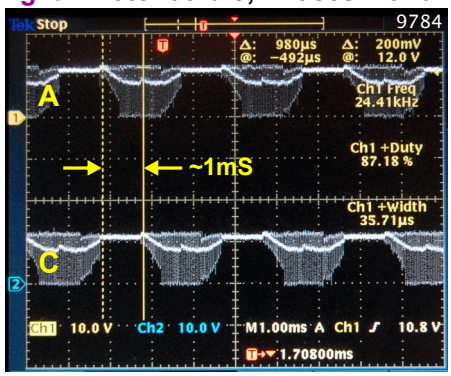
Fig. 8 – Motor at idle; Phases A and B

Ch 1: 10v/div
Ch 2: 10v/div
Sweep: 1ms/div
Trig: Ch 1 +slope



CH 1: Motor drive "A"
CH 2: Motor drive "B"

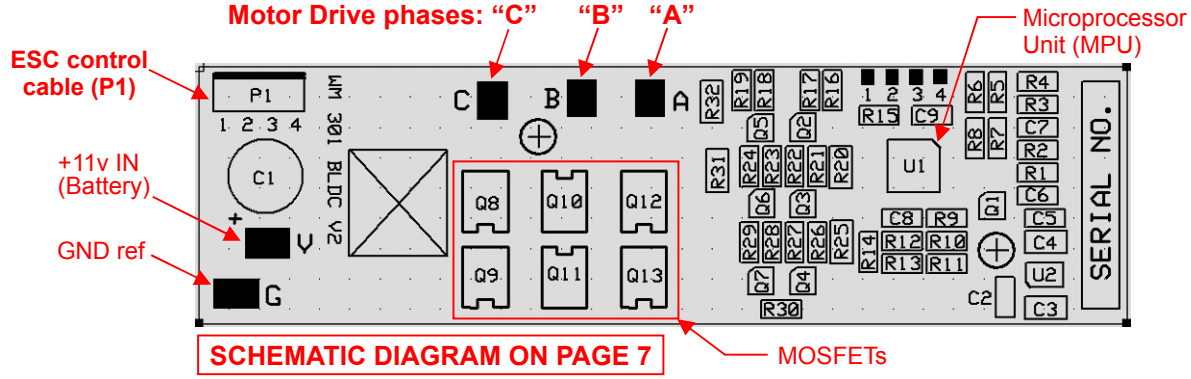
Fig. 9 –Motor at idle; Phases A and C



CH 1: Motor drive "A"
CH 2: Motor drive "C"

OK: Motor phase "B" and "C"drive bursts about 1mS and 2mS from drive "A" indicates the proper 120° phase difference between the 3 phases. Whether "A" to "B" is 1mS or 2mS depends if a CW or CCW motor.

Fail: **If one (or more) of the phases is missing, most likely a MOSFET failure.**
If not 120° between A,B and C, or phase not stable (jumping around), possible failure of BEMF rotor sensing. **Goto Step 5.**



SCHEMATIC DIAGRAM ON PAGE 7

4 MOSFET High- and Low-side Switching

In Fig. 10, Q13 is the high-side switch (connected to +11v) and Q12 is low-side switch (connected to ground). However, the low- and high-side MOSFETs on the same winding are never turned on at the same time. Fig. 11 shows the normal current flow used to energize two windings, in this case, A–B.

The high-side switch (a P-channel MOSFET) is turned on to provide the battery +11v to the proper winding pair; the low-side switch (N-channel MOSFET) sinks current to ground, modulated with the speed control drive pulses.

Checking these inputs with the associated motor drive outputs can isolate a bad MOSFET.

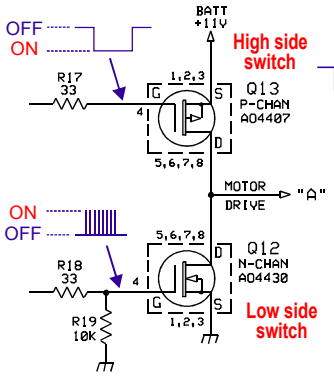


Fig. 10 –High-side and Low-side switching

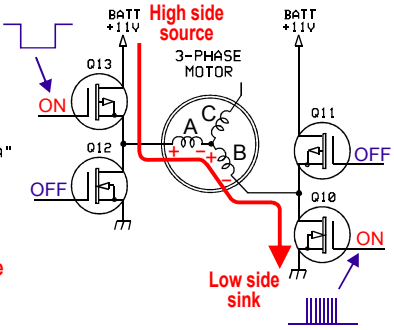
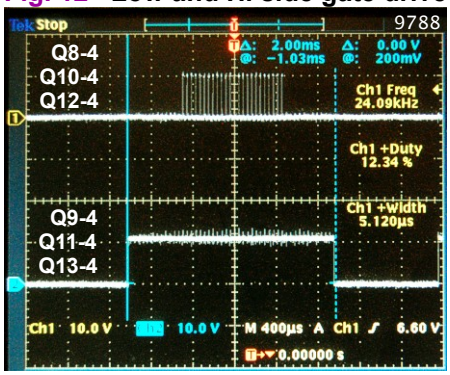


Fig. 11 –High and Low side switching to energize two windings

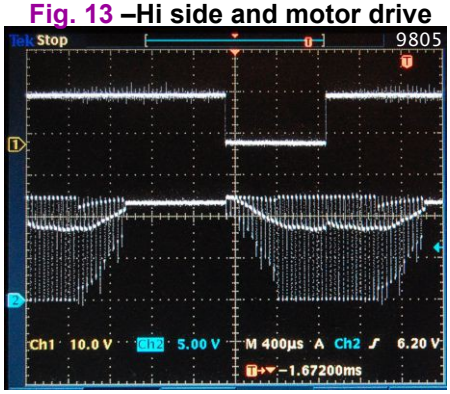
1) **O-scope setup**: Ch.1 10v/div; Ch.2 10v/div; sweep 1mS/div; trigger: Ch.1
2) Turn on motors to idle. Place Ch. 2 probe on Motor Drive "A"
3) Ch. 1 probe, check gate input pin 4 on Q9, Q11 and Q13 for high side drive signal (**Fig. 13**)
4) Ch. 1 probe, check gate input pin 4 on Q8, Q10 and Q12 for low side drive signal (**Fig. 14**)

Fig. 12 –Low and Hi side gate drive



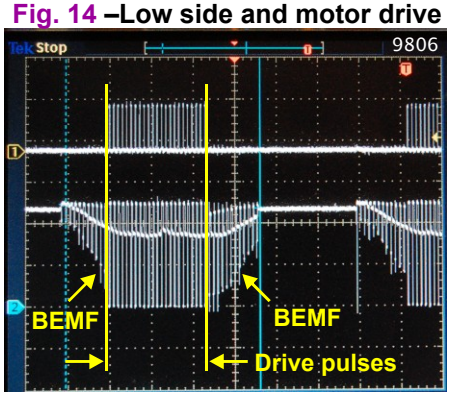
CH 1: Low-side drive "A" (Q12-4)
CH 2: High-side drive "A" (Q13-4)

Fig. 13 –Hi side and motor drive



CH 1: Low-side drive "A" (Q12-4)
CH 2: Motor drive "A"

Fig. 14 –Low side and motor drive



CH 1: High-side drive "A" (Q12-4)
CH 2: Motor drive "A"

OK: Motor phase "B" and "C" drive bursts about 1mS and 2mS from drive "A" indicates the proper 120° phase difference between the 3 phases. Whether "A" to "B" is 1mS or 2mS depends if a CW or CCW motor.

Fail: **If one (or more) of the phases is missing, most likely a MOSFET failure.**
If not 120° between A,B and C, or phase not stable (jumping around), possible failure of BEMF rotor sensing. **Goto Step 0.**

FAILED ESC BOARD

A failed ESC board is usually caused by the failure of one or more MOSFETs. A MOSFET usually fails from excessive current (often caused by shorting out internally), creating excessive heat. The MOSFET chip(s) will usually show signs of excessive heat or being "burned," and often easy to spot. Damage to the printed circuit board may also result.