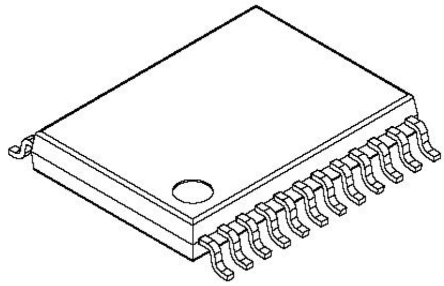
TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

TB9110FNG

Automotive Pre-driver IC for DC brushed motor with PWM control

TB9110FNG is the Automotive Pre-Driver IC for DC brushed motor.
This controls the speed of the motor by input PWM signal.
Built-in 5V power supply for internal logic, charge pump circuit for driving Nch MOSFET, AD converter , an oscillator circuit .
This is equipped with various features anomaly detection,
It is possible that anomaly detection conditions make the adjustment in the external devices.



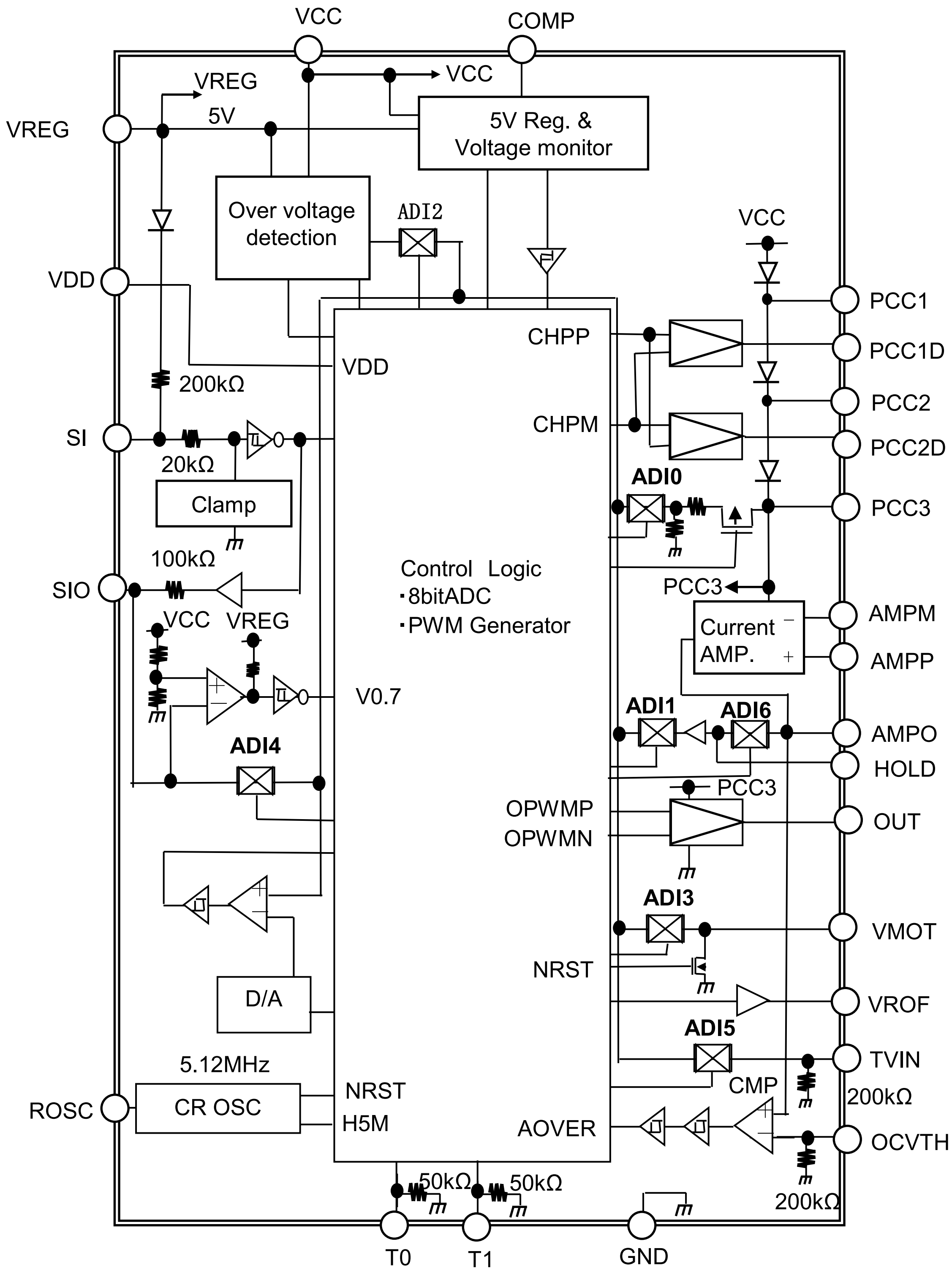
SSOP24-P-300-0.65A

Weight: 0.14 g (typ.)

Feature

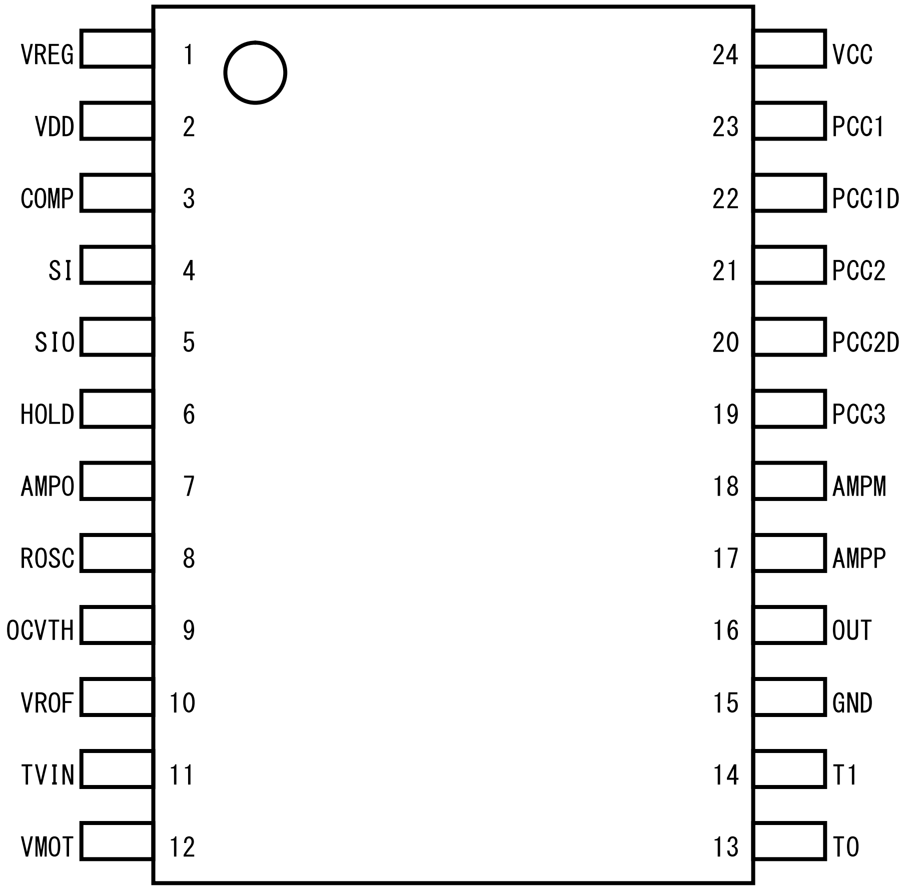
- DC brushed motor GATE-driver for Nch MOSFET.
- Motor Speed control by PWM Input.
- Built-in 5V Regulator.
- Built-in Charge pump circuit with external capacitor.
- Built-in 8bit AD converter.
- Built-in Oscillator (5.12MHz).
- Miscellaneous Abnormal Detection.
  (Over Current / Over Temperature / Over Voltage / Low Voltage / Motor Lock Detection)
- Operating supply voltage range: 7 to 18V
- Operating temperature range: -40 to105 °C
- Package: SSOP24pin (pin pitch:0.65 mm)
- The product(s) is/are compatible with RoHS regulations (EU directive 2011 / 65 / EU) as indicated, if any, on the packaging label ("[[G]]/RoHS COMPATIBLE", "[[G]]/RoHS [[Chemical symbol(s) of controlled substance(s)]]", "RoHS COMPATIBLE" or "RoHS COMPATIBLE, [[Chemical symbol(s) of controlled substance(s)]]>MCV").

Block Diagram



Note: Some of the functional blocks, circuits, or constants in the block diagram are omitted or simplified to clarify the descriptions of the relevant features.

Pin Assignment



Pin Description

Pin No.	Pin Name	Description	IN/OUT
1	VREG	5V Output Pin for internal logic. Built-in Clamp circuit.	IN/OUT
2	VDD	5V Input Pin for internal logic.	IN
3	COMP	Capacitor connection Pin for 5V phase compensation .(between COMP-VREG)	IN
4	SI	PWM Input Pin. Built-in Clamp circuit. Built-in pull-up resistor .(200kΩ)	IN
5	SIO	Output reverse PWM signal, External capacitor connecting terminal. Built-in series resistor. (100kΩ)	IN/OUT
6	HOLD	Capacitor connection Pin for sampling of voltage to detect Motor Lock.	IN/OUT
7	AMPO	Resister connection Pin to decide amp rate for Over Current Detection.	IN/OUT
8	ROSC	Resister connection Pin for internal CR OSC which set up OSC frequency. External resistance is 10 kΩ ± 0.5%.	IN/OUT
9	OCVTH	Resister connection Pin to set up Over Current detection value. Built-in pull-down resistor .(200kΩ)	IN
10	VROF	5V power supply for a voltage setup.	OUT
11	TVIN	Thermistor connection Pin for external temperature detection. Built-in pull-down resistor. (200kΩ)	IN
12	VMOT	Monitor Pin feed backed from motor drive voltage.	IN
13	T0	Test mode setting Pin. Built-in pull-down resister. (50kΩ) Please connect this Pin to GND in your application.	-
14	T1	Test mode setting Pin. Built-in pull-down resister. (50kΩ) Please connect this Pin to GND in your application.	-
15	GND	Connect to ground.	-
16	OUT	Pre-driver output Pin for motor. (Drive Nch MOSFET) Built-in100Ω series resistor only for the high side.	OUT
17	AMPP	Input Pin for Over Current Detection Amp + side.	IN
18	AMPM	Input Pin for Over Current Detection Amp - side.	IN
19	PCC3	Output Pin of Internal Charge Pump voltage.	IN/OUT
20	PCC2D	Resister and capacitor connection Pin for Internal Charge Pump.	OUT
21	PCC2	Resister and Capacitor connection Pin for Internal Charge Pump.	IN/OUT
22	PCC1D	Resister and Capacitor connection Pin for Internal Charge Pump.	OUT
23	PCC1	Resister and Capacitor connection Pin for Internal Charge Pump.	IN/OUT
24	VCC	Battery 12V Input Pin.	IN

Pin Description (cont.)

Note

Note1: Do not place VCC line near Pin 1 to 12. Should any of Pins 1 to 12 be shorted with VCC, internal CMOS logic circuit may have damage or be destroyed.

Note2: When Pin soldering is not enough and make open Pin, motor may not rotate, make unstable or abnormal detection may not be operated properly.

Note3: Adjacent Pin Short circuit may make damage or destroy the device.

Note4: Keep proper assembling and connection to avoid each device damage and destroy.

Note5: Any short circuit to the output of the 5V power supply may destroy the IC.

Functional Description

TB9110FNG is a Pre-Driver IC for Brushed DC Motor. TB9110FNG operate Motor according to PWM signal which is input from Pin “SI”. Output Pin ”OUT” release PWM signal to operate Motor which is the same Duty as the Input and that frequency is converted to 20kHz (Typ..) .
It is controlling so that input voltage (SIO terminal voltage) and motor voltage become the same.

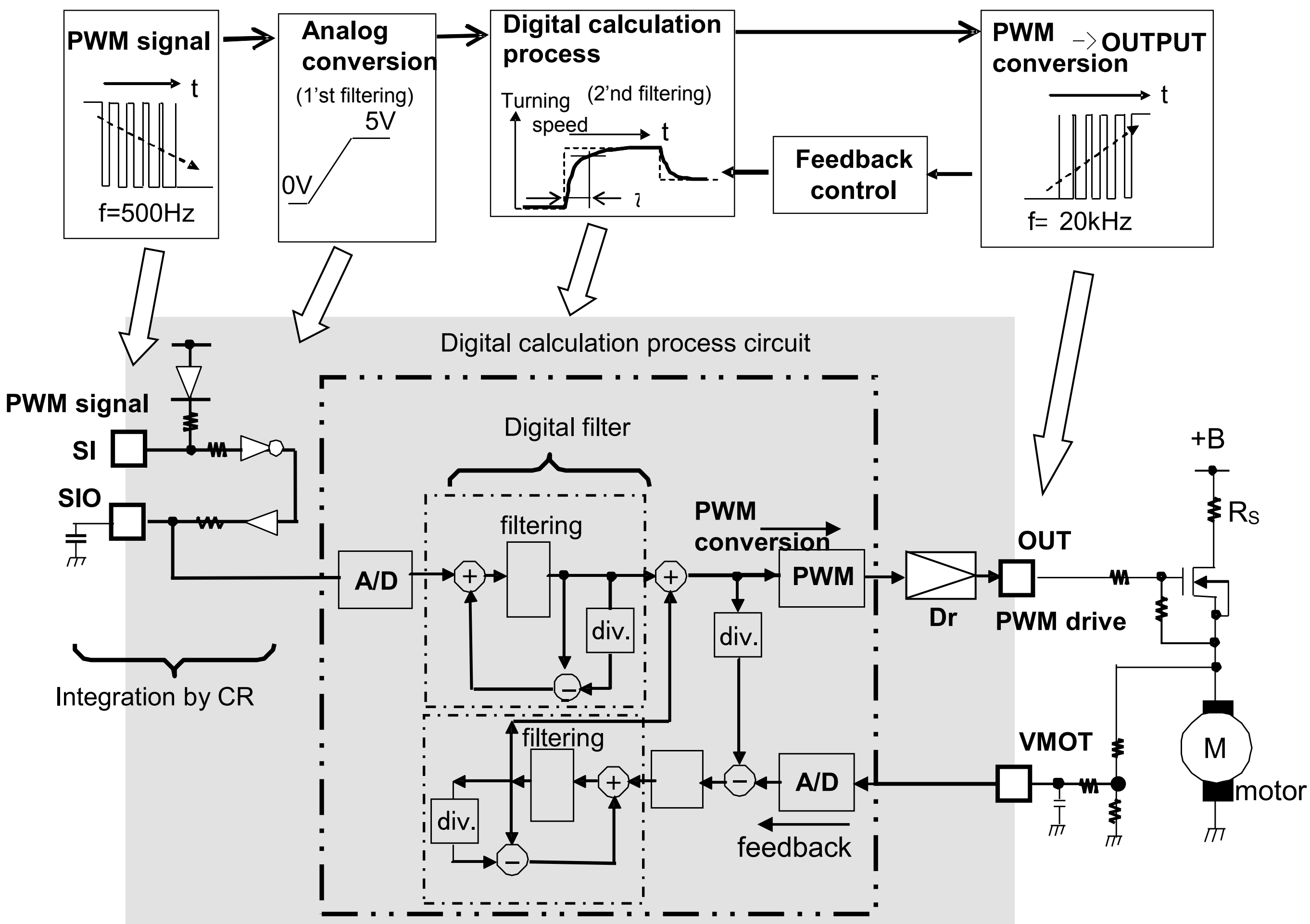
TB9110FNG has the Charge Pump for Pre-Driver and can directory drive External Nch MOSFET.

(1) Built-in Servomechanism for Motor controlling

TB9110FNG has the Servomechanism Motor control circuit. During Motor operation, TB9110FNG check the Motor voltage from Pin “VMOT”. TB9110FNG detect the Motor speed by this Input voltage. And compare this speed with input PWM from Pin “SI” to adjust Output PWM to Input automatically.

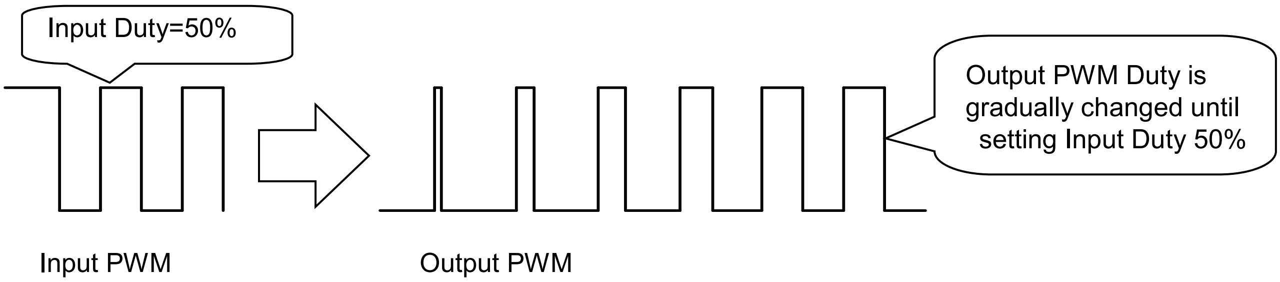
(2) EMI Noise reduction circuit for external PWM signal

TB9110FNG has a conversion circuit and an integration circuit to reduce EMI Noise for PWM signal. Slow frequency PWM, such as 500Hz is acceptable to use for Motor controlling.
TB9110FNG convert this slow Input PWM 500Hz (Typ.) to Hi speed frequency PWM, such as 20kHz with keeping original PWM Duty.



(3) Soft Start up for Motor control

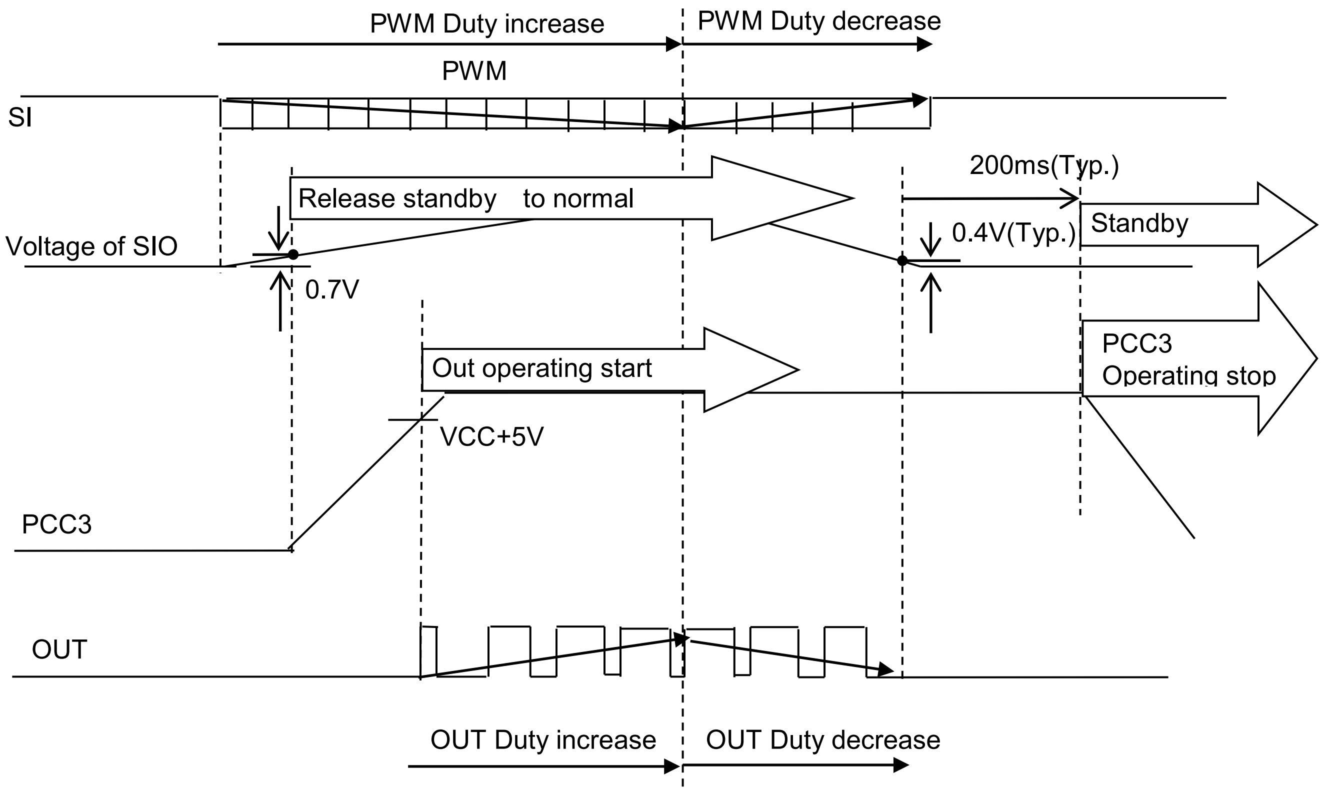
Also 2type of integration circuit are built-in. 1st integration is consisted by internal Resister and external
Capacitor which is connected by Pin " SIO ". 2nd integration circuit is consisted by logic.
By these 2 type of integration circuit, Motor speed is gradually up, and it accelerates to the speed set up by an input PWM signal. By this Soft Start up function, TB9110FNG can reduce Rush Current at Motor Start up.



(4) Standby operation

TB9110FNG receives a PWM input signal from SI terminal, and outputs the inversion signal to the SIO terminal. TB9110FNG checks the voltage at Pin "SIO" which is connected with external Capacitor to make integration circuit. In Standby, when this voltage rises to 0.7V (Typ.) (It means Input PWM Duty 14% of a low active PWM signal), TB9110FNG goes from standby to normal operation and the sequence of wake up is started, as follows.

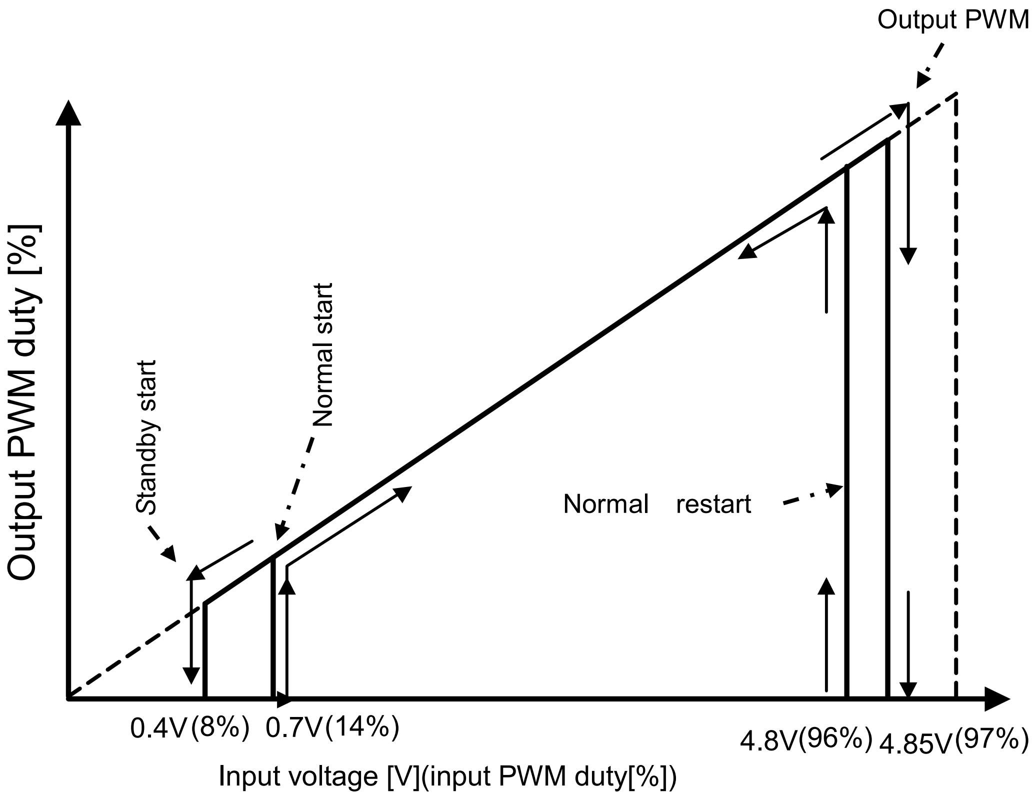
Internal CR OSC start
-> Charge Pump start and rise up output voltage
-> Logic and 5V operation circuit start
-> Release output PWM from Pin "OUT" according to the Input PWM Duty



(4) Standby operation (Cont.)

In normal operation, when the SIO voltage drop to under 0.4V (Typ.) (It means input PWM Duty 8%) during 200ms or more. TB9110FNG goes from Normal Operation to Standby.
(Standby: internal OSC stop, logic circuit is kept reset)
When SIO voltage is over 4.85V (Input PWM duty is over 97%), the Output PWM Duty become 0% and stop Motor.
When SIO voltage drop to under 4.8V (Input PWM drop to under 96%), the Output PWM Duty change to normal operation which is decided by Input PWM.

Relationship between input PWM Duty and Output PWM Duty



Note1: PWM input signal is low active.
Note2: PWM output signal is high active.

5) 5V Regulator and RESET circuit

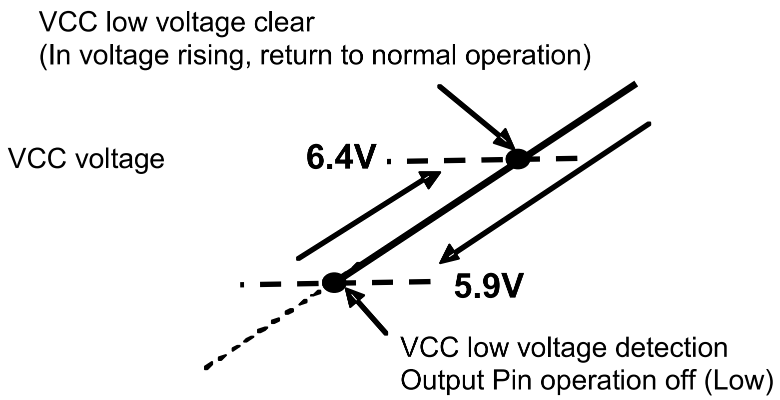
TB9110FNG has built-in 5V regulator which make 5V from VCC. It is used for internal circuit.
5V regulator circuit also work in Standby.
When this 5V Regulator output voltage dropped to under 4.45V (min.), internal logic circuit is reset.
When the voltage is rise to over 4.90V (max.), the circuit is restarted.

(6) Abnormal Diagnosis

TB9110FNG has miscellaneous Abnormal Detection circuit, such as for VCC Low Voltage Detection, VCC Over Voltage Detection, Over Temperature Detection and Over Current Detection.

(6)-1. VCC Low Voltage Detection

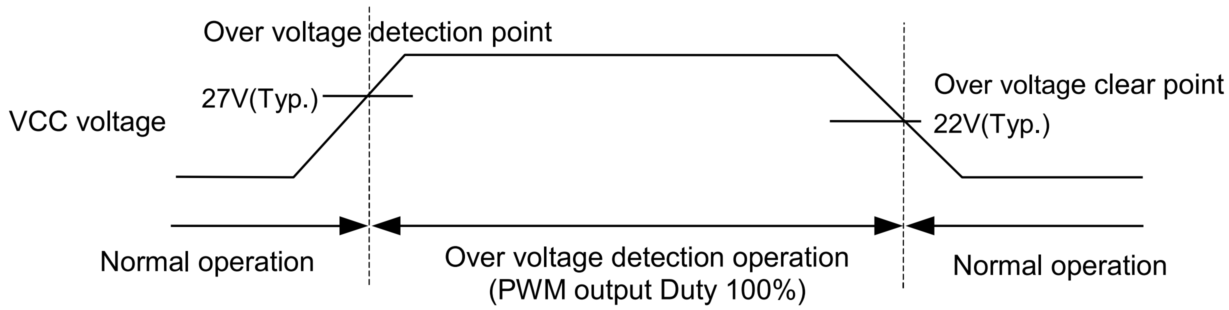
In normal operation, when VCC is dropped lower than 5.9V (Typ.), Pin “OUT” is OFF (Low). When VCC is risen over 6.4V (Typ.), TB9110FNG return to normal operation and Pin “OUT” release PWM signal which duty is set up by INPUT from “SI”.



(6)-2. VCC Over Voltage Detection

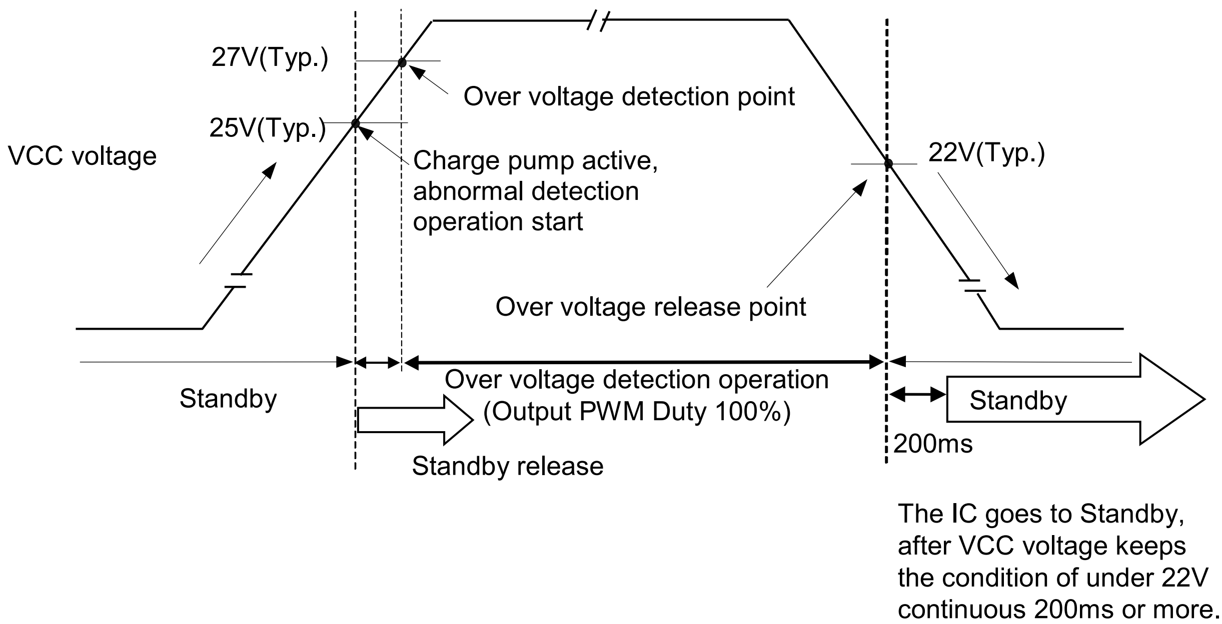
In normal operation, when VCC is over 27V (Typ.), PWM signal which is out from Pin “OUT” is changed Duty100%. When VCC is dropped lower than 22V (Typ.), PWM out return to normal duty which is set up by Input from Pin SI.

・VCC over voltage detection function when operating by PWM signal SI



In standby, when VCC rise to 25V (Typ.), internal Charge Pump circuit and each abnormal detection circuit are started the operation to prepare for Over Voltage Detection. Then, when VCC reach to 27V (Typ..), the Input PWM Duty which is input from Pin “SI” is ignored and TB9110FNG output 100% duty PWM signal from Pin “OUT”. Even in Over Voltage Detection, Over Current/Over Temperature can be detected. When VCC is dropped under 22V (Typ.) during 200ms (Typ.) or more, TB9110FNG returns to Standby. When this period is shorter than 200ms (Typ.), TB9110FNG keep Over Voltage Detection function (PWM Duty 100%)

Over voltage detection function in case operating standby



(6)-3. Over Temperature Detection

(6)-3-1. Thermal Shut Down of CHIP Over Temperature Detection

When the temperature of CHIP which is inside of the Package is over 165°C(Typ.), Input PWM is ignored and Output Pin “OUT”, “PCC1D” and “PCC2D” are off (Hi-Z).
Hi-Z：High-impedance

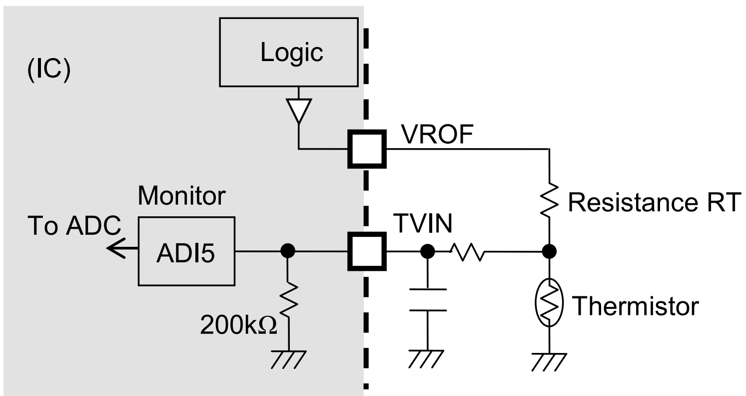
Note: The storage temperature range of the absolute maximum rating of this product is 150°C (Max.). Storage exceeding this temperature and the use not only cannot guarantee the normal performance of subsequent IC, but may cause emitting smoke and ignition. Please avoid the storage to which this temperature is exceeded in any cases, and use.
Moreover, although this product contains the above-mentioned over temperature detection function, this function should not keep the temperature of this IC to 165°C or less, and it is a function outside the temperature guarantee range, and please consider it as a strictly auxiliary function.
(In addition the shipment test is not done about this function.)

(6)-3-2. Over Temperature Detection for external circuit (ex. MOSFET)

With external thermistor which is connected on Pin ”TVIN”, Over Temperature of external circuit can be detected. Detection Temperature is determined from RT resistance and the characteristic of Thermistor spec.
The threshold of external over-temperature detection is calculated by the ratio of VREG to TVIN voltage (VTVIN). PIN ”TVIN” is built-in pull down resister 200kΩ.

When the temperature of external Thermistor exceeds over detection temperature, Detection continuously 1.7s or more, Pin “OUT” output OFF (Low) and stop Motor.
When the temperature of Thermistor decreases to lower than Over detection temperature, Detection Cancellation,
TB9110FNG immediately return to normal operation and Motor is controlled by input of Pin ”SI”.

Over Temperature Detection : $V_{TVIN} / 5 < 0.194$ (Typ.)
Over Temperature Detect Cancellation : $V_{TVIN} / 5 > 0.434$ (Typ.)
(V_{TVIN} is the Voltage at Pin “TVIN”)



(6)-4. Over Current Detection

TB9110FNG can detect Over Current of Motor by using built-in Current-AMP.
The following figure is a reference circuit to detect Motor Over Current. The Over current is detected
and is calculated by voltage conversion, as follows.

I LOAD = VB / (R3+ R_{motor}+R_{ON})

VB: Battery voltage, R3: shunt resistance, R_{motor} : Resistance of MOTOR
Ron : Nch-FET On resistance

Shunt Detection Voltage = ILOAD x R3

Detected voltage is amplified by internal Current-AMP. as follows.

The gain of amplifier : Gv = R5 / R4

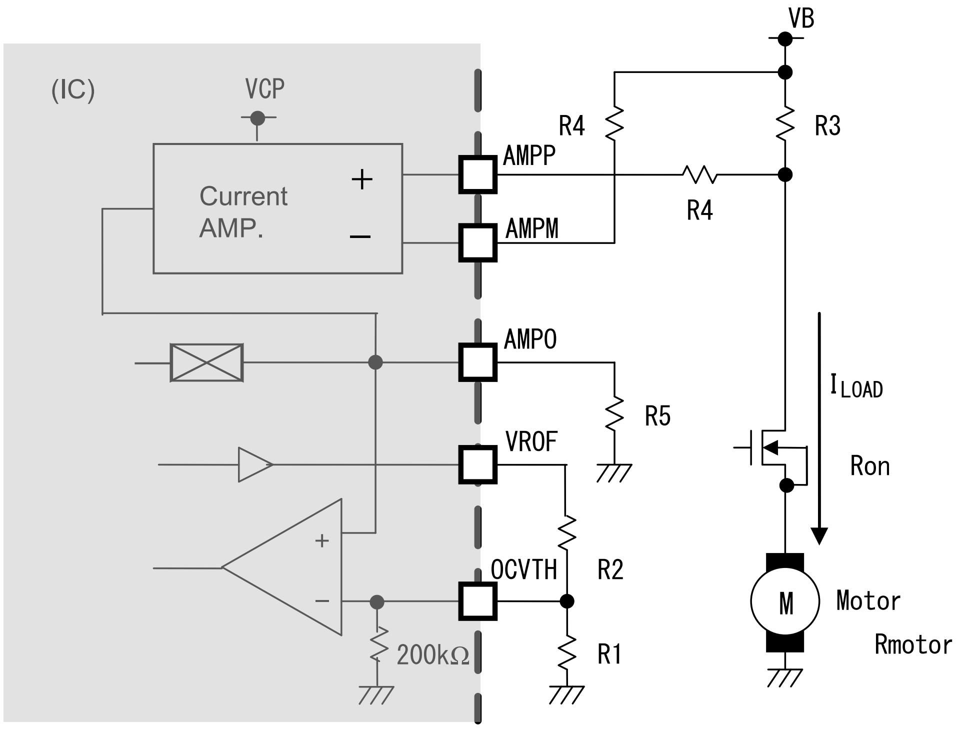
Detection Reference Voltage is as follows

VOCVTH = R1 / (R1+R2) x VROF

Detection Voltage (VAMPO)= ILOAD x R3 x (R5 / R4) = VB / (R3+R_{motor}+R_{on}) x R3 x (R5/R4)

And as a comparison,
Detection Reference Voltage (VOCVTH) = R1 / (R1+R2) x VROF

Notes: Since the pull down resistor of 200kΩ is built in the OCVTH terminal, please take into consideration in the case of a setup of threshold voltage.



(6)-4. Over Current Detection (cont.)

When Motor current is over the above setting detection, Pin “OUT” output is off “Low” and stop.

Motor during 100ms. After stopping Motor for 100ms, TB9110FNG return to normal operation and start to detect Motor Over Current again.

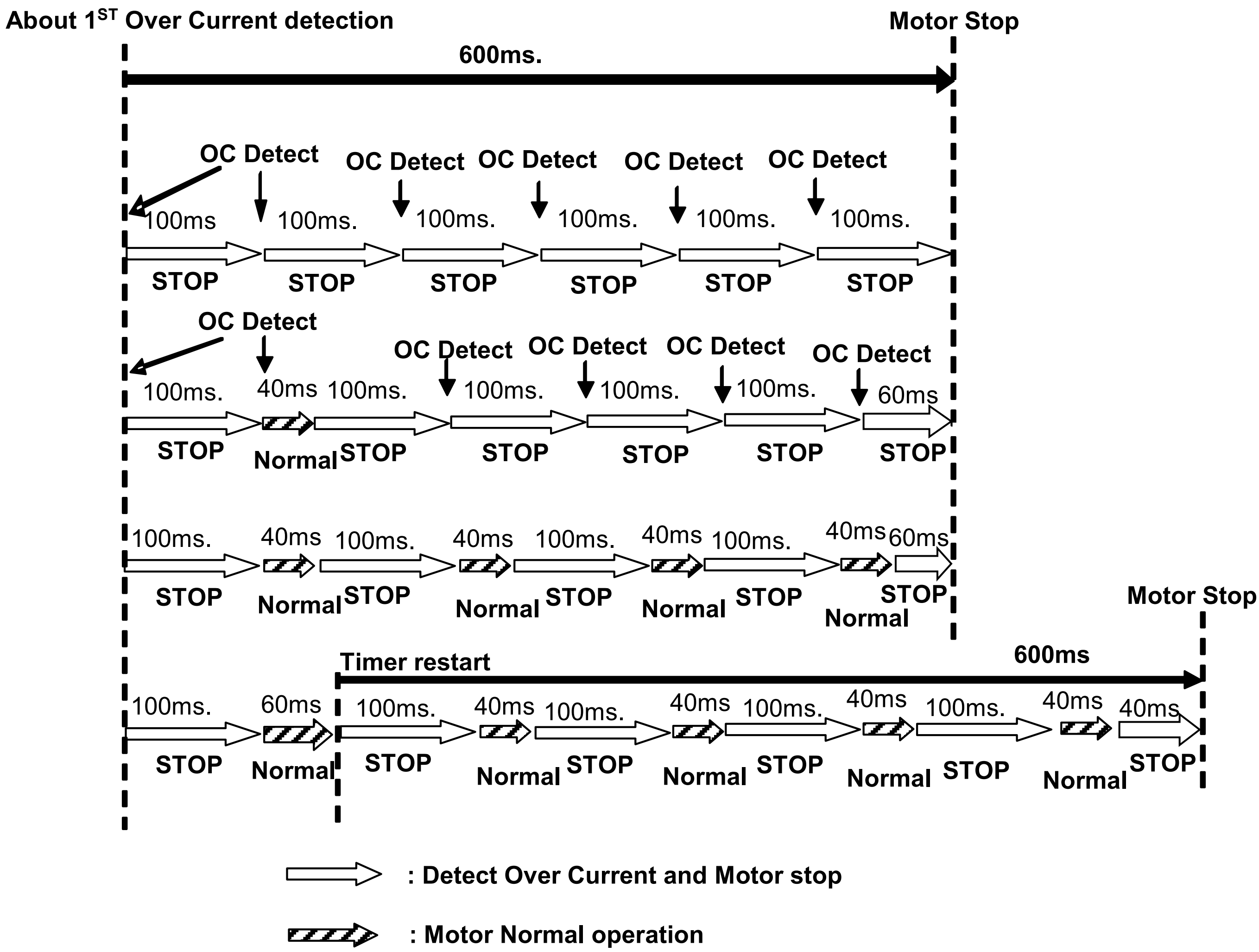
After return to normal operation, when Motor Over Current is detected again within 50ms.

TB9110FNG recognize as continuous Over Current status. When this continuous Over Current status is kept for 600ms TB9110FNG stop Motor, immediately (Motor Sleep).

To return to normal operation from Motor Sleep, TB9110FNG is needed to go into Standby,

or need to be Power On, again.

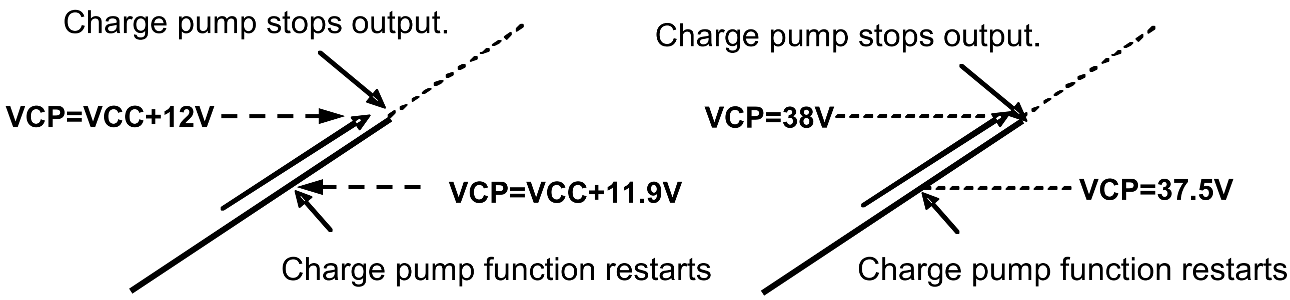
(Over Current detection)



(7) Charge Pump

TB9110FNG has Charge Pump which has Voltage monitor function to drive external Nch MOSFET. The Voltage monitor function is operated as follows.

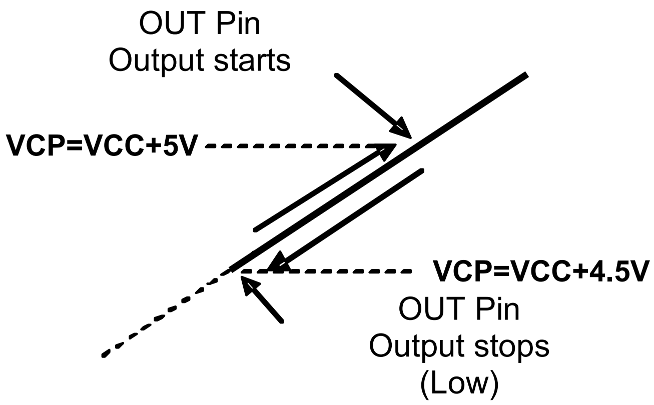
When output voltage of Charge Pump VCP (PCC3) is over VCC+12V (Typ.) or 38V (Typ.), Charge Pump stops the output. This is to protect the external MOSFET. Then, when the output voltage of Charge Pump (PCC3) is dropped lower than VCC+11.9V (Typ.) or 37.5V (Typ.), Charge Pump restart to output voltage.



VCP:Charge pump voltage

(Example) When VCC become 12V Charge Pump function stops at 24V and re-start by 23.9V.

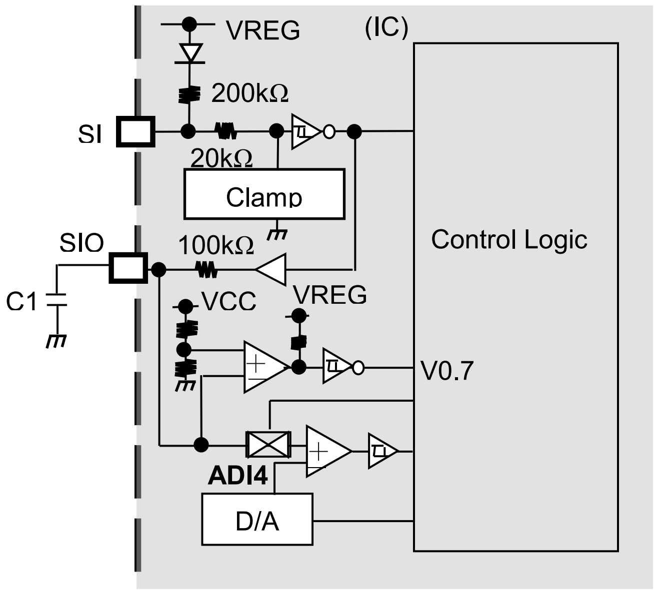
Also, pre-driver output for external MOSFET which is released from Pin “OUT” is controlled according to Charge Pump output voltage.
When output voltage of Charge Pump VCP (PCC3) is over VCC+5V, Pin “OUT” start to drive external Nch MOSFET. Then, when output voltage of Charge Pump (PCC3) is dropped lower than VCC+4.5V, Pin “OUT” is OFF (Low) and external Nch MOSFET is OFF.



Note: The VCP voltage is clamped so as not to exceed 38 V (Typ.). When the VCC potential exceeds 40 V, however, the VCP voltage exceeds 40 V. Be sure to suppress the VCC voltage under 40 V.

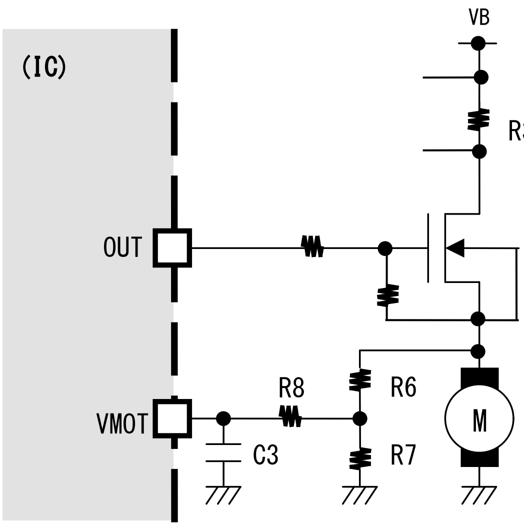
(8) Motor Pre- Driver

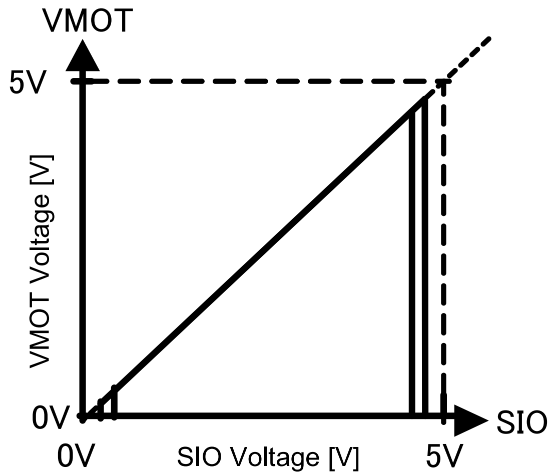
TB9110FNG outputs the PWM signal for driving external FET from Pin "OUT".
Duty of the PWM output signal is controlled by processing Duty of the input PWM signal inputted into Pin "SI", and the motor voltage Pin "VMOT" fed back by internal logic.
The PWM signal inputted from Pin "SI" is smoothed in the integration circuit which consists of the capacitor C1 connected to internal resistance of Pin "SIO" after being reversed with an internal inverter. The A/D translation of the smoothed value is carried out, and it is read into the logic circuit.



(8) Motor Pre- Driver (Cont.)

The PWM output duty (motor speed) is measured by measuring the terminal voltage VMOT divided from the motor voltage . The voltage which occurred at the motor voltage is divided by R7 and R6 resistor. And then it will be smoothed by the l integrating circuit consisting of both resistance R8 and capacitor C3, and put it VMOT Pin.

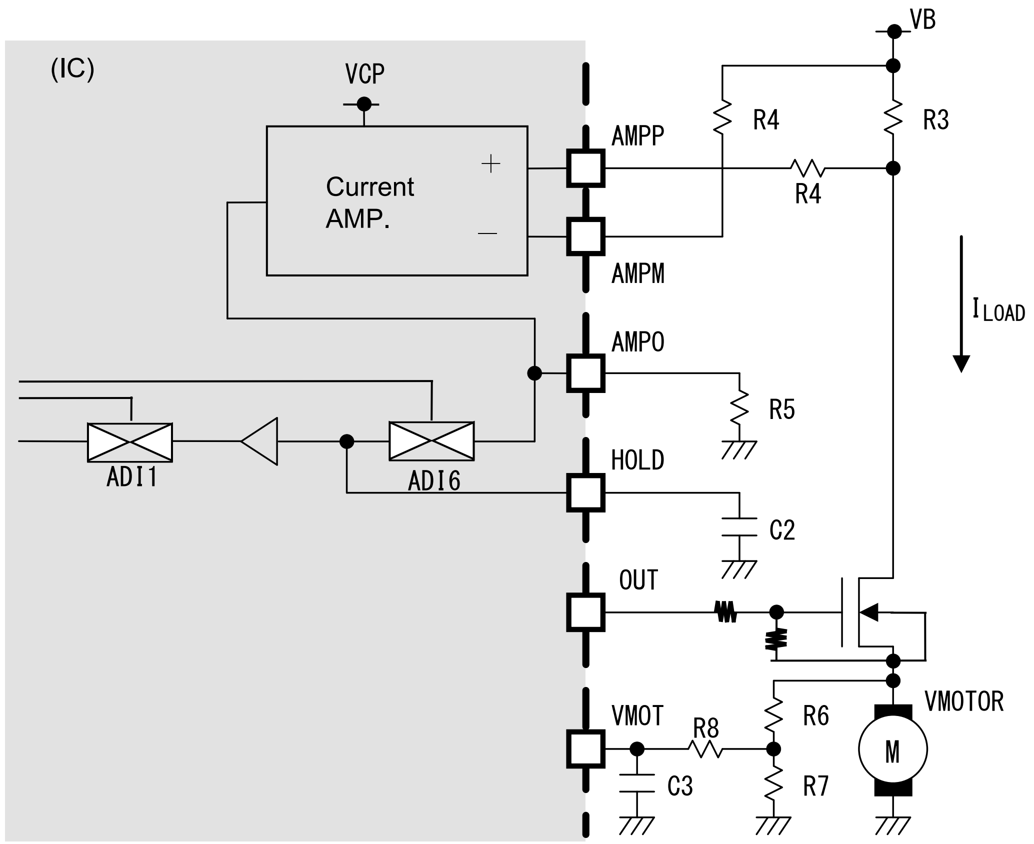




TB9110FNG controls the duty ratio of the PWM output signal so that the voltage which is fed back to VMOT is equal to the SIO voltage. And, if SIO voltage is low, or high, as described earlier in (4) Standby, the motor voltage is 0V to become a standby.
You need to set the R7, R6 appropriate depending on the characteristics of the motor resistance.

(9) Motor Lock detection

TB9110FNG has Motor Lock detection circuit. Motor lock is detected by the load current value and the motor lock detection voltage VMOT input voltage determined from the motor voltage. In case of motor lock, the load current value which was measured by the shunt resistor R3 is detected bigger than VMOT, and so the motor lock detection is active.



As described in (6) -4, ILOAD load current is measured as the voltage of the terminal VAMPO formula consisting of AMPO, R4, R5 R3 resistance. VAMPO is held by the sample and hold circuit using an external capacitor C2.And It is converted A / D and it is loaded into the logic circuit.

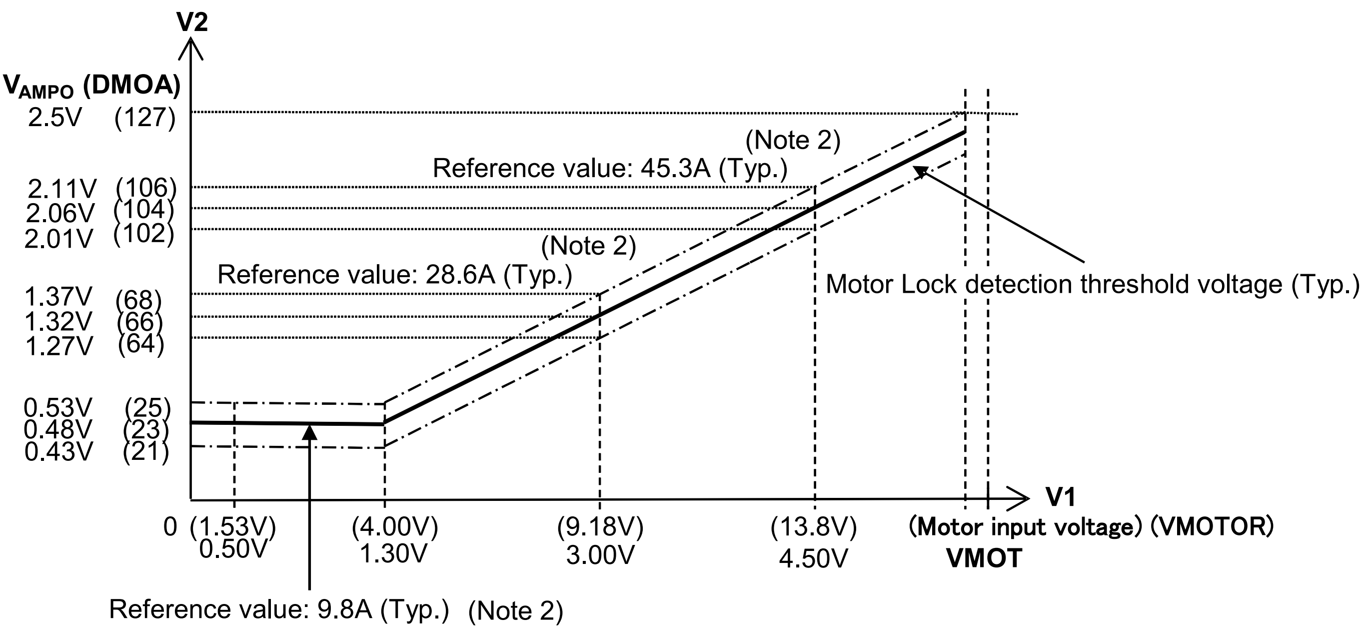
(9) Motor Lock detection (cont.)

The AD converter reads Motor input voltage which VMOTOR is divided by R6 and R7, namely Motor monitor voltage VMOT. The upper-limit motor drive current value is calculated from read data using a preset formula. For the motor drive current, the voltage value amplified from a drop potential developing across a sensing resistor and converted into the reference output against the ground is fetched by the AD converter from the AMP0 Pin after sample hold. If the fetched data is higher than the upper-limit motor drive current value and detected for at least 1.7 s, the motor is considered as being locked. The load current may exceed the specified locking current and then fall below that locking current within 1.7 s. In this case, if the load current exceeds the specified locking current again within 50 ms after an inspection start, the motor is regarded as being locked consecutively from the initial locking to continue to monitor locking time. If the locked motor has been detected, motor drive is stopped forcedly. This stoppage is cleared when standby is set or when the system is turned on again.

Motor lock detection threshold voltage used to detect motor lock is calculated by the internal logic voltage from VMOT. The formula is as follows.

Motor lock detection threshold voltage formula VMLock [V]=0.494×VMOT - 0.164

About Relationship between VMOT and motor lock detection voltage

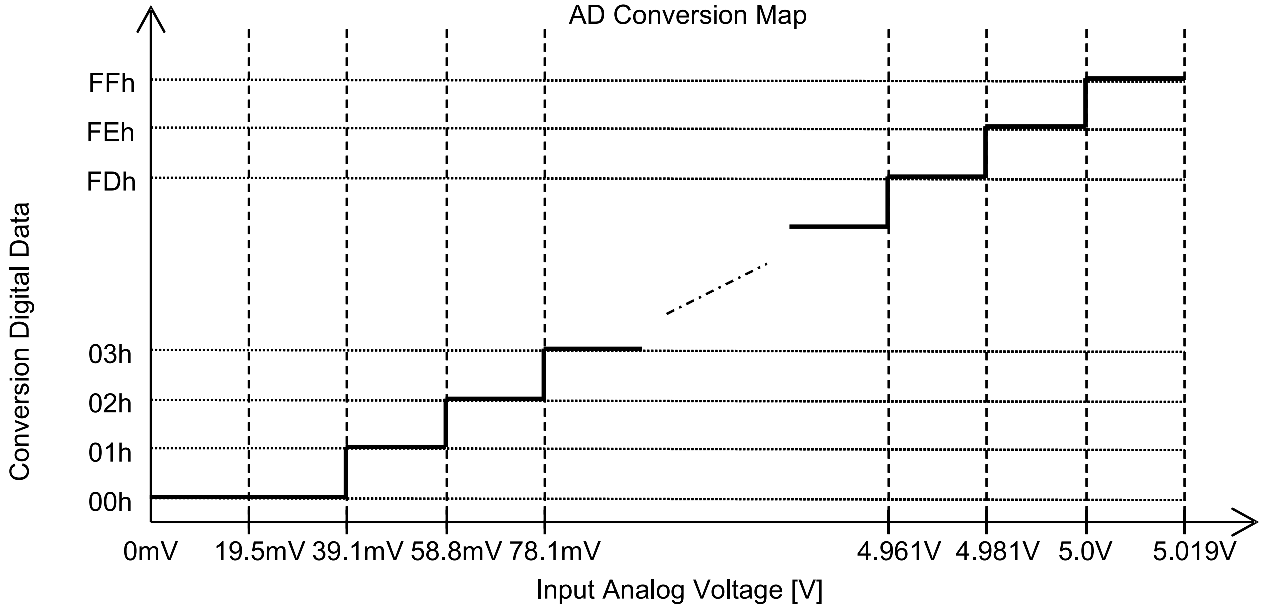


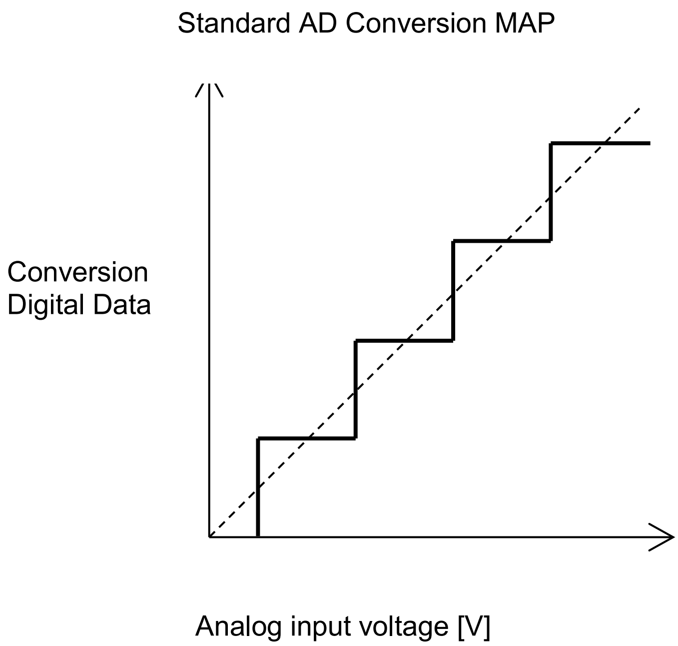
Note2: (Reference value) Motor Lock detection threshold voltage formula
(Motor load current): ILoad
Iload[A]=3.6375×VMOTOR - 4.75

Note about AD Converter

Reference Characteristics

AD converter is the Type of a decimal point truncation.





Absolute Maximum Ratings (Ta = 25°C)(Note 1)

Characteristic	Symbol	Applicable Pins	Test Condition	Rating	Unit	Note
Supply voltage	VCC	VCC	−	−0.3 to 40	V	−
	VDD	VDD	−	−0.3 to 6		
Current through the protective diode	I diode	(Note 2)	−	±10	mA	−
Output current	IOUT	VROF	−	±5		
		VREG	−	−10		
		OUT	DC current value	±20		
			Peak current value	±400		
		PCC1D, PCC2D	Peak current value	±100		
Input and output voltages	VIN, VOUT	AMPP, AMPM, PCC1, PCC2, PCC3, OUT	−	−0.3 to 40	V	−
		PCC1D, PCC2D	−	−0.3 to VCC+0.3		Max 40V
		SI,SIO, AMPO VROF, OCVTH,TVIN HOLD, T0, T1, VMOT COMP	−	−0.3 to VREG+0.3		Max 6V
		ROSC		−0.3 to 2		−
Storage temperature	Tstg	−	−	−55 to +150	°C	−
Power dissipation	PD	−	−	1 .32	W	(Note 3)

Note 1: The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded during operation, even for an instant. Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may damage any other equipment. Applications using the device should be designed such that the absolute maximum ratings will never be exceeded in any operating conditions. The device must be used within the specified operating range.

Note 2: Applicable pin is SI,SIO,HOLD,AMPO,ROSC,OCVTH,VROF,TVIN,VMOT,T0,T1,PCC2D,PCC1D.
I diode -10mA only applicable pin is VREG,VDD,COMP,OUT,AMPP,AMPM,PCC3,PCC2,PCC1,VCC.

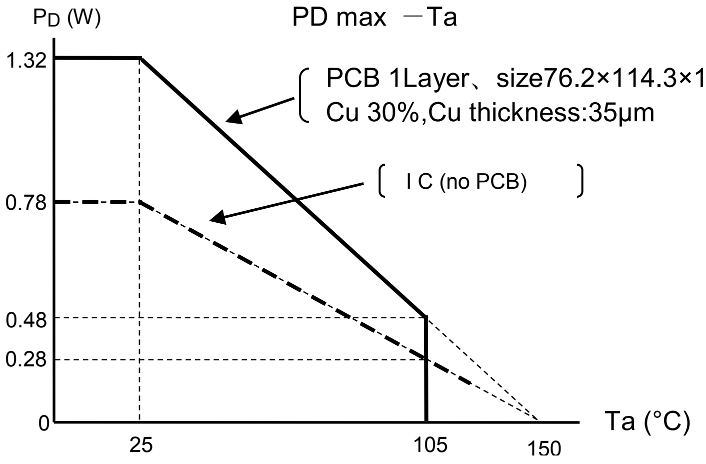
Note 3 : Mounted on a board (76.2 × 114.3 × 1.6 mm, Cu: 30%) when Ta = 25°C.

Note 4 : This product are sensitive to electrostatic discharge. When handling this product, protect the environment to avoid electrostatic discharge.

Package (SSOP24-P-300-0.65A)　Thermal Resistance

ITEM	SYMBOL	RATING	CONDITION	UNIT
Thermal Resistance	Rθj-a	160	IC	°C／W
		95	PCB 1Layer, size:76.2×114.3×t1.6mm、Cu：30%、Cu thickness：35μm	°C／W

Reference Characteristics



Note: PD ＝ (150－Ta）／Rθj-a

IC(no PCB) at 25°C
PD= (150-25)/160＝0.78（W）

Using PCB size 76.2×114.3×1.6mm Cu 30% at 25°C
PD= (150-25)/95＝1.32(W)

Electrical Characteristics

Operating Range

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Rating	Unit	Note
Supply voltage	VCC	7 to 18 (24[*1])	V	*1: The DC voltage is applied for 1 min at 25°C (Ta).
	VDD	3 to 5.5		Range of CMOS logic operation
Operating temperature	Topr	-40 to 105	°C	—

General IC characteristics

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Test Condition		Min	Typ.	Max	Unit
VCC standby current	ISTVCC	VCC	Standby state SI = VDD OUT = GND	Ta = 25°C	—	—	250	μA
				Ta = -40 to 105°C	—	—	300	
Current consumption (VCC)	ICC	VCC	Operation under no load		—	10	20	mA
			Operation under a load		—	30	100	
H-level output voltage 1	VOH1	VROF	SI = 0 V, IOH = -5 mA		VDD-0.5	VDD-0.25	VDD	V
L-level output voltage 1	VOL1		SI =5 V, IOL =5 mA		0	0.25	0.5	
H-level output current 2	IOH2	SIO	SI=VOUT=0 V		-100	-50	-25	μA
L-level output current 2	IOL2		SI=VOUT=5 V		25	50	100	
L-level input current	IIL1	SI	VIN=0 V		-50	-25	0	μA
H-level input current	IIH1		VIN=5 V, VDD=5 V		-10	0	10	
Detected L-level input voltage	VIL1		—		1.75	2.25	2.75	V
Detected H-level input voltage	VIH1		—		2.25	2.75	3.25	
Hysteresis width	VH1		—		0.3	0.5	0.7	

Note :The test pins, which are used for a delivery inspection, are not covered in the above Table, and are excluded from the standard. You have to use an applied circuit after having grounded it. (T0 and T1 contain a pull-down resistor rated at 50 kΩ.)

Electrical Characteristics

Oscillator

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Charge pump frequency	fCPD	PCC1D, PCC2D	—	SI = 60% (3 V) ROSC = 10 kΩ	17	20	23	kHz
PWM frequency	fPWM	OUT	—					
CR oscillation frequency	fosc	—	—	ROSC = 10 kΩ (Note: Reference value)	—	5.12	—	MHz

Note: The on-chip CR oscillator cannot be measured directly. The above value is for reference.

5-V power supply

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
5-V power supply's output voltage	VREG1	VREG	—	Ta = -40 to 105°C	4.85	5.00	5.15	V
	VREG2			Ta = 25°C	4.984	5.050	5.116	
Reset clear voltage	VRSTH			VREG measurement	4.60	4.75	4.90	V
Reset detection voltage	VRSTL				4.45	4.60	4.75	
	ΔVTH			VREG1－VRSTL	0.35	0.40	0.45	
Reset voltage hysteresis	ΔVRST			VRSTH－VRSTL	—	0.15	—	

A/D converter

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Input voltage range	VADIN	—	—	VCC = 7 V	0	—	4.7	V
				VCC = 14 V, 18 V	0	—	VREG	
Nonlinear tolerances	VADdLE			VREG =VDD =5.0V	-1	—	+1	LSB
Total tolerances	VADLE				-2	—	+2	
Conversion Time per channel	t1ch				25	50	—	μs
1-bit conversion time	t1bit				3.125	6.25	—	

Electrical Characteristics

Pre-driver and charge pump

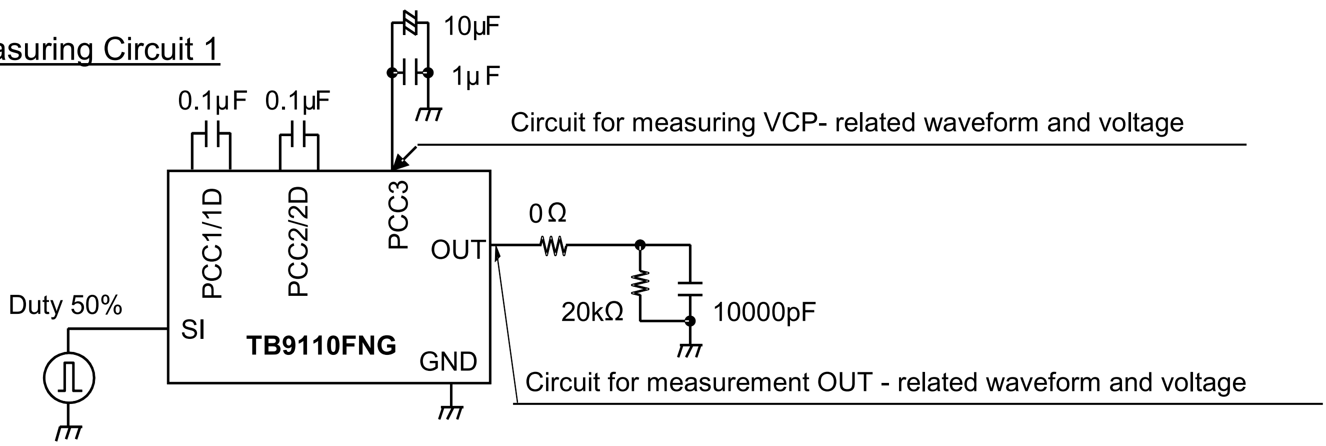
Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Pre-driver output voltage	VOH2	OUT	Measurement Circuit 1	Stable voltage	VCP-2	–	VCP (Note1)	V
	VOL2				–	–	1	
Pre-driver output resistance	RONH1			OUT=High output condition	–	100	–	Ω
	RONL1			OUT=Low output condition	–	7	15	
Pre-driver output voltage	VOHD			IOUT=-20 mA	VCP-4	–	VCP	V
	VOLD			IOUT=20 mA	–	–	1	
Turn-on time	TONP			Voltage measurement point 0 V - VCC+6 V	–	3	6	µs
Turn-off time	TOFFP			Voltage measurement point VCP - 3V	–	5	8	
Charge pump driver output voltage	VOH3	PCC1D, PCC2D		Iout = -100 mA	VCC-2	–	VCC	V
	VOL3			Iout = 100 mA	0	–	1	
Charge pump output voltage	VCP7V	PCC3		VCC = 7 V	VCC+7	–	–	V
Charge pump clamp voltage 1	VCPCLH1			–	VCC + 10	VCC + 12	VCC + 14	
Charge pump clamp voltage 2	VCPCLH2			VREG = VDD = 5 V	36.5	38	40.0	
	VCPCLL2				36.0	37.5	39.5	
Charge pump voltage reduction detection voltage	VCPLH			–	VCC + 4.0	VCC + 5.0	VCC + 6.0	V
	VCPLL				VCC + 3.5	VCC + 4.5	VCC + 5.5	
Temperature at which to detect a shutdown	TSDH	OUT		(Note2) (Reference value)	–	165	–	°C

Note1: VCP is charge pump voltage.

Note2: Temperature shutdown detection test cannot be testing directly, thus it is not tested on production.

Measuring Circuit 1



Electrical Characteristics

Comparator

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Input voltage range	VIN	SIO	—	—	0	—	VREG	V
SI standby clear voltage	VSTOF			—	0.6	0.7	0.8	
SI0 comparator offset voltage	VOFFSET			(Note: Reference value)	—	0	—	mV
Standby detection voltage	VSTON			VREG = VDD = 5 V	0.3	0.4	0.5	V
High input voltage detection	VHOON			VREG = VDD = 5 V	4.75	4.85	4.95	
High input voltage turn-off	VHOOFF1			VREG = VDD = 5 V	4.70	4.80	4.90	
Detected SI ground-fault hold VCC voltage	VHOOFF2	VCC		SIO = VREG = VDD	—	—	5.4	V
Standby clear overvoltage	VOVR-ST			Standby	23	25	27	V
Motor start overvoltage	VOVRMON			During operation VREG =VDD = 5 V	—	27	29	
Motor stop overvoltage	VOVRMOFF				20	22	—	
Low VCC clear voltage	VDRPOFF			During operation VREG = VDD = 5 V PCC3 = 15 V	5.9	6.4	6.9	V
Low VCC detection voltage	VDRPON				5.4	5.9	6.4	
Low VCC hysteresis width	VDRPHIS				—	0.5	—	
Ground-fault input voltage range	VOCVTHLT	AMPO OCVTH		—	0	—	3	
Ground-fault comparator same-phase input range	VCMVIH			—	0	—	3	
Motor ground-fault detection voltage	VOCVTHON			OCVTH = 2.5V	2.45	2.50	2.55	
Ground-fault detection comparator offset voltage	VCOMPIO			Difference from OCVTH = 2.5 V	-10	—	10	mV
Comparator conversion time	TCOMPCNV			—	—	1	—	µs
Abnormal external temperature detection voltage ratio	TVINON	TVIN		During operation When VREG = VDD = 5 V Detection voltage/5V Clear voltage/5V	0.174	0.194	0.214	—
Abnormal external temperature clear voltage ratio	TVINOFF				0.414	0.434	0.454	

Note: The offset voltage of the on-chip SIO comparator cannot be measured directly. The above value is provided only for reference.

Electrical Characteristics

Current amplifier

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition		Min	Typ.	Max	Unit
AMP input offset	VAMPIO1	AMPP AMPM	Measurement Circuit 2	Load current=0 mA SIO = 2.5 V		-3	0	+5	mV
	VAMPIO2			Load current =3 mA SIO = 2.5 V	Ta = -40°C	-3	0	+12	
					Ta = 25°C	-3	0	+9	
					Ta = 105°C	-3	0	+7	
AMP slew rate	TTHRO	AMPO		Gain: 14.2	Load current =1 mA	0.15	0.3	1.0	V/μs
					Load current =5 mA	1.0	1.5	5.0	
AMP responsibility 1	TAMPO1			Gain: 14.2	—	—	0.8	2.0	μs
AMP responsibility 2	TAMPO2			Response under dead short conditions on release of standby (Load current =10 mA)	—	—	—	2.0	μs
AMP output voltage range	VAMP			—	—	0	—	3	V
AMP output current range	IAMP			—		0	—	5	mA
Current amplification voltage	VAMPL1			Load curren t=1 mA	Ta = -40°C	0.425	0.468	0.567	V
					Ta = 25°C	0.425	0.468	0.552	
					Ta = 105°C	0.425	0.468	0.539	
	VAMPL2			Load curren t=3 mA	Ta = -40°C	1.360	1.403	1.573	
					Ta = 25°C	1.360	1.403	1.530	
					Ta = 105°C	1.360	1.403	1.502	
	VAMPL3			Load current =5 mA	Ta = -40°C	2.280	2.338	2.593	
					Ta = 25°C	2.280	2.338	2.494	
					Ta = 105°C	2.280	2.338	2.437	

Note: The formula below is used to calculate the AMP input offset voltage from the current amplification voltages under load currents of 0 mA and 3 mA.

Calculation

AMP input offset voltage [V]

= [{current amplification voltage (V) under the specified load current}
/{resistance ratio for gain setting (5,100 Ω/360 Ω)}] – [{ load current (A)} × 33 Ω]

Please refer to 29 pages for details.

Electrical Characteristics

Supplementary description of load current

The testing circuit applies currents of 1 mA, 3 mA and 5 mA through a resistor rated at 33 Ω to check the current amplifier application circuit that is designed to apply currents of 9.4 A, 28.3 A and 47.1 A through a shunt resistor rated at 3.5 mΩ. The load current denotes the current flowing through the current detection resistor (shunt resistor). The voltage developing across the current detection resistor (shunt resistor) is set at the same value under application and testing conditions.

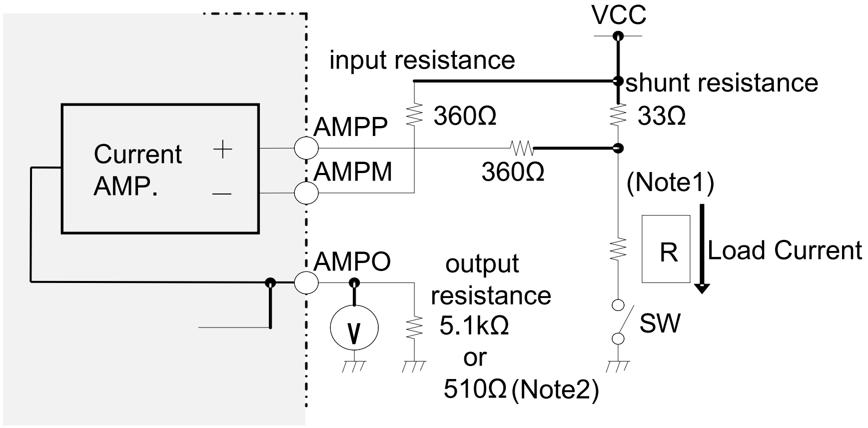
Table 1. Relation between the Testing Load Current and the Current Flowing through the AMPM Pin

Testing load current [mA]	Voltage developing across the testing current detection resistor (rated at 33 Ω) [mV]	Current flowing through the AMPM pin [μA]
0.0	0	0.0
1.0	33	91.7
3.0	99	275.0
5.0	165	458.3

The input resistance and output resistance used to determine the current amplifier gain are fixed at 360 Ω and 5.1 kΩ, respectively.

Electrical Characteristics

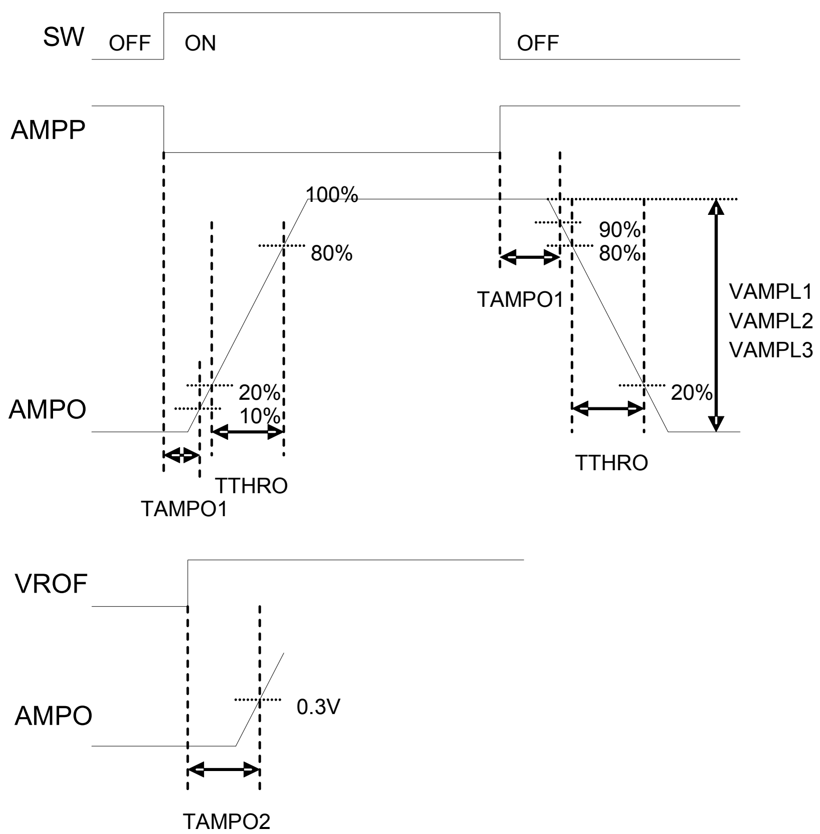
Measuring circuit 2



Note 1: Set the R value so that the load current for measurement flows.

Note 2: During measurement of the AMPO output current range, set the output resistance is 510Ω.

Measured waveforms diagram



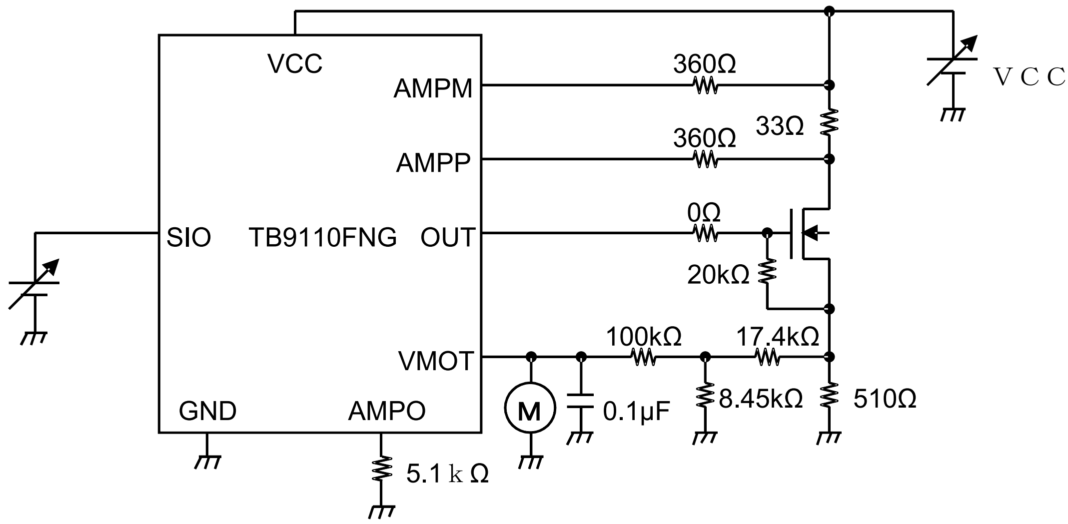
Electrical Characteristics

Controller

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Specified value control motor voltage	VMOT-C1	VMOT SIO	Measurement Circuit 3	VCC = 7 V, SIO = 0.80 V	0.70	0.80	0.90	V
	VMOT-C2			VCC = 7 V, SIO = 1.65 V	1.55	1.65	1.75	
	VMOT-C3			VCC = 14 V, SIO = 0.80 V	0.70	0.80	0.90	
	VMOT-C4			VCC = 14 V, SIO = 2.60 V	2.50	2.60	2.70	
	VMOT-C5			VCC = 14 V, SIO = 4.10 V	4.00	4.10	4.20	
	VMOT-C6			VCC = 18 V, SIO = 0.80 V	0.70	0.80	0.90	
	VMOT-C7			VCC = 18 V, SIO = 2.60 V	2.50	2.60	2.70	
	VMOT-C8			VCC = 18 V, SIO = 4.50 V	4.40	4.50	4.60	

Measuring circuit 3



M:Measurement

Electrical Characteristics

Time settings for each detection functions

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Standby entry time	tst	VROF	—	ROSC =10 kΩ	0.15	0.20	0.25	s
External temperature monitoring time	tTvin	OUT			1.4	1.7	2.0	s
Motor lock monitoring time	tMLOCK	OUT			1.4	1.7	2.0	s
Consecutive motor lock detection time	tcnt1	OUT			40	50	60	ms
Temporary output turn-off time on ground-fault detection	tOFF1	OUT			75	100	125	ms
Consecutive checking time for ground-fault detection	tcnt2	OUT			40	50	60	ms
Ground-fault monitoring time	tDead	OUT			450	600	750	ms

Note: In delivery inspection, the counter's clock count value is measured in test to determine time settings and to comply with the functions' time setting standards.

Output leak current

Electrical characteristics (VCC = 40 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Output leak current	ILEAK-U	PCC1D PCC2D OUT	—	When in standby VOUT = 0 V	-10	—	—	μA
		VREG		VREG OFF				
	ILEAK-L	PCC1D PCC2D OUT		When in standby VOUT = 40 V	—	—	10	

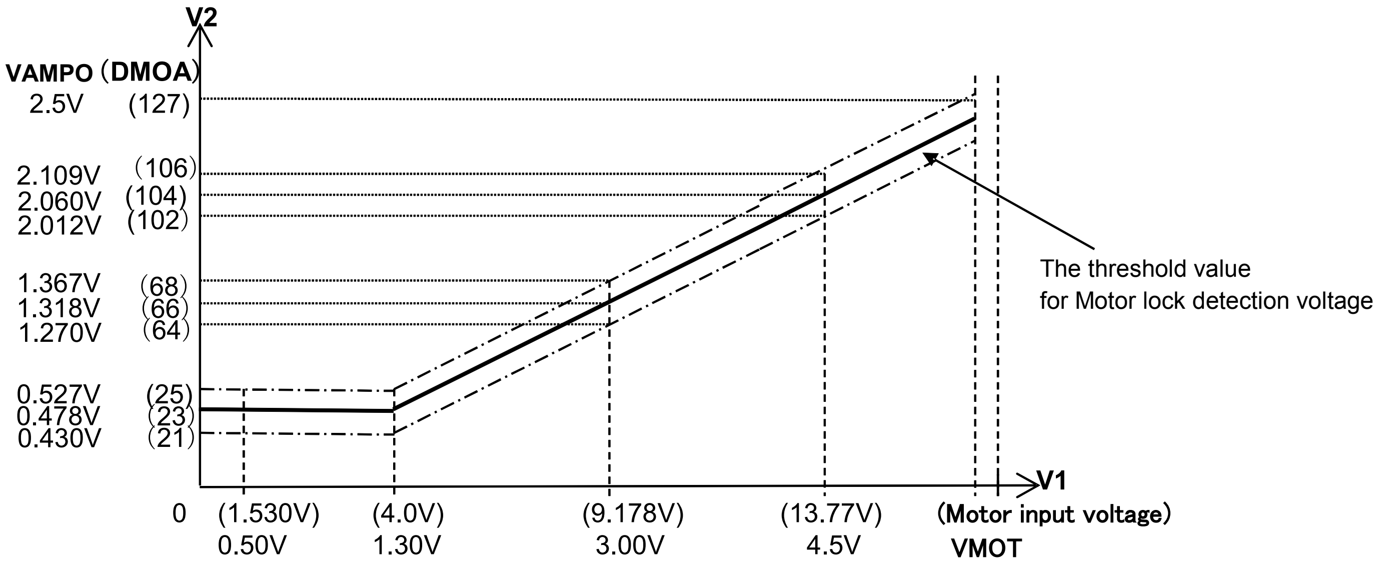
Electrical Characteristics

Motor lock detection characteristics

Electrical characteristics (VCC =7 to 18 V ,VDD = VREG = 5 V, Ta = -40 to 105°C unless otherwise specified)

Characteristic	Symbol	Applicable Pins	Measurement Circuit	Test Condition	Min	Typ.	Max	Unit
Motor lock detection voltage	VMOA-C1	VMOT AMPO	Measurement Circuit 4	VREG = VDD = 5 V, VMOT = 0.50 V	0.430	0.478	0.527	V
	VMOA-C2			VREG = VDD = 5 V, VMOT = 1.30 V	0.430	0.478	0.527	
	VMOA-C3			VREG = VDD = 5 V, VMOT = 3.00 V	1.270	1.318	1.367	
	VMOA-C4			VREG = VDD = 5 V, VMOT = 4.50 V	2.012	2.060	2.109	

Relation between motor input voltage and motor lock detection voltage



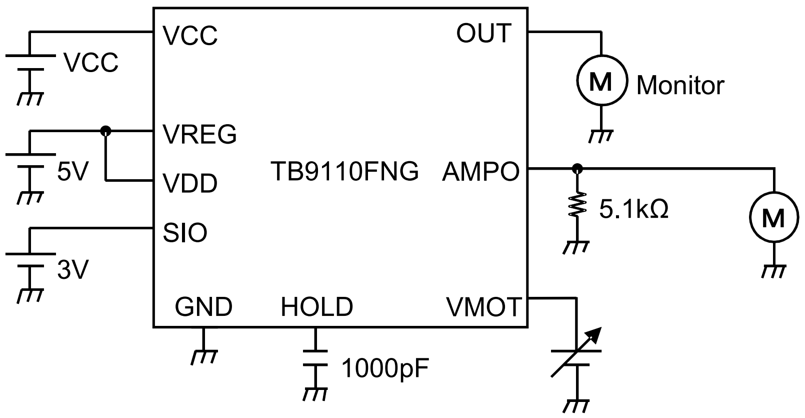
Note: DMOA: Digital value which be converted AMPO output voltage

VMOT : Motor input voltage divided by R7 and R6 , thus Compressed to 5V.

(Digital value which be converted Motor voltage)

Electrical Characteristics

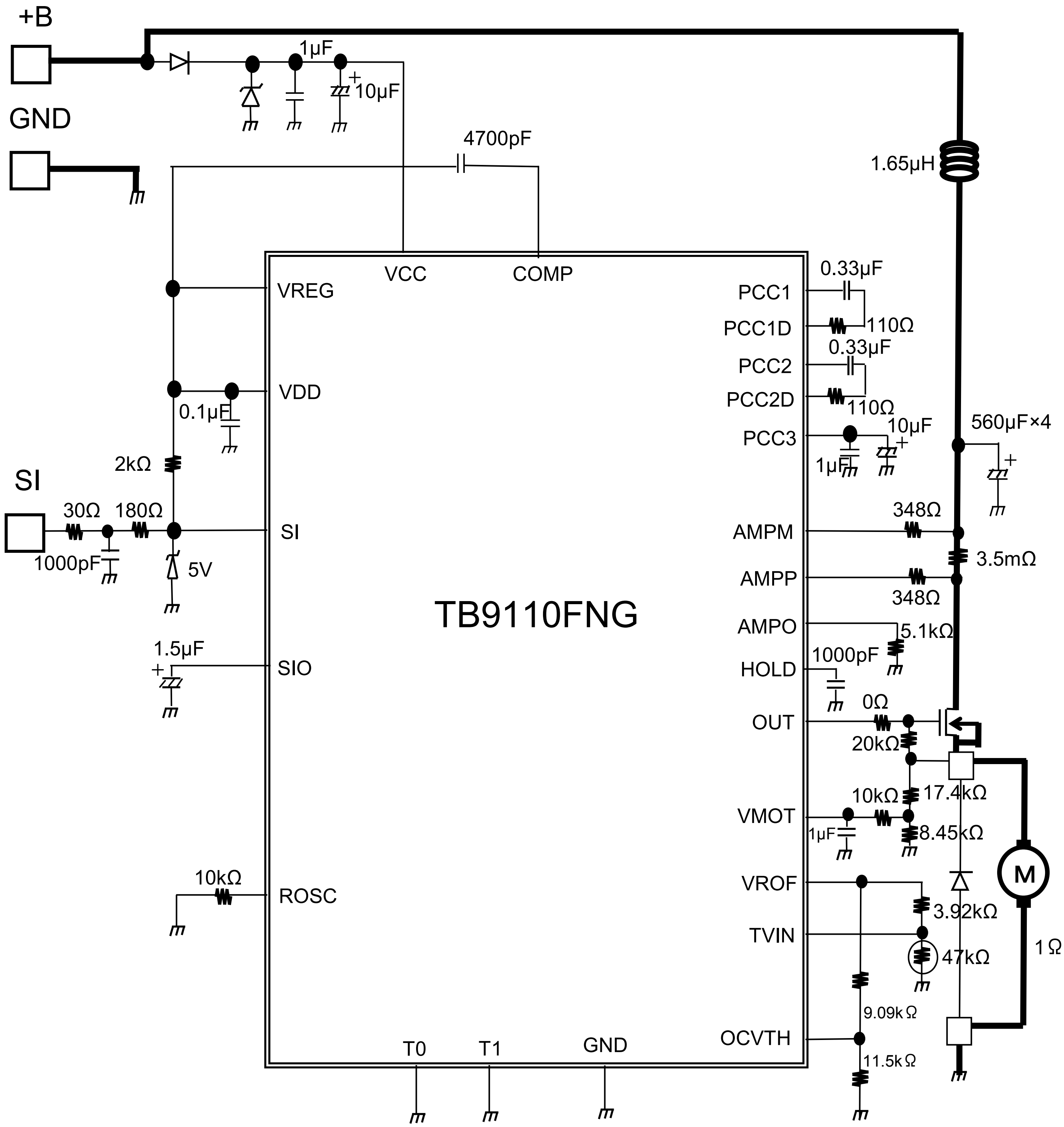
Measuring Circuit 4



Note: Components in measuring circuits are used solely to check characteristics. We cannot guarantee that no malfunction or failure will occur should the same components be used in application equipment.

Application Examples

Example of application circuit (Input signal : PWM)



Notes

Note 1: Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

Note 2: The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

Note 3: Timing charts may be simplified for explanatory purposes..

Note 4: Ensure that the IC is mounted correctly as specified. Failing to observe the correct mounting procedure or requirements may damage the IC or target equipment.

Note 5: The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

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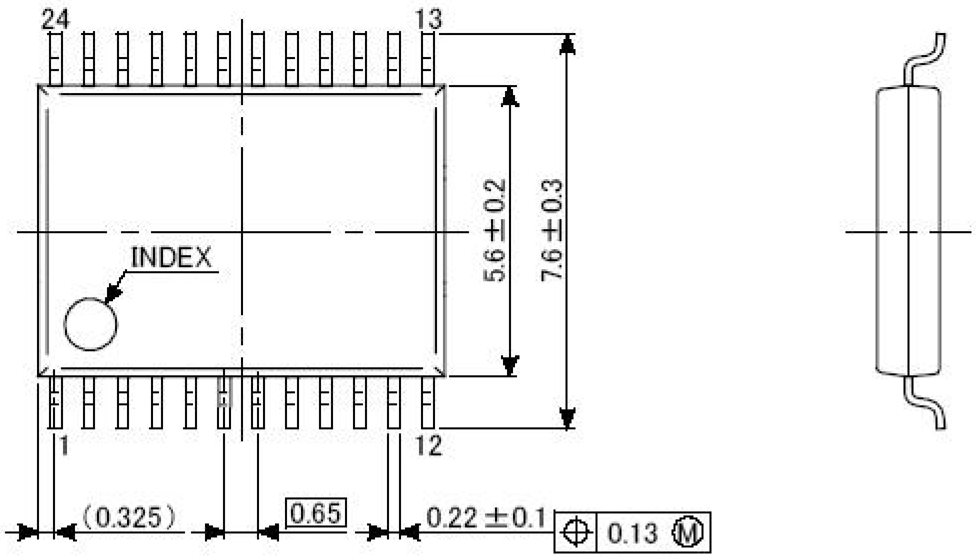
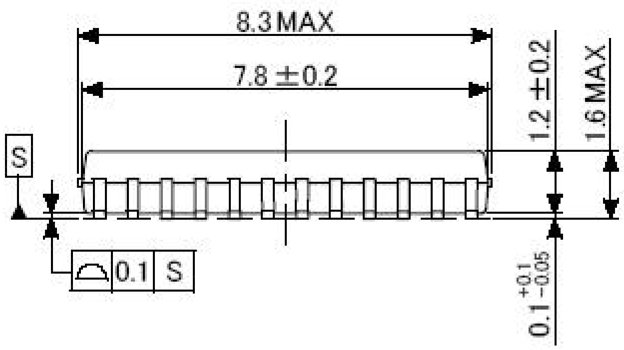
Note 6: Components in measuring circuits are used solely to check characteristics. We cannot guarantee that no malfunction or failure will occur should the same components be used in application equipment.

Package Dimensions

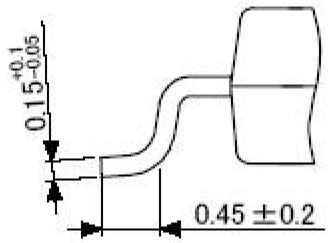
SSOP24-P-300-0.65A

Unit : mm





Lead edge dimension



Weight: 0.14 g (Typ.)

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