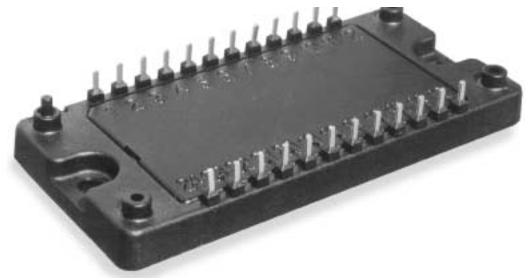
BC05

HTTP://WWW.APEXMICROTECH.COM (800) 546-APEX (800) 546-2739

FEATURES

- 10V TO 200V MOTOR SUPPLY AT 5A CONTINUOUS AND 10A PEAK OUTPUT CURRENT
- OPERATION WITH 10.8V TO 16V VCC, ALLOWING NOMINAL 12V OR 15 V VCC SUPPLIES
- THREE PHASE FULL BRIDGE OPERATION WITH 2 OR 4 QUADRANT PWM
- AUTOMATIC BRAKING WHEN USING 2 QUADRANT PWM
- THERMAL PROTECTION
- ANTI SHOOT THROUGH DESIGN
- 50 KHZ INTERNALLY SET PWM FREQUENCY, WHICH MAY BE LOWERED WITH EXTERNAL CAPACITORS
- SELECTABLE 60° OR 120° COMMUTATION SEQUENCES
- COMMUTATION TRANSITIONS OUTPUT FOR DERIVING SPEED CONTROL
- MAY BE USED OPEN LOOP, OR WITHIN A FEEDBACK LOOP
- ANALOG MOTOR CURRENT MONITOR OUTPUT, MAY BE USED FOR TORQUE CONTROL OR FOR TRANSCONDUCTANCE AMPLIFIER DRIVE.
- ANALOG REFERENCE, FEEDBACK, AND TORQUE INPUTS



APPLICATIONS

- 3 PHASE BRUSHLESS MOTOR CONTROL

DESCRIPTION

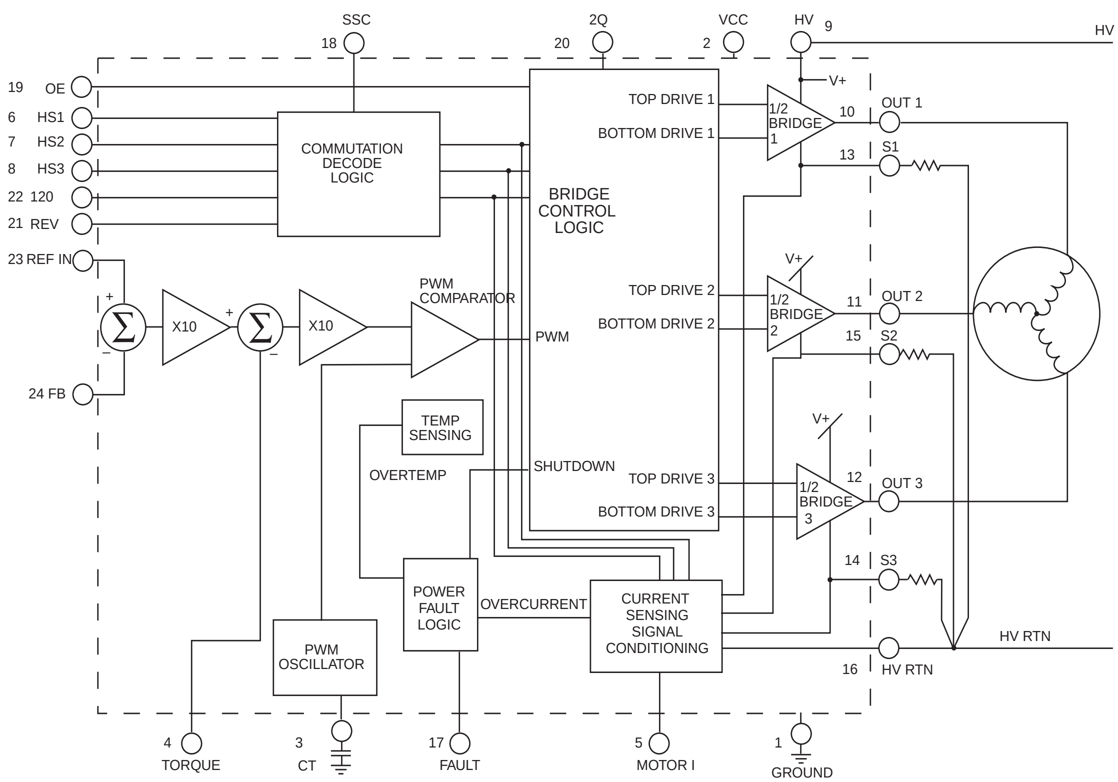
The BC05 Brushless DC Motor Controller provides the necessary functions to control conventional 3-phase brushless DC motors in an open loop or closed loop system. The BC05 is able to control motors requiring up to 1kW continuous input power.

The controller drives the motor, generates the PWM, decodes the commutation patterns, multiplexes the current sense, and provides error amplification. Operation with either 60° or 120° commutation patterns may be selected with a logic input.

Current sense multiplexing is used to make the current monitor output always proportional to the active motor coils current. Therefore the current monitor output may be used in generating transconductance drive for easy servo compensation.

The controller may generate 4-quadrant PWM for applications requiring continuous transition through zero velocity, or 2 quadrant PWM for electrically quieter operation in unidirectional applications. Direction of rotation may be reversed in 2-quadrant mode by using the reverse command input. When in 2-quadrant mode if the motor is stopped or decelerating dynamic braking is automatically applied. In this way deceleration profiles may be followed even when using 2-quadrant PWM.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

MOTOR VOLTAGE, V+	200V
CIRCUIT SUPPLY, Vcc	16V
OUTPUT CURRENT, peak	10A
OUTPUT CURRENT, continuous	5 A
ANALOG INPUT VOLTAGE	–0.3V to Vcc+0.3V
DIGITAL INPUT VOLTAGE	–0.3V to 5.3V
TEMPERATURE, pin solder, 10s	300°C
TEMPERATURE, junction[2]	150°C
TEMPERATURE RANGE, storage	–65 to 150°C
OPERATING TEMPERATURE, case	–25 to 85°C

SPECIFICATIONS

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
ERROR AMP					
OFFSET VOLTAGE		–3.3	0	3.3	mV
BIAS CURRENT				4	pA
DC GAIN		19.8	20	20.2	db
BANDWIDTH		15	16	17	kHz
INPUT AMP					
STAGE GAIN[1]	Set by internal and/or external resistors		20	20.2	db
INPUT IMPEDANCE[1]			2		Kohm
COMMON MODE VOLTAGE	Applied at input terminals, Vcc = 10.8V	–0.5	5.0	8.5	V
COMMON MODE VOLTAGE	Applied at input terminals, Vcc = 16V	–0.5	5.0	14	V
COMMON MODE REJECTI0N		50			db
DIFFERENTIAL OFFSET		–3.3	0	3.3	mV
GAIN BANDWIDTH PRODUCT		700			kHz
OUTPUT					
TOTAL R_{on}	Junction Temperature = 125°C		0.65		Ohms
EFFICIENCY, 5A, 200V	Dependent on individual application		93		%
SWITCHING FREQUENCY		45	50	55	kHz
CURRENT, continuous		5			A
CURRENT, peak		10			A
POWER SUPPLY					
VOLTAGE, V+		20		200	V
VOLTAGE, Vcc		10.8		16	V
POWER DISSIPATION					
Operating Power Dissipation[2]	Calculated at 100V,10A, 50 kHz PWM, 12 mHy, 6.4 ohms, 95% duty cycle and 4-quadrant PWM			124	watts
Single FET Dissipation[2]	Calculated at 100V,10A, 50 kHz PWM, 12 mHy, 6.4 ohms 95% duty cycle and 4-quadrant PWM, To each of 6 power FETs, motor stalled			62	watts
Thermal resistance				1.92	°C/watt

NOTES: 1. Set internally
2. Long term operation at the maximum junction temperature will result in reduced product life.

CAUTION The BC05 is constructed from static sensitive components. ESD handling procedures must be observed.

PIN FUNCTION

All Logic Positive TKUC

I/O	SIGNAL	DESCRIPTION	PIN
I	HV	Unregulated high current motor supply voltage	9
I	HVRTN	Return line for the motor current	16
O	OUT1	Half bridge output for driving motor coil	10
O	OUT2	Half bridge output for driving motor coil	11
O	OUT3	Half bridge output for driving motor coil	12
I/O	S1	Source of the N-rail FET in half bridge 1	13
I/O	S2	Source of the N-rail FET in half bridge 2	15
I/O	S3	Source of the N-rail FET in half bridge 3	14
I	HS1	Commutation sensor input 1	6
I	HS2	Commutation sensor input 2	7
I	HS3	Commutation sensor input 3	8
I	120	Sets commutation logic for 120° phasing	22
I	REV	Reverses direction when 2 quadrant PWM is used	21
I	GROUND	Signal ground	1
I	Vcc	Control circuit power	2
I	REF IN	Velocity/speed input	23
I	FB	Input for analog voltage proportional to velocity or speed	24
I	TORQUE	Input for an analog voltage proportional to motor current	4
O	MOTOR I	Analog voltage proportional to motor current	5
O	SSC	HCMOS level pulse for each sensor state change.	18
O	FAULT	HCMOS logic level output, a 0 indicates over temperature or over current condition.	17
I	OE	HCMOS 1 enables power FET operation	19
I/O	CT	The PWM frequency may be lowered by installing a capacitor between this output and ground.	3
I	2Q	A logic 1 on this input enables 2 quadrant PWM	20

COMMUTATION AND OUTPUT TABLES

TABLE 1

Position	0	60	120	180	240	300
R	0	0	0	0	0	0
2Q	0	0	0	0	0	0
120	0	0	0	0	0	0
OE	1	1	1	1	1	1
HS1	1	1	1	0	0	0
HS2	0	0	1	1	1	0
HS3	1	0	0	0	1	1
OUT1	T	+	+	T	–	–
OUT2	–	–	T	+	+	T
OUT3	+	T	–	–	T	+

TABLE 2

Position	0	60	120	180	240	300
R	0	0	0	0	0	0
2Q	0	0	0	0	0	0
120	1	1	1	1	1	1
OE	1	1	1	1	1	1
HS1	1	1	1	0	0	0
HS2	1	1	0	0	0	1
HS3	1	0	0	0	1	1
OUT1	T	+	+	T	–	–
OUT2	–	–	T	+	+	T
OUT3	+	T	–	–	T	+

TABLE 3

Position	0	60	120	180	240	300
R	0	0	0	0	0	0
2Q	1	1	1	1	1	1
120	0	0	0	0	0	0
OE	1	1	1	1	1	1
HS1	1	1	1	0	0	0
HS2	0	0	1	1	1	0
HS3	1	0	0	0	1	1
OUT1	T	+	+	T	0	0
OUT2	0	0	T	+	+	T
OUT3	+	T	0	0	T	+

TABLE 4

Position	0	60	120	180	240	300
R	0	0	0	0	0	0
2Q	1	1	1	1	1	1
120	1	1	1	1	1	1
OE	1	1	1	1	1	1
HS1	1	1	1	0	0	0
HS2	1	1	0	0	0	1
HS3	1	0	0	0	1	1
OUT1	T	+	+	T	0	0
OUT2	–	–	T	+	+	T
OUT3	+	T	0	0	T	+

GENERAL

Much useful application information for these products can be obtained from Application Notes 1 (General Operating Considerations) and 30 (PWM Basics).

PWM CONSIDERATIONS

The BC05 can be configured with a logic-input (2Q) to operate either as a 2-quadrant or 4-quadrant controller. 2-quadrant PWM holds one coil terminal at a constant level and applies PWM at the other. PWM is applied at the positive terminal when in 2-quadrant mode. 4-quadrant PWM switches both terminals. 2-quadrant PWM is electrically slightly quieter and slightly more efficient, but cannot transition through zero. Therefore 4-quadrant PWM is required for applications such as position servos, phase locked motor control, or accurately following complex velocity profiles. 2-quadrant PWM is preferable for unidirectional speed control applications. The R input may be used to reverse the motor when using 2-quadrant PWM, but must be at logic “0” when in 4-quadrant mode.

COMMUTATION

The BC05 may be configured to operate with either 60° or 120° Hall sensor patterns by the state of the 120 input. (Obviously also with encoder outputs having the same logic.) When 120 is low the BC05 operates with 60° commutation; when 120 is high they operate with 120° commutation.

The relationship between commutation states and motor drive output is tabulated in the following tables [See Tables 1-4 on previous page]. For the purposes of these tables PWM that is mostly positive will be designated +; PWM that is mostly low will be designated −; a tri-state condition will be designated T; REF IN is more positive than FB; and “Forward” rotation is the only direction tabulated. Position is given in electrical degrees.

Some motor manufacturers may not use the same conventions in identifying motor and Hall sense leads as Apex. In that event you may have to experimentally identify the corresponding motor and Hall Sense leads. For 3 binary square waves with equal phase shifts between the square waves, such as Hall sense outputs, there are only 8 possible states. 60° commutation fills 6 of the states and 120° commutation fills the other set of 6 states. Therefore all such patterns are truly only 60° or 120°. Changing pattern is done in the Apex controller by inverting HS2 internally.

Once the proper commutation patterns are obtained it is necessary to determine the motor lead orientation to the Hall sense. This may be done by turning the motor with a test fixture and observing the relationship between the HS patterns and the EMF, or by running the motor at low voltage and systematically switching motor leads until smooth running in the desired direction is obtained. The motor can be expected to run smoothly in the desired direction, run reverse, not run at all, or vibrate violently between 2 positions as this is done.

SAFETY CIRCUITS

There are four safety circuits in the BC05.

1. The peak current sensing circuit, which is programmed by the value of the current sense resistors placed by the user between the DMOS sources and HV return. This circuit is reset each PWM cycle. If three current sense resistors are used, as recommended, an analog multiplexer selects the current sense resistor, which has the same current as the motor coil. This technique blanks out noise and provides an excellent sensing of actual coil current. The programming of this circuit is accomplished by the folowing formula:

   $$I_{TRIP} = 0.5/R_{SENSE}$$

   Note that for large currents R_{SENSE} becomes very small, therefore stray resistance in the high current path can have a large effect. Heavy etch should be used in the current sensing path, and leads should be very short between the resistors and the pins of the controller.
2. Thermal Protection
   The junction temperature of all power devices is sensed, and the controller is shut down when too hot. This circuit is a a latch and can be reset when OE is turned on, providing the power devices have cooled to a safe temperature.
3. There is an over-current protection circuit which shut down the controller when the current provided by the HV supply exceeds about 1.5 times the peak current rating. This circuit latches and may be reset by cycling the OE input. Although this is “top rail” protection, a short to ground will probably destroy the BC05.
4. The output circuit will shut down if a power supply is missing. This is not an alarmed fault.

FAULT

There is an alarm output, FAULT, which goes to logic 1 when OE is at logic 0, or if any of the overcurrent or overtemperature conditions occur. It is an active line, being reset once each PWM cycle when the peak current sensing circuit is limiting.

OPEN LOOP OPERATION

1. The controller can be operated open loop by connecting an analog voltage at the TORQUE input, pin 4. The voltage applied to the motor will be:

   $$V_{MOTOR} = (2.5HV)(V_{DD} - V_{IN})$$

   V_{DD} is an internally generated 5V which is not brought to a pin. When in this mode of operation the input dynamic range for linear operation is $V_{DD} \pm 0.5V$.

2. The contoller can be operating open loop by connecting an analog voltage to REF IN, pin 23; and its reference to FB, pin 24. The voltage applied to the motor will be:

$$V_{MOTOR} = 25HV(VIN)$$

When in this mode of operation the differential dynamic range for linear operation is ±50mV, and the common mode dynamic range is -0.5V to V_{CC} – 2.5V. Putting matched resistors in series with the REF IN and FB inputs can lower the gain. When this is done the gain equation becomes:

$$V_{MOTOR} = (100/(4(1+R)))(HV)(V_{IN})$$

Where R_{IN} is expressed in k-ohms

The common mode dynamic is increased to:

$$-V_{COMMONMODE} = (-1+R_{IN})\ (0.5V)$$

$$+V_{COMMONMODE} = V_{CC} -2.5\ (1+R_{IN})\ (0.5V)$$

CLOSED LOOP OPERATION

The controller may be operated in a closed loop by applying the command signal to the REF IN input, pin 23, and analog feedback to FB, pin 24. In this case the gain as a servo amplifier is given by the equation of sections 2 or 3 of the "Open Loop Operation" section.

TRANSCONDUCTANCE AMPLIFIER OPERATION

The controller can be operated in a transconductance amplifer mode by connecting the MOTOR I output to the TORQUE input through a resistor. The value of the sense resistors should have been chosen for the desired value of current limiting, then the desired value of transconductance can be obtained from the following equation:

$$G_M = 200(10 + R_{IFB})/(R_{SENSE}(R_{IN}+1))$$

R_{IFB} is the resistor from MOTOR I to TORQUE, R_{SENSE} is the value of the 3 sense resistors placed between the S_1, S_2 and S_3 outputs and HV RTN; and R_{IN} is the value of the 2 matched resistors in series with the REF IN and FB inputs.

EFFICIENCY

The power dissipation tabulated in the specifications section is for maximum delivered power at maximum PWM frequency. This equates to an efficiency of 87%. Under these conditions dissipated power is 22% I^2 R losses and 78% switching losses. Switching losses are directly proportional to load current, HV supply voltage, and PWM frequency. Therefore improved efficiency can be obtained by lowering the PWM frequency if the motor inductance is high enough to filter the current. PWM frequency may be conveniently lowered by installing a capacitor from the CT pin to signal ground. (Located conveniently close!)

PWM frequency = 50 kHz x 1nf /(CT+ 1nf)

I^2 R losses, unfortunately, are proportional only to I^2 and the sum of Rds on and other resistance in the current path.

APPLICATION REFERENCES

For additional technical information please refer to the following Application Notes:
AN 1: General Operating Considerations
AN 30: PWM Basics