

Board Size & System Cost Advantages of the Hitachi Integrated ECN303x BLDC Solution

versus

A MicroController (Discrete) BLDC Solution

The design challenge was to replace an obsolete 3-Phase BLDC motor drive controller: the Allegro UDN2936-120. The device offered BrushLess commutation and provided BLDC motor drive power. Each of (3) outputs was rated at 45VDC and $\pm 2A$ ($\pm 3A$ peak) with internal ground clamp and fly back diodes. The obsolete device also featured internal PWM current control and thermal shutdown. The 3-Phase BLDC motor was required to run up to 10,000 rpm. The original BLDC drive controller board fit inside a 4.8 cubic inch volume, however, the updated design needed to fit into 3.25 cubic inches.

The updated BLDC controller must be Cost Comparable, meet all original requirements, but additionally:

- Fit into a 3.25 cubic inch volume package (33% smaller)
- Operate at up to 50VDC input
- Provide 3 Amps of average motor current (150Watts Electrical Input)
- Feature input reverse polarity protection
- Feature Tachometer output
- Feature Open Loop Speed Control
- Feature an external rotation direction preset
- Feature Over Current protection
- Feature Under Voltage protection
- Feature Over Temperature ShutDown

Considering these above system requirements, after researching the available integrated BLDC controllers, the choices narrowed down to two (2) alternatives:

- A MicroController-Based Discrete design
- An Integrated approach based on the Hitachi ECN3030F.

Size and Cost Advantages of the Hitachi Integrated ECN303x BLDC Solution

As the Figures show on pages 5, 6 & 7, a MicroController Discrete Design requires more peripheral components plus an additional low voltage supply (a 5v supply for the MicroController). The MicroController Discrete Design was excluded due to its increased Cost and PC Board area. The time to develop and debug MicroController firmware were additional Cost issues. MicroController cost is also driven by I/O pin count and the higher interrupt response times needed to execute tasking routines. A MicroController must adequately handle Motor Commutation in-addition-to ALL control functions. Given the 10,000 rpm BLDC design spec, Commutation response alone meant 2KHz (~500 msec) interrupts. The Hitachi ECN3030F Integrated BLDC Motor Controller was selected because it integrates the following set of needed BLDC functions:

- 3-Phase BLDC motor commutation logic
- Directly drive MOSFET / IGBT gates at up to 2kWatts
- Six MOSFET / IGBT (TOP and BOTTOM Arm) gate drivers
- Charge Pump Bias Voltage for 3 TOP Arm gates at up to 185VDC
- Analog input, PWM Speed Control (0 to 100% Duty Cycle controlled)
- A rotation direction control logic input
- A Tachometer (Duty Cycle) output
- Under Voltage (protection) ShutDown
- Over Current protection ("Sense") input.

The Hitachi ECN3030F is packaged in a small, 28-pin SOIC {FP-28DJ (JEDEC)}.

A single ECN3030F BLDC controller costs less than (3) TOP/BOTTOM Arm Gate Driver chips normally required by any MicroController Discrete Design. That is, a 5VDC MicroController can not drive the needed 12V steps into the (50VDC) TOP Arm Gates or, BOTTOM Arm Gates to switch the MOSFET motor bridge ON and OFF.

The Hitachi ECN3030F Integrated BLDC Motor Control solution greatly simplified the design task. It involved the following design steps:

- Select Power Switches to drive the BLDC motor coils
- Select 6 Gate Drive resistors for the 6 (On-Chip) Gate Drive outputs
- Choose a low voltage (VCC) supply design
- Select the Over Current Limit components
- Choose an Over Temperature protection circuit
- Select a frequency for the (On-Chip) PWM oscillator
- Select a pulse width for the (On-Chip) Tachometer output
- Select capacitors / diodes for the (On-Chip) Charge Pump (TOP Arm Bias)
- Select the Hall Sensor pull-up resistors
- Select resistors / capacitors for the I/O circuits
- Select a layout / packaging method for the controller board

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Selecting the Power Devices:

The Siliconix SI9945AEY (Dual MOSFET) was chosen for its small size, performance ratings and thermal characteristics. These MOSFETs are designed to carry the heat from the junction through the leads of the device. This is a good fit for the heat sink provided by the controller packaging method discussed below. Hitachi Tech Tips are very helpful during this selection process, especially numbers 11 through 14.

Selecting the Gate Drive Resistors:

These choices must match the Gate Charge requirements of your Power MOSFETs, the Hitachi ECN3030F Charge Pump capabilities and the need to control switching speeds and thermal losses within the Power MOSFETs. Refer to Hitachi Tech Tips, especially number 16, for many technical details. This design uses 100 Ohm resistors to drive the TOP Arm Gates and 220 Ohm resistors to drive the BOTTOM Arm Gates. This simple way to drive the 6 Power MOSFET Gate inputs allows the shortest (most direct) connections and thereby greatly enhances the robustness (reliability) of the resulting BLDC controller: clearly a major advantage of integrated, BLDC control ICs.

It is not universally agreed that low value isolation resistors are needed for the motor winding connections (MU, MV, MW). However, this design uses 5.1 Ohm resistors.

Low Voltage Power Supply Design:

A series transistor regulator (Q4) was chosen. This method offers simplicity and low component count. The Hitachi ECN3030F Integrated BLDC solution permits the choice of a less sophisticated power supply since it also provides an on-chip voltage regulator (VCB) to bias Hall Sensors and other external system circuit blocks. PC Board space was more important than power conservation in this application.

Dropping resistors R25 and R26 can accommodate various input power sources from 18 to 50VDC. One Watt power resistors are adequate with the heat sink capability of the Thermalume board.

By contrast, the MicroController Discrete BLDC solution requires a 3rd voltage supply, i.e., a 5VDC supply to power the MicroController chip.

Over Current Protection Components

The Over Current protection (Sense) resistor was set to limit Peak current at 3.3 amps. This allows the BLDC motor to run at a 3 amp continuous current and protect the motor (and controller) from excessive, damaging current overloads (at 3.3 amps). The internal ECN3030F current limit threshold voltage at the RS input (pin 10, Vref) is set internally at 0.5 +/- 10%. Using available standard resistor values, the current sense resistor was set to 150 milli-Ohms. This sets the actual current limit to 3.33 Amps +/- the tolerance of the resistor and the threshold voltage. Use caution to select correct power level for these sense resistors since they will be dissipating just over 1.5 Watts.

A Schottky diode (D3) was added to prevent excursions below ground at this pin. A small ceramic capacitor (C10) provides added transient protection. The ECN3030F has on-chip filtering and, the added capacitor may not be necessary. If noise is a problem, a series resistor can be placed between the current sense resistor and the RS pin to further isolate the sense circuit.

This type of Over Current protection is of the cycle-by-cycle type: see Tech Tips 18.

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Over Temperature Protection Circuit:

An NTC thermistor and LM393 comparator were chosen to provide a settable thermal trip point. R11 and R12 form a divider that sets the trip voltage. R13 and TR1 form a second divider with a center voltage dependent on thermistor temp. The thermistor was placed near the Power MOSFETs on the Thermalume board.

Q1 and Q2 add a logic crowbar, buffered by Q3, to force a Power-OFF Reset (ShutDown) after Over Temp detection. This Power-OFF Reset signals a condition outside acceptable operating conditions that's normally resolved by human intervention. This crowbar function is provided in the Microcontroller software of the Discrete solution.

PWM Clock Frequency Selection:

Components R4 and C4 set the PWM Clock Frequency. A frequency was chosen sufficiently high to avoid audible noise, but sufficiently low to minimize switching losses in the Power MOSFETs and to avoid electromagnetic interference. A value of 20 KHz was chosen for this design. The application specification for the Hitachi ECN3030F provides the necessary details to make this selection:

$$\text{Clock (in Hz)} = 0.494 / (R4 \times C4)$$

Where: R4 is in Ohms
C4 is in Farads

Tachometer Output Pulse Width Selection:

The ECN3030F application specs provide the details for this resistor and capacitor (R5, C5). For this design, a 4-microsecond pulse width was chosen. At the maximum motor speed of 10,000 rpm the tachometer output pulses at a 2.0kHz rate (500 msec period) based on a 12-Slot, 3-Phase BLDC motor with a 4-Pole rotor.

Charge Pump Components:

The ECN3030F application specifications provide the necessary details to choose these components. This design uses 1N4148 diodes and 1 mf tantalum capacitors.

Hall Effect Pull -Up Resistor Selection:

These resistors are chosen to be compatible with the Hall Effect Devices used, and the ECN3030F interface requirements. The application specification for the ECN3030F should be followed for this selection.

Input/Output Components:

These components were chosen to isolate and protect the controller, and to provide a reasonably simple interface to this Integrated BLDC controller. Cost and board space were major factors in this I/O approach.

Size and Cost Advantages of the Hitachi Integrated ECN303x BLDC Solution

BILL OF MATERIALS

MicroController Discrete BLDC Solution

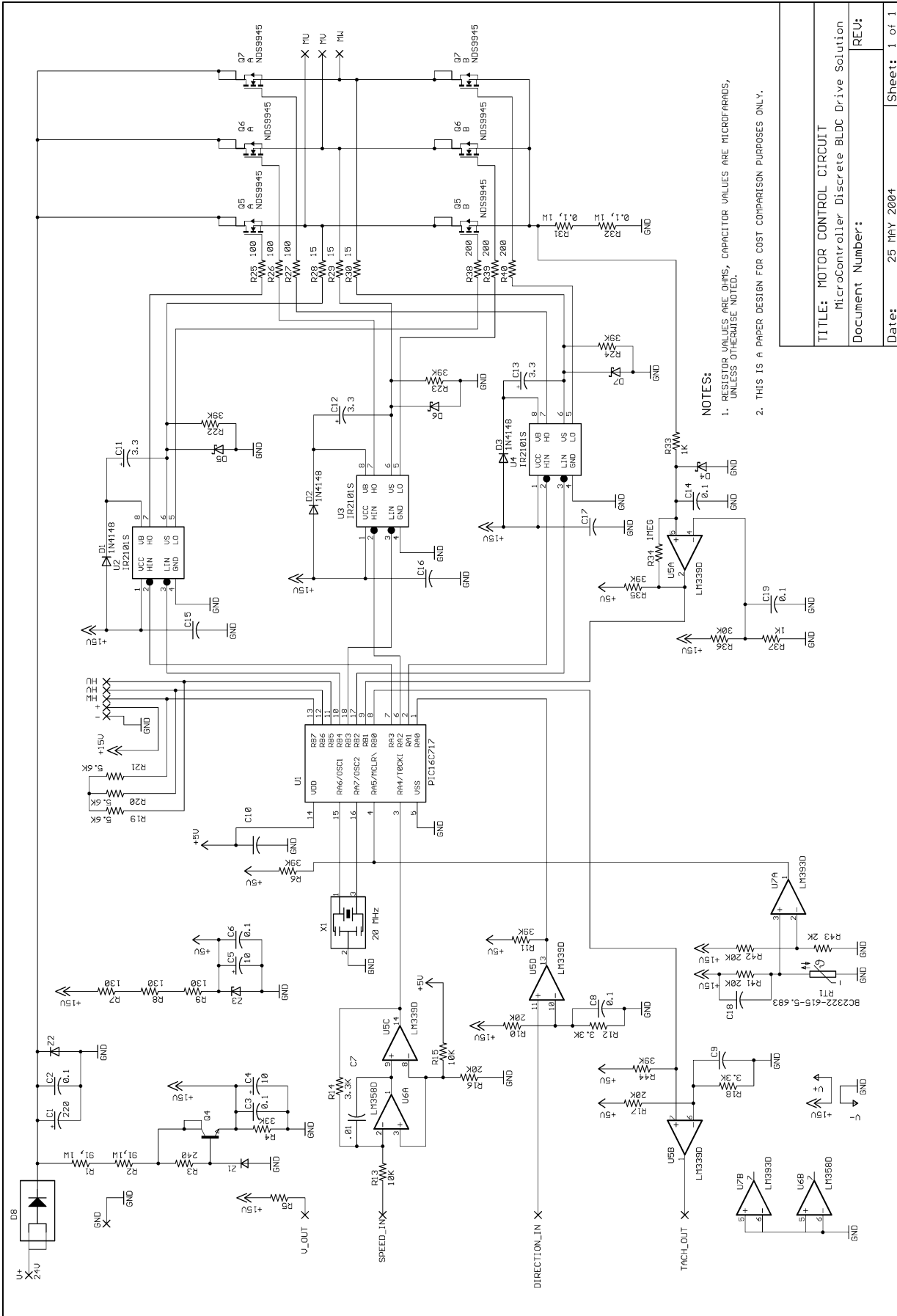
CIRCUIT							
DESIGNATOR	DESCRIPTION	RATING	PACKAGE	MANUFACTURER	PRICE	QTY	EXTENDED
C1	CAP,AL EL	50V	SMT(G)	PANASONIC		1	
C2,3,C6-10,C14-19	CAP,CERAMIC,X7R	50V	C0805			13	
C4	CAP,AL EL(FK)	25V	SMT(B)	PANASONIC		1	
C5	CAP,AL EL(FK)	10V	SMT(B)	PANASONIC		1	
C11,12,13	CAP,AL EL(FC)	35V	SMT(B)	PANASONIC		3	
D1,2,3	DIODE	1N4148WS	SOD323			3	
D4,5,6,7	DIODE,SCHOTTKY	30V	SOD323			4	
D8	DIODE,SCHOTTKY	60V,45A	MBRM560	DIODE INC		1	
Q1,Q2,Q3	NOT USED						
Q4	TRANSISTOR,NPN	60V,1W	SOT223	ZETEX		1	
Q5,6,7	MOSFET,DUAL	60V,3.7A	SO8	SILICONIX		3	
R1,2,31,32	RESISTOR,THICK FILM		5%	R2512		4	
R3-30,R33-47	RESISTOR,THICK FILM		5%	R0805		43	
RT1	THERMISTOR			R0805		1	
U1	PIC16C717	PIC16C717I/SO	SO18W			1	
U2,3,4	IC,FET DRIVER	IR2101S	SO8			3	
U5	IC,COMPARATOR	LM339D	SO14			1	
U6	IC,OP AMP	LM358D	SO8			1	
U7	IC,COMPARATOR	LM393	SO8			1	
X1	RESONATOR,CERAMIC	20 MHz	SMD			1	
Z1	DIODE,ZENER	18V	SOD323			1	
Z2	TVS,60V,400W	DIODE-SMB	SMB			1	
Z3	DIODE,ZENER	5 V	SOD323			1	
CIRCUIT BOARD	FR4,4LAYER,4.8SQ.IN.					1	
CIRCUIT BOARD	THERMALUME,4.0SQ.IN.			MIDWEST CIRCUITS		1	
						TOTAL	\$15.922

Hitachi ECN3030F Integrated BLDC Drive Solution

CIRCUIT BOARD							
DESIGNATOR	DESCRIPTION	RATING	PACKAGE	MANUFACTURER	PRICE	QTY	EXTENDED
C1-6,C9-11,C13,C18	CAP,CERAMIC,X7R	50V	C0805			11	
C7,8	CAP,TE	35V	Y(A)	PANASONIC		2	
C12	CAP,AL EL	25V	SMT(B)	PANASONIC		1	
C14	CAP,AL EL	50V	SMT(G)	PANASONIC		1	
D1,2	DIODE,1N4148WS		SOD323			2	
D3	DIODE,SCHOTTKY	30V	SOD323			1	
D4	DIODE,SCHOTTKY	60V,45A	MBRM560	DIODES INC		1	
Q1	TRANSISTOR,PNP		SOT23			1	
Q2,Q3	TRANSISTOR,NPN		SOT23			2	
Q4	TRANSISTOR,NPN	60V,1W	SOT223	ZETEX		1	
Q5,6,7	MOSFET,DUAL	60V,3.7A	SO8	SILICONIX		3	
R1-24,R29-33	RESISTOR,THICK FILM		5%	R0805		29	
R25 THRU R28	RESISTOR,THICK FILM		5%	R2512		4	
RT1	THERMISTOR,NTC			R0805		1	
U1	IC,MOTOR CONTROL	ECN3030F	28SOIC	HITACHI		1	
U2	IC,COMPARATOR		8SOIC			1	
Z1	DIODE,ZENER	15V,500mW	SOD323			1	
Z2	TVS	60V,400W	SMB			1	
CIRCUIT BOARD	FR4,4LAYER,4.0SQ.IN.					1	
CIRCUIT BOARD	THERMALUME,4.0SQ.IN.			MIDWEST CIRCUITS		1	
						TOTAL	\$12.129

Savings = \$3.793

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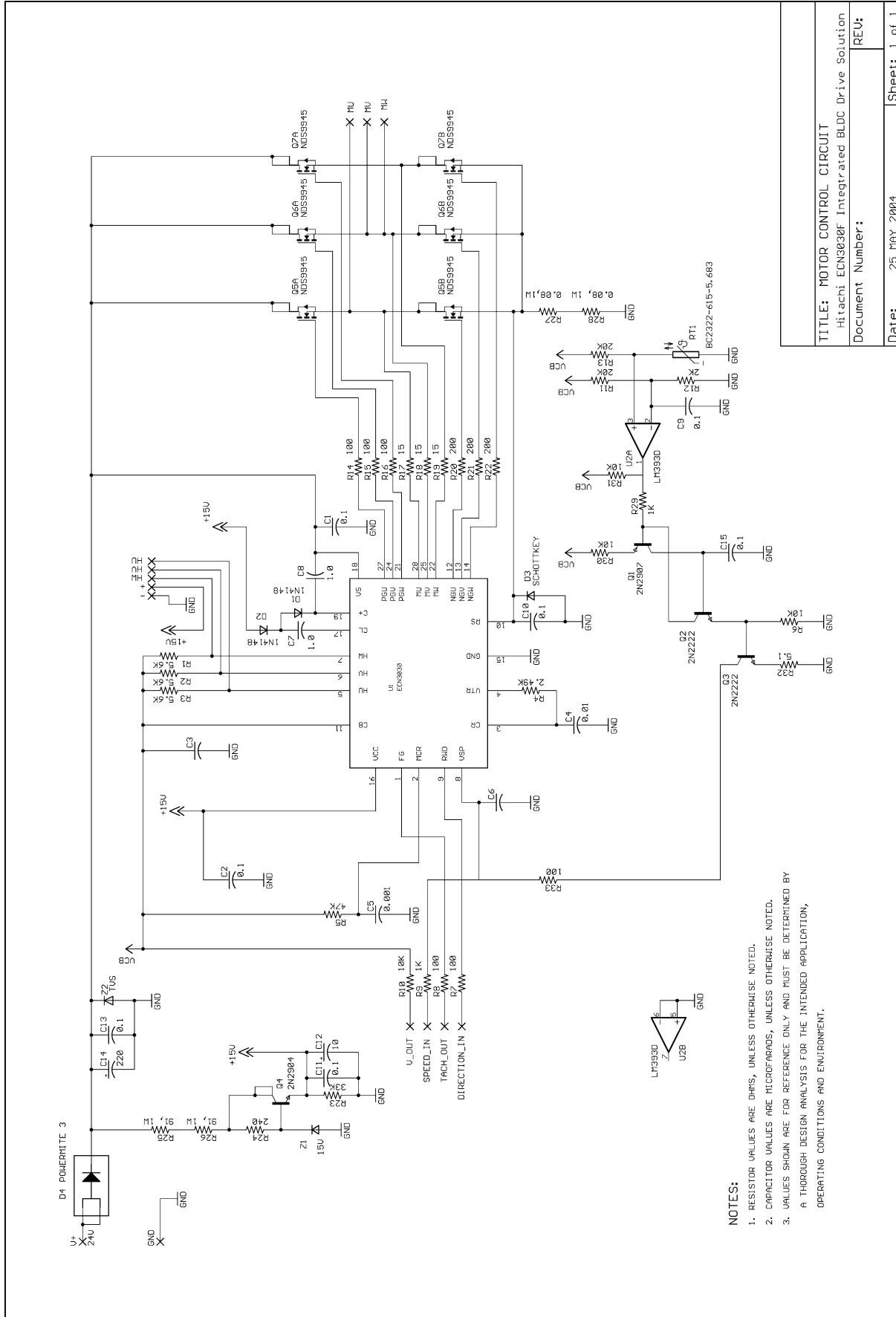


NOTES:
 1. RESISTOR VALUES ARE OHMS, CAPACITOR VALUES ARE MICROFARADS, UNLESS OTHERWISE NOTED.
 2. THIS IS A PAPER DESIGN FOR COST COMPARISON PURPOSES ONLY.

TITLE: MOTOR CONTROL CIRCUIT MicroController Discrete BLDC Drive Solution	
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MOTOR CONTROL CIRCUIT: MicroController Discrete BLDC Drive Solution

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TITLE: MOTOR CONTROL CIRCUIT Hitachi ECN3030F Integrated BLDC Drive Solution	
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Date: 25 May 2004	Sheet: 1 of 1

MOTOR CONTROL CIRCUIT: Hitachi 3030F Integrated BLDC Drive Solution

Size and Cost Advantages of the Hitachi Integrated ECN303x BLDC Solution

The Tachometer Output (FG) was provided directly to the user via a 10K-Ohm isolation resistor. The user has the option to filter this output to obtain a dc voltage proportional to motor speed or, to count pulses.

The reference voltage from the ECN3030F was provided as an output through an isolation resistor (R10). This can be used as a voltage source to the user for speed control. It can be the input voltage to a potentiometer with the wiper going to the Speed Command Input VSP (Pin 8) via isolation resistor R9 (1K Ohm). If another voltage source is to be used for speed control care must be taken to not exceed voltage VB of the ECN3030F unless current is limited to less than 1 milliamp. Please refer to the ECN3030F application specification for these details. To operate the motor in an "ON/OFF" configuration only, tie the V_SPEED lead to the V_OUT lead.

The Direction Control RWD (Pin 9) is brought out through a small value isolation resistor. For this controller design, this pin is to be used to set the direction of rotation only when the motor is not running. If you wish to implement speed reversal during operation of the motor please refer to other applicable Hitachi Tech Tips including Number 9, "Single Chip Safe Direction Reversal and Tach Pulse."

Packaging Method:

Size and cost were at a premium for this design. To utilize the small SO-8 dual MOSFET power devices a circuit board with integrated metal heatsink (IMH) would be needed. Conventional IMH boards were cost prohibitive for this application. A product called "Thermalume" from Midwest Circuits, Ferndale Michigan, is available at approximately the same cost as plain FR4 material. It has excellent thermal and transient thermal conductivity from the copper pads to the Aluminum heat sink.

The total solution was a two-board solution. Each board was approximately the same size at 3.25 square inches. One was a conventional 1/16 FR-4, 4 layer. All high power-dissipating components were placed on a second board of Thermalume material. The two were connected via a stacking connector so that maximum height did not exceed one inch.

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For additional information and/or support, contact Marty Kehoe, (914) 524-6656

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