ECN3035F/3036F

HITACHI

3-Phase Brushless DC (BLDC) Motor Drive IC

The ECN3035F/3036F integrates BLDC Control Logic with a 3-Phase BLDC Motor Bridge Driver that directly drives IGBT/MOSFET Motor Bridges powered by Motor Supply Voltages from 50 to 380VDC at reduced motor current losses. The TOP Arm of each phase is DC-biased by an internal Charge Pump that works down to zero speed. On-Chip Brushless (electronic) commutation logic is fully integrated with analog OSC/PWM functions that permit an analog (VSP) voltage to control motor speed.

Description

- Integrated 3-Phase BLDC Motor Bridge Driver IC operating from 50 to 380VDC
- Integrated Charge Pump - Constant TOP Arm bias independent of motor speed
- Integrated 3-Phase Brushless (Electronic) commutation via external Hall ICs
- All TOP and BOTTOM Arm gate drive outputs are Push/Pull
- BOTTOM Arms switch at up to 20kHz via an on-chip OSC/PWM
- Latch-Up free monolithic IC built with a high voltage Dielectric Isolation (DI) process

Functions

- Simple Variable Speed Control via a single (VSP) analog input
- PWM Speed Control without requiring a MicroController
- Tachometer - Generates a (RPM/60)**x**(P/2)**x**3 Hertz speed signal (FG)
- On-Chip 7.5VDC regulator (CB) with a guaranteed External Min load (25mA)
- Over-Current protection is set by an external Sense Resistor (RS)
- Under-Voltage protection for TOP and BOTTOM Arms

Block Diagram

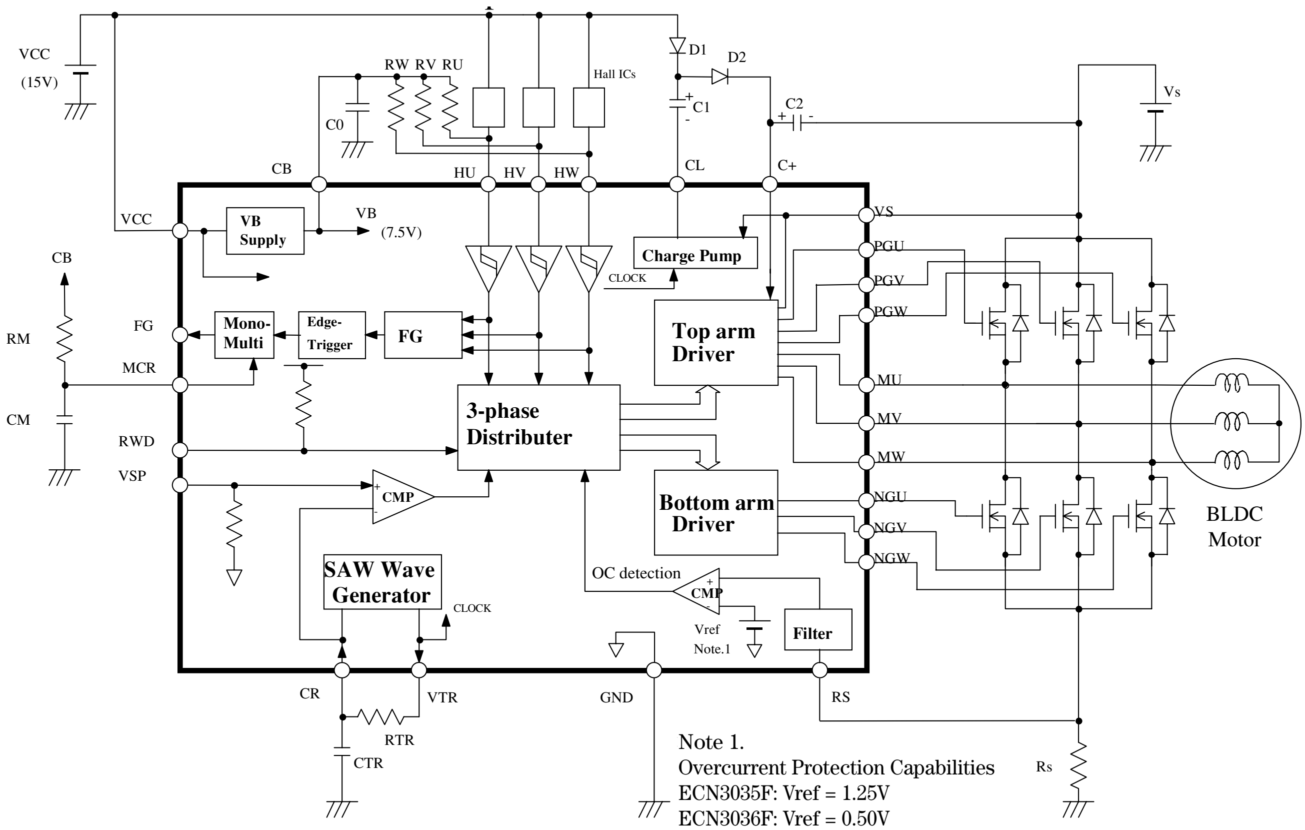
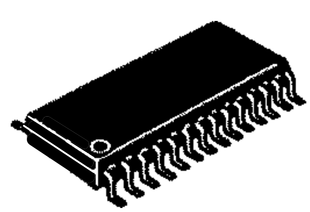


Figure 1 Block Diagram

Part Names and Packaging

FP-28DJ(JEDEC)



ECN3035F / ECN3036F
(Package Type:FP-28DJ (JEDEC)

The ECN3035F and ECN3036F are differentiated by their Overcurrent protection capabilities.

1. General

(1) Type ECN3035F, ECN3036F
(2) Application 3-Phase BLDC Motor
(3) Structure Monolithic IC
(4) Package FP-28DJ (JEDEC)

2. Maximum Allowable Ratings

No.	Items	Symbols	Terminal	Ratings	Unit	Condition
1	Output Device Breakdown Voltage	VSM	VS MU, MV, MW	500	V	
2	Supply Voltage	VCC	VCC	18	V	
3	Input Voltage	VIN	VSP, RS, RWD HU, HV, HW	-0.5 ~ VB+0.5	V	
4	Operating Junction Temperature	Tjop		-20 ~ +125	°C	Note 1
5	Storage Temperature	Tstg		-40 ~ +150	°C	

Note 1: Thermal resistance Rj-a = 100 °C/W (When ICs are installed on a printed circuit board)

General Note: To determine appropriate deratings for these absolute maximum ratings, please refer to the “Precautions of Use” on our website.

Motor current transients (during Start & Speed-Up) may require a Soft Start circuit to limit initial currents. See: Motor Control Tech Tips, Volume 1, Issue 1 (Feb’02), “Motor Soft-Start” on our website.

Additionally, during Under and Over Voltage conditions, there may be other System Logic necessary for safe operation. See Motor Control Tech Tips, Volume 1, Issue 7 (Aug ‘02), “BLDC Power Bus Under/Over Voltage Protection” on our website.

3. Recommended Operating Conditions

No.	Items	Symbols	Terminal	MIN	TYP	MAX	Unit	Condition
1	Supply Voltage	VS	VS	50	325	380	V	Within allowable rating at Tjop
2		VCC	VCC	13.5	15	16.5	V	

4. Electrical characteristics

Suffix: T = Top arm, B = Bottom arm
Suffix *; U, V, W Phases
Unless otherwise specified, VCC =15V, VS = 325V Ta = 25°C

No.	Items	Symbols	Terminal	MIN	TYP	MAX	Unit	Condition
1	Standby Current	IS	VS	-	1.0	2.5	mA	VSP < VSAWL
2		ICC	VCC	-	3.0	6.0	mA	HU = L
3	Output Source Current	IO+T	PG*	30	50	100	mA	20V between C+ and PG*
4		IO+B	NG*	100	200	300	mA	10V between VCC and NG*
5	Output Sink Current	IO-T	PG*	100	200	300	mA	10V between PG* and M*
6		IO-B	NG*	100	200	300	mA	10V between NG* and GND
7	High Level Output Voltage	VOHT	C+, PG*	-	-	0.2	V	Between C+ and PG* Voltage; IO = 0A
8		VOHB	VCC, NG*	-	-	0.2	V	Between VCC and NG* Voltage; IO = 0A
9	Low Level Output Voltage	VOLT	PG*, M*	-	-	0.2	V	Between PG* and M* Voltage; IO = 0A
10		VOLB	NG*, GND	-	-	0.2	V	Between NG* and GND Voltage; IO = 0A
11	Output Resistance at VTR terminal	RVTR	VTR	-	200	400	Ω	IVTR = 1mA
12	Amplitude Level of SAW wave	VSAWH	CR	4.9	5.4	6.1	V	Note 2
13		VSAWL	CR	1.7	2.1	2.5	V	
14	Amplitude of SAW wave	VSAWW	CR	2.8	3.3	3.8	V	Note 5
15	Reference Voltage for Over Current detection	Vref	RS	1.10	1.25	1.35	V	Only for ECN3035F
				0.45	0.50	0.55	V	Only for ECN3036F
16	Input Voltage	VIH	HU,HV,HW	3.5	-	-	V	
17		VIL	RWD	-	-	1.5	V	
18	Input Current	IIH	VSP	-	-	50	uA	VSP = 5.0V Note 1 Pull Down Resistance
19		IIL	HU,HV,HW RWD	-100	-	-	uA	HU,HV,HW,RWD=0V Note 1 Pull Up Resistance
20	VB Output Voltage	VB	CB	6.8	7.5	8.2	V	IB = 0mA
21	VB Output Current	IB	CB	25	-	-	mA	delta VB ≤ 0.2V
22	Output Resistance at FG terminal	RFG	FG	-	250	400	Ω	Note 3 IFG = 1mA
23	Reference Voltage for FG pulse	Vref2	MCR	VB×2/3 ×0.95	VB×2/3	VB×2/3 ×1.05	V	Note 4
24	Charge Pump Voltage	VCP	C+, VS	13.3	14.5	-	V	At Stand-By Note 6

Note 1. The pull up resistance and the pull down resistance are typically 200kΩ.
Note 2. See Note 2 in item 6 for determining the frequency of the SAW wave.
Note 3. The equivalent circuit at FG terminal is shown in Fig. 2.
Note 4. See Note 3 in item 6 for determining the FG output pulse width.
Note 5. The amplitude of SAW (VSAWW) is determined by the following equation: VSAWW = VSAWH - VSAWL (V)
Note 6. The charge pump voltage (VCP) is determined by the voltage between C+ and VS.

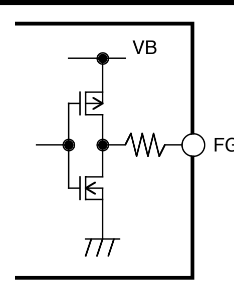


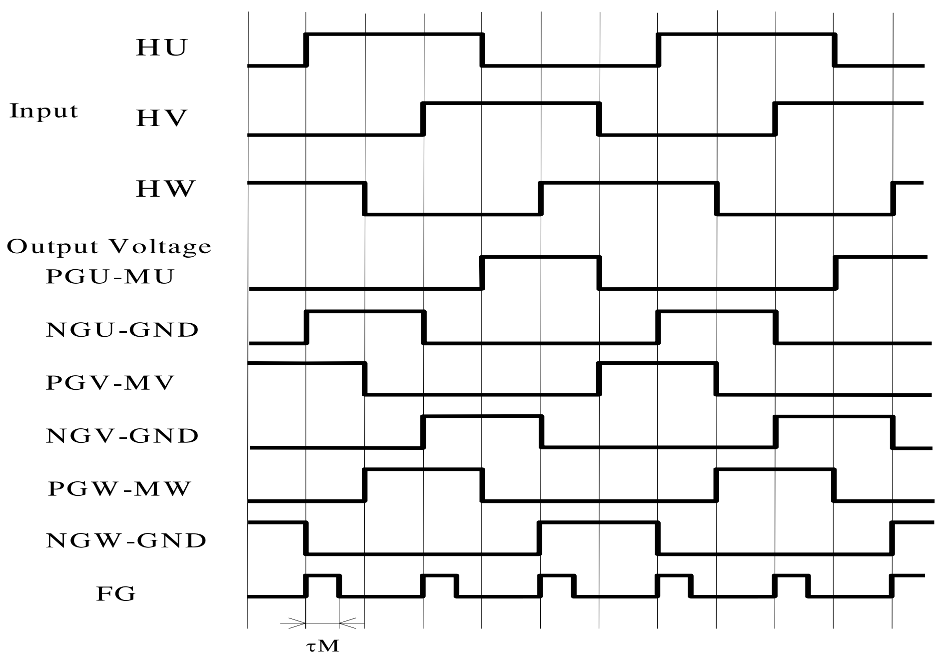
Figure 2 Equivalent circuit around FG

5. Function

5.1 Truth Table

Input				U Phase		V Phase		W Phase	
RWD	HU	HV	HW	Top	Bottom	Top	Bottom	Top	Bottom
H	H	L	H	L	H	H	L	L	L
H	H	L	L	L	H	L	L	H	L
H	H	H	L	L	L	L	H	H	L
H	L	H	L	H	L	L	H	L	L
H	L	H	H	H	L	L	L	L	H
H	L	L	H	L	L	H	L	L	H
L	H	H	L	L	L	H	L	L	H
L	H	L	L	H	L	L	L	L	H
L	H	L	H	H	L	L	H	L	L
L	L	L	H	L	L	L	H	H	L
L	L	H	H	L	H	L	L	H	L
L	L	H	L	L	H	H	L	L	L
-	L	L	L	L	L	L	L	L	L
-	H	H	H	L	L	L	L	L	L

5.2 Timing chart (RWD = H)



Note 1. TOP Arm: Output voltage between PG* and M*
BOTTOM Arm: Output voltage between NG* and GND.

Note 2. It is possible to change the motor rotation direction by signalling direction on the RWD pin. To properly process a Reverse Command see: Motor Control Tech Tips, Volume 1, Issue 6 (July '02), "BLDC Safe Direction Reversal" on our website. Also item 5.7

5.3 PWM Operation

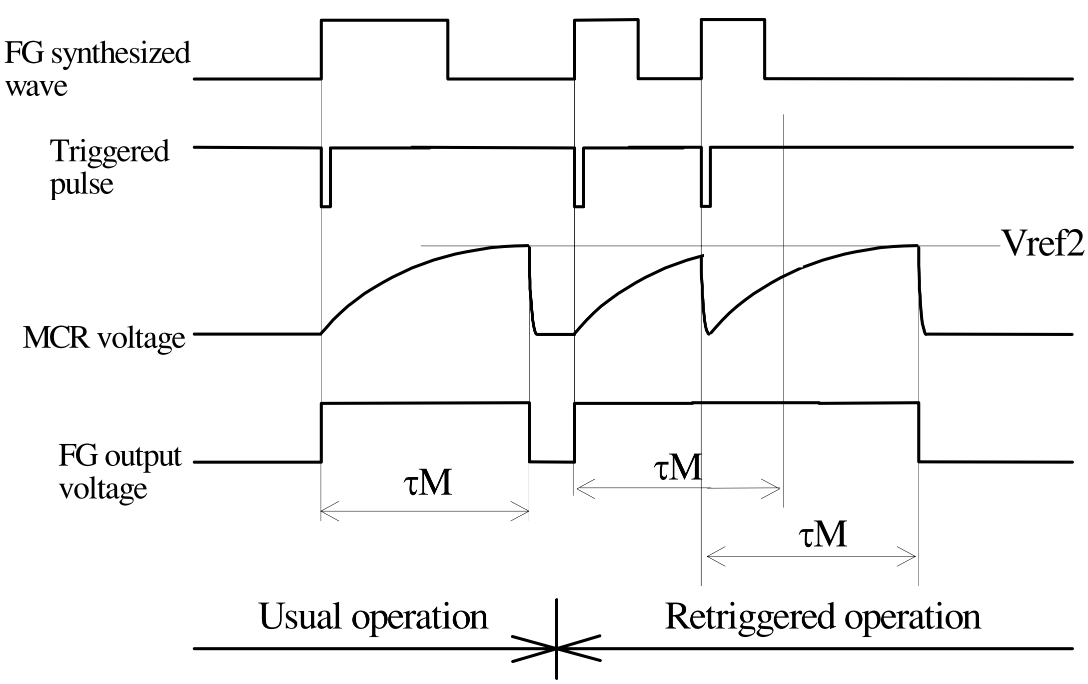
The PWM signal is generated by comparing the input voltage at the VSP pin with an internal SAW wave voltage (also available at the CR pin). The Duty Cycle of the resulting PWM signal is linearly controlled by VSP pin voltage: from a Min of VSAWL to the Max of VSAWH. That is, when VSP is below VSAWL, the PWM duty cycle is at the Minimum value of 0%. When VSP is above VSAWH, the PWM Duty Cycle is at the Maximum value of 100%. ECN3035/6 can operate in 2 Quadrants (only) by chopping the BOTTOM Arms via this PWM Duty Cycle during the appropriate commutation times (phases). Thus, PWM Duty Cycle controls motor torque and speed.

5.4 Over Current Limiting Operation

Over Current is monitored via the voltage drop across an external sense resistor RS. Whenever the input voltage at the RS pin exceeds the internal Reference voltage (Vref, see line #15 in Table 4), all BOTTOM Arms are Turned-OFF. Following an Over Current event, reset is automatically attempted during each OSC period. Note, the on-chip OSC signal is available at the VTR pin. If the Over Current function is not used, the RS pin must be connected to the GL pin using less than 100Ω.

5.5 FG operation

A one-shot pulse is output at the FG pin which is synchronized to the rising edge of each Hall sensor signal input at HU, HV, HW. The pulse width (tM) is set by the R and C at the MCR pin. This circuit has a retrigger feature which keeps the FG signal high whenever a trigger is input during the high time of any FG output. The frequency (in Hertz) of this motor shaft Tachometer signal is equal to (RPM/60)x(P/2)x3.



5.6 VCC Under Voltage Detection Operation
When VCC drops below Low Voltage Shut Down (LVSD), all Arm operations and the Charge Pump are forced to Stop. The LVSD detection voltage is typically 11.5V with, a hysterisis of 0.5V.

5.7 Reverse the Rotating Direction of the Motor
The rotating direction of the motor can be changed by inputing an “H” or “L” signal at the RWD pin. However, do NOT change this signal while the motor is at speed as that may cause a short through of the output Switch Device. However, it is OK to change the RWD logic input signal if the VSP analog input voltage is below VSAWL(1.7V typ). For a more complete discussion of motor speed reversal see: Motor Control Tech Tips, Volume 1, Issue 6 (July’02), “BLDC Safe Direction Reversal” on our website.

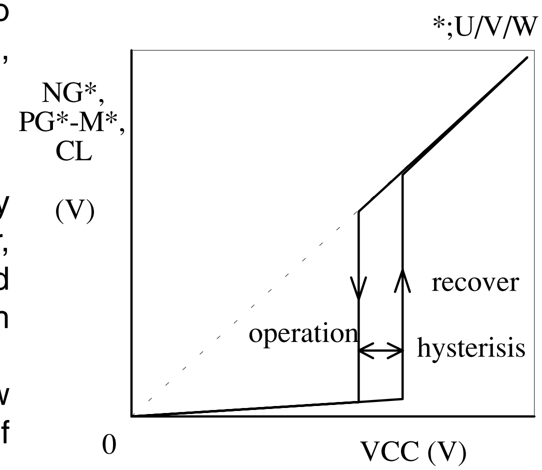


Figure 3.
VCC Under Voltage
Protection Hysteresis

6. Standard Application

6.1 External Parts

Component	Recommended Value	Usage	Remark
C0	At least 0.22 μF	Filters the Internal Power Supply (VB).	Stress voltage is VB
C1, C2	1.0 μF ± 20%	Holds the Charge Pump Voltage	Stress voltage is VCC
D1, D2	Hitachi DFG1C6(glass mold) or equivalent parts	Charge Pump	600V / 1.0A trr ≤ 100ns
RS	Note 1	Sets Over Current Limit	
CTR	1800 pF ± 5%	Scales the PWM Frequency	Note 2
RTR	22 kΩ ± 5%		
RU,RV,RW	5.6 kΩ ± 5%	Pull up resistance	
CM	More than 1000pF	These set the Output Pulse width at FG pin	Note 3
RM	More than 10 kΩ		

Note 1. The start up current is limited by the following equation.
IO = Vref / Rs (A)

Note 2. The PWM frequency is approximately determined by the following equation. At the recommended Value of CR, the IC has an equivalent error of about 10%.
fPWM = -1 / (2CxRxLn[1-(3.5/5.5)]); Where, Ln is the Natural Logarithm
= 0.494 / (CxR) (in Hz)

Note 3. The FG output pulse width is determined approximately by the following equation.
tM ≥ 10μs
tM = -(CMxRMxLn[1-VBx(2/3/VB)]) = 1.1xCMxRM (seconds)

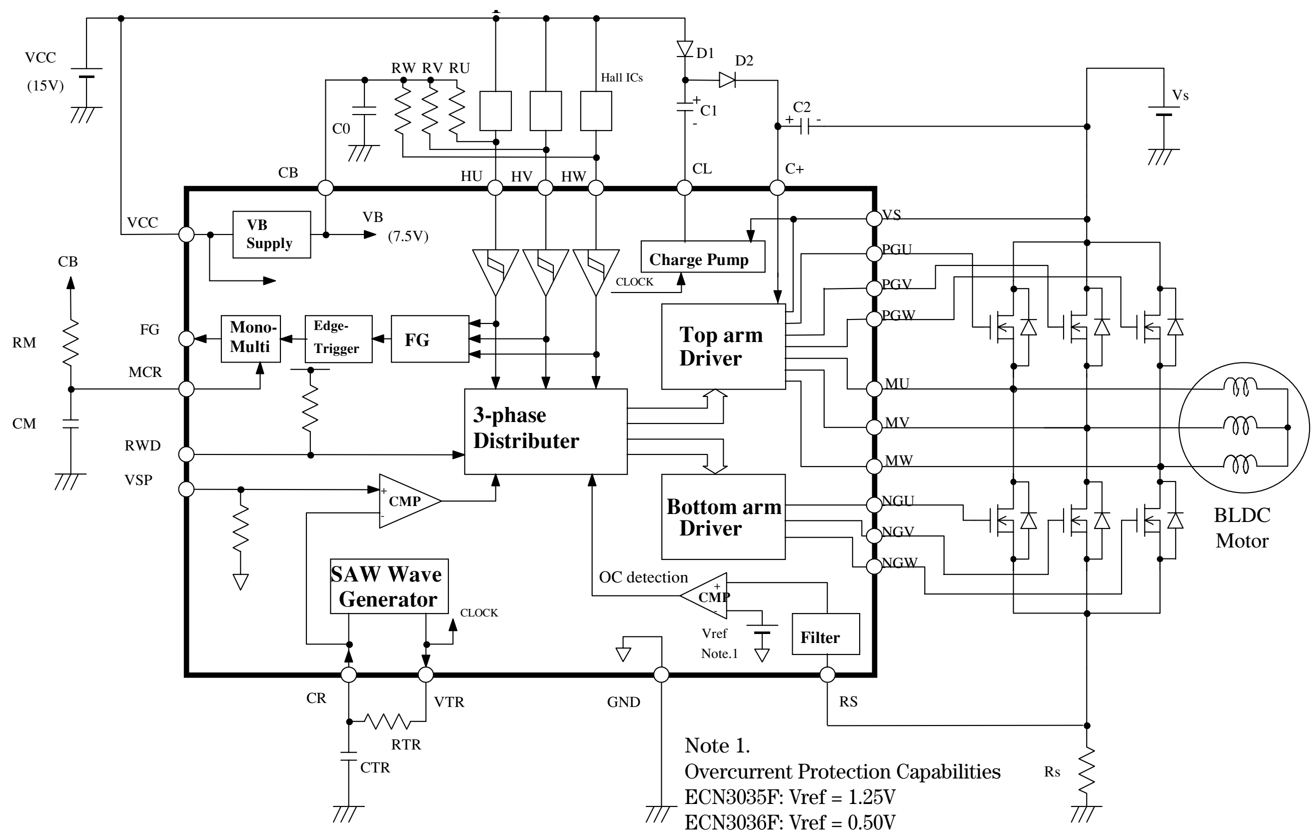
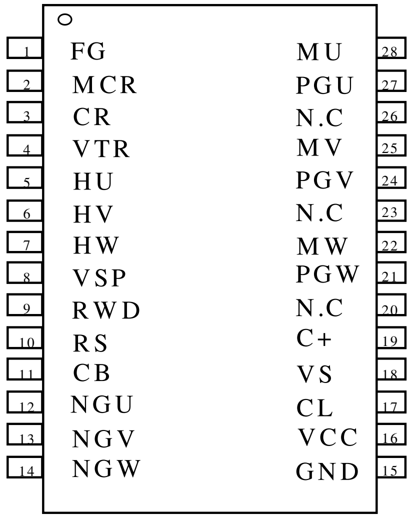


Figure 4. Block Diagram with External Parts

6.2 Supply Voltage Sequence

The order for turning ON power supplies should be (1)Vcc, (2)VS then (3)VSP. The order for turning OFF should be (1)VSP, (2)VS then (3)Vcc. A useful System aid is to employ a Soft-Start circuit. See: Motor Control Tech Tips, Volume 1, Issue 1 (Feb’02), “Motor Soft-Start” on our website.

7. Pinout



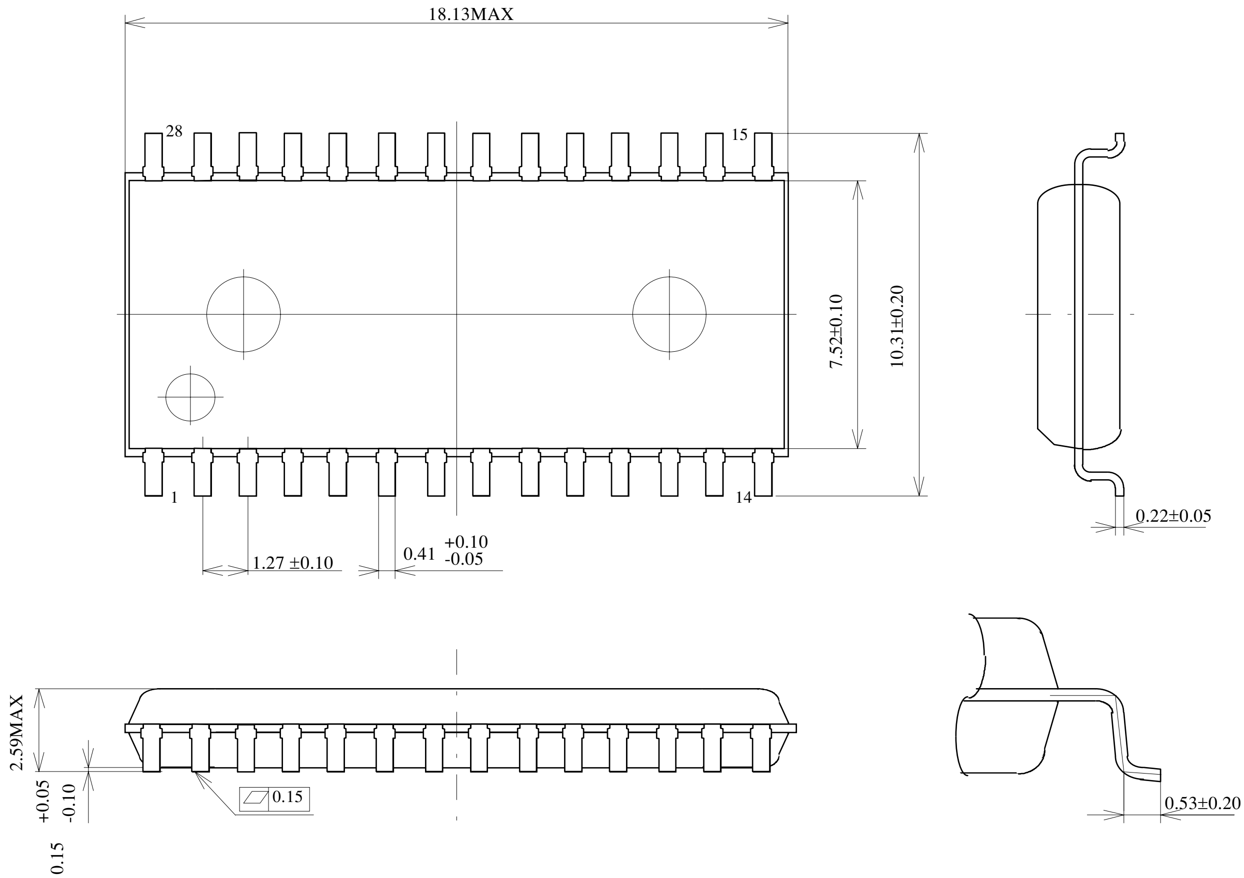
(Marking side)

Figure 5. Pin Connections

8. Pin Definitions

Pin #	Symbol	Pin Definition
1	FG	Tachometer output signal whose frequency is (RPM/60)**x**(P/2)**x**3 Hertz
2	MCR	Tachometer output Pulse Width Set by these R/C values ~ (1.1) **x** R **x** C
3	CR	Connected Resistance/Capacitance Generate the PWM clock frequency
4	VTR	Connect resistance to generate the PWM clock frequency
5	HU	Input signal from the Hall IC of phase U
6	HV	Input signal from the Hall IC of phase V
7	HW	Input signal from the Hall IC of phase W
8	VSP	Input analog voltage that varies the PWM duty cycle from 0% to 100%
9	RWD	Logic Input to Reverse Direction of the BLDC Motor (See Tech Tip #6)
10	RS	RS voltage detect input for the on-chip Over Current limit detection
11	CB	Internally regulated (VB) 7.5V Output Pin (External 25mA guarantee)
12	NGU	BOTTOM Arm Gate Drive for Phase U
13	NGV	BOTTOM Arm Gate Drive for Phase V
14	NGW	BOTTOM Arm Gate Drive for Phase W
15	GND	Analog ground
16	VCC	Analog Power Supply from External supply (15VDC +/- 10%)
17	CL	Part of Charge Pump circuit (Bias supply for ALL TOP Arm drive circuits)
18	VS	BLDC Motor Power Bus (50VDC Min through 380VDC Max)
19	C+	Part of Charge Pump circuit (Bias supply for ALL TOP Arm drive circuits)
20	NC	No Connection
21	PGW	TOP Arm Gate Drive for Phase W
22	MW	TOP Arm Return (“ground”) Reference Rail for Phase W
23	NC	No Connection
24	PGV	TOP Arm Gate Drive for Phase V
25	MV	TOP Arm Return (“ground”) Reference Rail for Phase V
26	NC	No Connection
27	PGU	TOP Arm Gate Drive for Phase U
28	MU	TOP Arm Return (“ground”) Reference Rail for Phase U

9. Package Dimensions



10. Quality Assurance

10.1 Appearance and dimension
ANSI Z1.4-1993 General inspection levels II AQL 1.0%
10.2 Electrical characteristics
ANSI Z1.4-1993 General inspection levels II AQL 0.65%

11. Do's and Don'ts

11.1 To protect this chip from Electrical Static Discharge (ESD), the ECN 3035F/3036F should be handled in accordance with normal industry standard procedures for protection against damage due to ESD. For a more detailed discussion of this area, please refer to the web "Precautions of Use" Section 5.

11.2 Depending on local industry/market regulations, conformal coating may be required for the following pin-to-pin spacings: 16-17, 17-18, 19-21, 22-23, 25-27.

11.3 Protective function against short circuit (ex. load short, line-to-ground short or TOP/BOTTOM Arm shorts) is not built into this IC. External protection may be needed to prevent IC breakdown under these potential application conditions.

11.4 Hitachi high voltage ICs are manufactured to meet standard industrial grade reliability specifications. In cases where extremely high reliability is required (such as nuclear power control, aerospace and aviation, traffic equipment, life-support-related medical equipment, fuel control equipment and various kinds of safety equipment) system integrity must be achieved via fail-safe system design. Additionally, it is the responsibility of the designer to insure that any IC failure does not damage property or human life. Users should evaluate and consider employing the following design precautions:

a) Sufficient derating of the specifications should be utilized to minimize the possibility of failures based on the maximum ratings, operating temperature and environmental conditions.

b) Design redundancy should be applied so that application performance will be maintained even in a case of IC failure.

c) The system design should implement fail-safe design techniques to protect property and human life even where incorrect system operation is experienced.

12. Precautions for Safe Use

If semiconductor devices are handled in an inappropriate manner, failure may result. For this reason, be sure to read "Precautions of Use" on our website before use.

CAUTION

(1). Regardless of changes in external conditions during use, "absolute maximum ratings" should never be exceeded in designing electronic circuits that employ semiconductors.
Furthermore, in the case of pulse use, "safe operating area (SOA)" precautions should be observed.

(2). Semiconductor devices may experience failures due to accident or unexpected surge voltages. Accordingly, adopt safe design features and practices, such as redundancy or prevention of erroneous action, to avoid extensive damage in the event of failure.

(3). In cases where extremely high reliability is required (such as use in nuclear power control, aerospace and aviation, traffic equipment, life-support related medical equipment, fuel control equipment and various kinds of safety equipment), safety should be ensured by using semiconductor devices that feature assured safety or by means of user's fail-safe precautions or other arrangement. Or consult Hitachi's sales department staff.

(If a semiconductor device fails, there may be cases in which the semiconductor device, wiring or wiring pattern will emit smoke or cause a fire or in which the semiconductor device will burst.)

13. Notices

1. This publication contains the specifications, characteristics (in figures and tables), dimensions and handling notes concerning power semiconductor products (hereinafter called "products" to aid in the selection of suitable products.

2. The specifications and dimensions, etc. stated in this publication are subject to change without prior notice to improve product's characteristics. Before ordering, purchasers are advised to contact Hitachi's sales department for the latest version of this publication and specifications.

3. In no event shall Hitachi be liable for any damage that may result from an accident or any other cause during operation of the user's units according to this publication. Hitachi asumes no responsibility for any intellectual property claims or any other problems that may result from applications of information, products or circuits described in this publication.

4. In no event shall Hitachi be liable for any failure in a semiconductor device or any secondary damage resulting from use at a value exceeding the absolute maximum rating.

5. No license is granted by this publication under any patents or other rights of any third party, Hitachi, Ltd. or Hitachi America, Ltd.

6. This publication may not be reproduced or duplicated, in any form, in whole or in part, without the expressed written permission of Hitachi, Ltd. or Hitachi America, Ltd.

7. The products (technologies) described in this publication are not to be provided to any party whose purpose in their application will hinder maintenance of international peace and safety nor are they to be applied to that purpose by their direct purchasers or any third party. When exporting these products (technologies), the necessary procedures are to be taken in accordance with related laws and regulations.