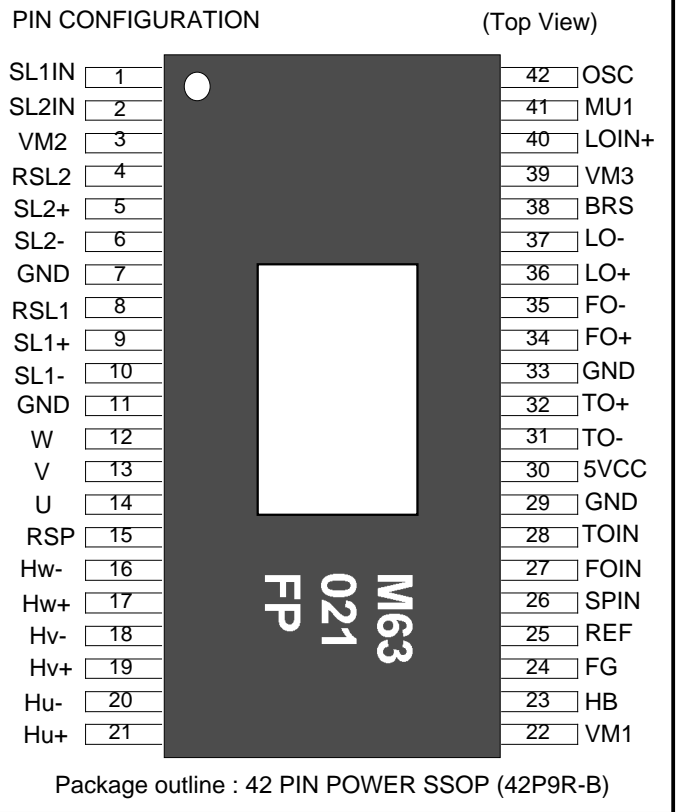


MITSUBISHI SEMICONDUCTORS  
**M63021FP**  
 SPINDLE MOTOR AND 5CH ACTUATOR DRIVER

[FEATURES]

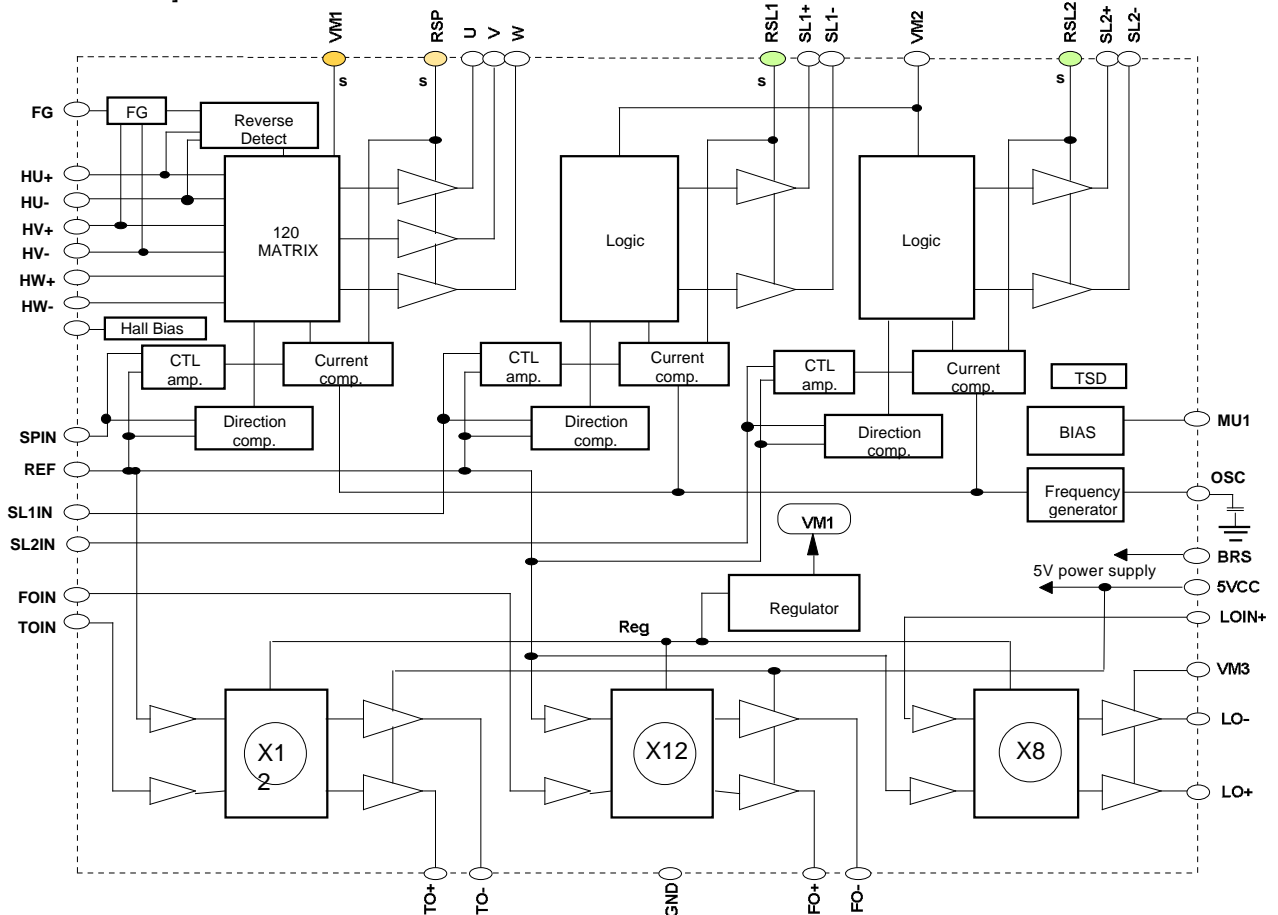
This IC is 1 chip driver IC for spindle motor and 5 channel actuators. All of the motor and actuator of optical disk drive system (CD-ROM etc.) can be driven by only this IC.  
 This IC has a direct PWM control system for Spindle and Slide channels drive due to reducing IC power dissipation.  
 This IC has three voltage supply terminals (for Spindle, Slide, Focus/Tracking and Loading), and three voltage supply can be set separately.  
 Further more this IC has **short braking select function**, FG amplifier, thermal shut down circuit, standby circuit, reverse rotation detect circuit.



[APPLICATION]

CD-ROM, DVD, DVD-ROM, DVD-RAM, Optical disc related system, etc

[BLOCK DIAGRAM]



## [PIN FUNCTION]

| TERMINAL | SYMBOL | TERMINAL FUNCTION               | TERMINAL | SYMBOL | TERMINAL FUNCTION                 |
|----------|--------|---------------------------------|----------|--------|-----------------------------------|
| 1        | SL1IN  | Slide control voltage input 1   | 42       | OSC    | PWM carrier oscilation set        |
| 2        | SL2IN  | Slide control voltage input 2   | 41       | MU1    | mute 1                            |
| 3        | VM2    | Motor Power Suppry 2(for Slide) | 40       | LOIN+  | Loading control input(+)          |
| 4        | RSL2   | Slide current sense 2           | 39       | VM3    | Power Supply3 (for Loading)       |
| 5        | SL2+   | Slide non-inverted output 2     | 38       | BRS    | Brake select control terminal     |
| 6        | SL2-   | Slide inverted output 2         | 37       | LO-    | Loading inverted output           |
| 7        | GND    | GND                             | 36       | LO+    | Loading non-inverted output       |
| 8        | RSL1   | Slide current sense 1           | 35       | FO-    | Focus inverted output             |
| 9        | SL1+   | Slide non-inverted output 1     | 34       | FO+    | Focus non-inverted output         |
| 10       | SL1-   | Slide inverted output 1         | 33       | GND    | GND                               |
| 11       | GND    | GND                             | 32       | TO+    | Tracking non-inverted output      |
| 12       | W      | Motor drive output W            | 31       | TO-    | Tracking inverted output          |
| 13       | V      | Motor drive output V            | 30       | 5VCC   | 5V Power Supply(for FS ,TS)       |
| 14       | U      | Motor drive output U            | 29       | GND    | GND                               |
| 15       | RSP    | Spindle current sensie          | 28       | TOIN   | Tracking control voltage input    |
| 16       | HW-    | HW- sensor amp. input           | 27       | FOIN   | Focus control voltage input       |
| 17       | HW+    | HW+ sensor amp. input           | 26       | SPIN   | Spindle control voltage input     |
| 18       | HV-    | HV- sensor amp. input           | 25       | REF    | Reference voltage input           |
| 19       | HV+    | HV+ sensor amp. input           | 24       | FG     | Frequency generator output        |
| 20       | HU-    | HU- sensor amp. input           | 23       | HB     | Bias for Hall Sensor              |
| 21       | HU+    | HU+ sensor amp. input           | 22       | VM1    | Motor Power Suppry 1(for Spindle) |

[ABSOLUTE MAXIMUM RATING] (Ta=25°C)

| SYMBOL      | PARAMETER                          | CONDITIONS   | RATING      | Unit    |
|-------------|------------------------------------|--|-------------|---------|
| <b>5VCC</b> | <b>5V power supply</b>             | <b>Focus and Tracking power supply</b>   | 7           | V       |
| VM1         | Motor power supply 1               | Spindle power supply   | 15          | V       |
| VM2         | Motor power supply 2               | Slide power supply   | 15          | V       |
| VM3         | Motor power supply 3               | Loading power supply   | 15          | V       |
| IoA         | Motor Output Current A             | Focus, Tracking and Loading output current<br>*note 1                              | 1.0         | A       |
| IoB         | Motor Output Current B             | Spindle output current<br>*note 1  | 1.2         | A       |
| IoC         | Motor Output Current C             | Slide output current<br>*note 1  | 0.5         | A       |
| Vin         | Maximum input voltage of terminals | MU1,Hw-,Hw+,Hv,Hv+,Hu-,Hu+,REF,SPIN, <b>BRS</b><br>TOIN,FOIN,OSC,SLIN1,SLIN2,LOIN+ | 0 to 5VCC   | V       |
| Pt          | Power dissipation                  | Free Air and on the grass epoxy board  | 2.6         | W       |
| K           | Thermal derating                   | Free Air and on the grass epoxy board  | 20.8        | mW / °C |
| Tj          | Junction temperature               |  | 150         | °C      |
| Topr        | Operating temperature              |  | -20 to +75  | °C      |
| Tstg        | Storage temperature                |  | -40 to +150 | °C      |

\*note1 ; The ICs must be operated within the Pt (power dissipation) or the area of safety operation

**The spindle output terminal is needed external shottky diode between each output and GND when it is used above 0.6A. Discription(IoA) is case of with external shottky diode.**

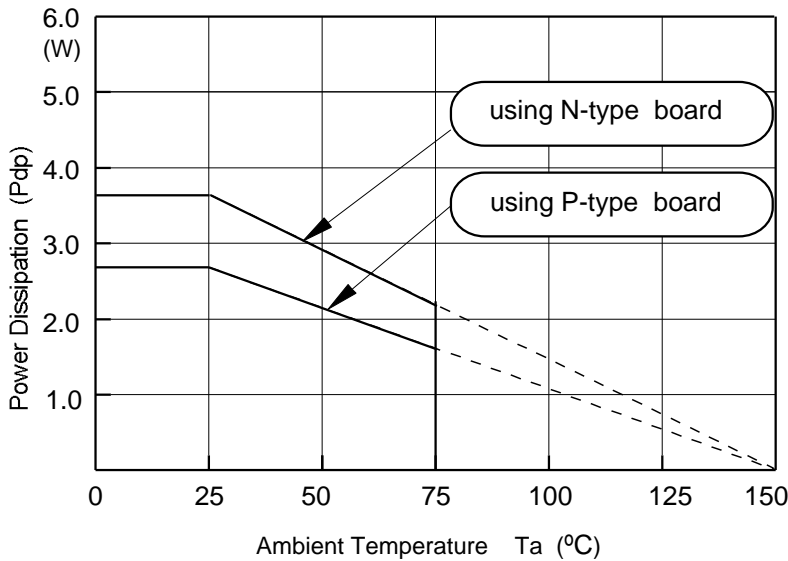
[RECOMMENDED OPERATING CONDITIONS] (Ta=25°C)

| SYMBOL      | PARAMETER                                  | LIMITS  |         |         | Unit     |
|-------------|--|---------|---------|---------|----------|
|             |  | minimum | typical | maximum |          |
| VM1         | VM1 power supply (for Spindle)             | 6       | 12      | 13.2    | V        |
| VM2         | VM2 power supply(for Slide)                | 4.5     | 12      | 13.2    | V        |
| VM3         | VM3 power supply(for Loading)              | 4.5     | 12      | 13.2    | V        |
| <b>5VCC</b> | <b>5V power supply(for FS,TS)</b>          | 4.5     | 5       | 7       | <b>V</b> |
| IoA         | Focus, Tracking and Loading Output Current | —       | 0.5     | 0.8     | A        |
| IoB         | <b>Spindle Output Current</b> *note 2      | —       | 0.5     | 1.0     | A        |
| IoC         | <b>Slide Output Current</b>                | —       | 0.25    | 0.4     | A        |
| <b>Fosc</b> | PWM carrier frequency                      | 30      | —       | 120     | KHz      |

\*note2

**The spindle output terminal is needed external shottky diode between each output and GND when it is used above 0.6A. Discription(IoA) is case of with external shottky diode.**

[THERMAL DERATING]



This IC's package is POWER-SSOP, so improving the board on which the IC is mounted enables a large power dissipation without a heat sink.

For example, using an 1 layer glass epoxy resin board, the IC's power dissipation is 2.6W at least. And it comes to 3.6W by using an improved 2 layer board.

The information of the N, P type board is shown in attached.

[ELECTRICAL CHARACTERISTICS]

Common

( $T_a=25^\circ\text{C}$ ,  $5V_{CC}=V_{M3}=5V$ ,  $V_{M1}=V_{M2}=12V$  unless otherwise noted.)

| SYMBOL             | PARAMETER                   | CONDITIONS   | LIMITS |     |     | Unit |
|--------------------|-----------------------------|--|--------|-----|-----|------|
|                    |                             |  | MIN    | TYP | MAX |      |
| I <sub>cc1</sub>   | Supply current              | 5V <sub>CC</sub> , V <sub>M1</sub> , V <sub>M2</sub> , V <sub>M3</sub> current                                     | —      | 60  | 78  | mA   |
| I <sub>cc2</sub>   | Sleep current               | 5V <sub>CC</sub> , V <sub>M1</sub> , V <sub>M2</sub> , V <sub>M3</sub> current under Sleep (M <sub>U1</sub> = 0V). | —      | 0   | 30  | μA   |
| F <sub>osc</sub>   | PWM carrier frequency       | OSC : with 330pF   | —      | 65  | —   | KHz  |
| V <sub>inREF</sub> | REF input voltage range     |  | 1.0    | —   | 3.3 | V    |
| I <sub>inREF</sub> | REF input voltage range     | V <sub>REF</sub> =1.65V  | -10    | —   | +10 | μA   |
| V <sub>MULO</sub>  | MUTE terminal low voltage   | M <sub>U1</sub>  | —      | —   | 0.8 | V    |
| V <sub>MUHI</sub>  | MUTE terminal high voltage  | M <sub>U1</sub>  | 3.0    | —   | —   | V    |
| I <sub>MU</sub>    | Mute terminal input current | M <sub>U1</sub> at 5V input voltage  | —      | —   | 500 | μA   |
| B <sub>RSLO</sub>  | BRS terminal low voltage    | B <sub>RS</sub>  | —      | —   | 0.8 | V    |
| B <sub>RSHI</sub>  | BRS terminal high voltage   | B <sub>RS</sub>  | 3.0    | —   | —   | V    |
| I <sub>BRS</sub>   | BRS terminal input current  | B <sub>RS</sub> at 5V input voltage  | —      | —   | 430 | μA   |
|                    |                             |  |        |     |     |      |

[ELECTRICAL CHARACTERISTICS]

**Spindle**

(Ta=25°C, 5VCC=VM3=5V, VM1=VM2=12V unless otherwise noted.)

| SYMBOL  | PARAMETER                                | CONDITIONS                 | LIMITS |      |      | Unit  |
|---------|--|----------------------------|--------|------|------|-------|
|         |  |                            | MIN    | TYP  | MAX  |       |
| Vdyc1   | Dynamic range of output                  | Io=0.5 [A]                 | 10.3   | 10.8 | —    | V     |
| Vdead1- | Control voltage dead zone 1              | SPIN<REF [REVERSE]         | -80    | -40  | 0    | mV    |
| Vdead1+ |  | REF<SPIN [FORWARD]         | 0      | +40  | +80  | mV    |
| Vin1    | Control voltage input range 1            | SPIN                       | 0      | —    | 5    | V     |
| Gvo1    | Control gain 1                           | Gio1=Gvo1/ Rs [A/V]        | 0.85   | 1.0  | 1.15 | V/V   |
| Vlim1F  | Control limit 1F                         | Ilim1F=Vlim1F/ Rs [A]      | 0.4    | 0.5  | 0.6  | V     |
| Vlim1R  | Control limit 1R                         | Ilim1R=Vlim1R/ Rs [A]      | 0.22   | 0.28 | 0.34 | V     |
| VHcom   | Hall sensor amp. common mode input range | Hu+,Hu-,Hv+,Hv-,Hw+ ,Hw-   | 1.3    | —    | 3.7  | V     |
| VHmin   | Hall sensor amp input signal level       | Hu+,Hu-,Hv+,Hv-,Hw+ ,Hw-   | 60     | —    | —    | mVp-p |
| VHB     | HB output voltage                        | at Load current (IHB)=10mA | 0.6    | 0.85 | 1.2  | V     |
| IHB     | HB terminal sink current                 | MU1=5V                     | —      | —    | 30   | mA    |

**Slide 1,2**

(Ta=25°C, 5VCC=VM3=5V, VM1=VM2=12V unless otherwise noted.)

| SYMBOL  | PARAMETER                     | CONDITIONS             | LIMITS |      |      | Unit |
|---------|-------------------------------|------------------------|--------|------|------|------|
|         |                               |                        | MIN    | TYP  | MAX  |      |
| Vdyc2   | Dynamic range of output       | Io=0.5 [A] at VM2=5[V] | 3.3    | 3.8  | —    | V    |
|         |                               | at VM2=12[V]           | 10.3   | 10.8 | —    |      |
| Vdead2- | Control voltage dead zone 2   | SL1IN,SI2IN < REF      | -80    | -40  | 0    | mV   |
| Vdead2+ |                               | REF < SL1IN ,SL2IN     | 0      | +40  | +80  | mV   |
| Vin2    | Control voltage input range 2 | SL1IN,SL2IN            | 0      | —    | 5    | V    |
| Gvo2    | Control gain 2                | Gio2=Gvo2/ Rs [A/V]    | 0.85   | 1.0  | 1.15 | V/V  |
| Vlim2   | Control limit 2               | Ilim2=Vlim2/ Rs [A]    | 0.43   | 0.5  | 0.58 | V    |
| Tdon    | Output turn-on delay          |                        | —      | 1.0  | 2.0  | µsec |
| Tdoff   | Output turn-off delay         |                        | —      | 2.0  | 3.5  | µsec |
| Tdsw    | Output switching delay        |                        | —      | 3.0  | 6.0  | µsec |
| Ileak   | Output leak current           | MU1=5v                 | -100   | —    | 100  | µA   |

[ELECTRICAL CHARACTERISTICS]

**Loading**

(Ta=25°C, 5VCC=VM3=5V, VM1=VM2=12V unless otherwise noted.)

| SYMBOL  | PARAMETER                    | CONDITIONS                              | LIMITS    |      |      | Unit |   |
|---------|------------------------------|---|-----------|------|------|------|---|
|         |                              |   | MIN       | TYP  | MAX  |      |   |
| Vdyc3-1 | Dynamic range of output      | Io=0.5[A]<br>VM1=12[V]                  | VM3=5[V]  | 3.9  | 4.2  | —    | V |
|         |                              |   | VM3=12[V] | 6.9  | 7.6  | —    |   |
| Vdyc3-2 | Dynamic range of output      | R=5.4[W]<br>VM3=4.75V, VM1=12V          | 3.3       | 3.5  | —    | V    |   |
| Vin3    | Control voltage input range3 | LOIN+                                   | 0         | —    | 5    | V    |   |
| Gvo3    | Control gain 3               | $\frac{(LO+) - (LO-)}{(LOIN+) - (REF)}$ | 16.7      | 18.1 | 19.3 | dB   |   |
| Voff1   | Output offset voltage        | $(LO+) - (LO-)$<br>at LOIN+=REF=1.65V   | -50       | 0    | +50  | mV   |   |

**Focus / Tracking**

(Ta=25°C, 5VCC=VM3=5V, VM1=VM2=12V unless otherwise noted.)

| SYMBOL | PARAMETER                     | CONDITIONS   | LIMITS |      |      | Unit |
|--------|-------------------------------|--|--------|------|------|------|
|        |                               |  | MIN    | TYP  | MAX  |      |
| Vdyc4  | Dynamic range of output       | Io=0.5[A]<br>VM1=12[V]   | 3.8    | 4.2  | —    | V    |
| Vin4   | Control voltage input range 4 | FOIN, TOIN   | 0      | —    | 5    | V    |
| Gvo4   | Control gain 4                | $\frac{(FO+) - (FO-)}{FOIN-REF}$ $\frac{(TO+) - (TO-)}{TOIN-REF}$      | 20.2   | 21.6 | 22.8 | dB   |
| Voff2  | Output offset voltage         | $(FO+) - (FO-)$ at REF=FOIN=1.65V<br>$(TO+) - (TO-)$ at REF=TOIN=1.65V | -47    | 0    | +47  | mV   |

NOTE : This IC need condenser between each supply lines and GND for stoped Oscillation.

[THERMAL CHARACTERISTICS]

| SYMBOL | PARAMETER         | FUNCTION START TEMPERATURE OF IC |     |     | FUNCTION STOP TEMPERATURE OF IC |     |     | Unit |
|--------|-------------------|----------------------------------|-----|-----|---------------------------------|-----|-----|------|
|        |                   | MIN                              | TYP | MAX | MIN                             | TYP | MAX |      |
| TSD    | Thermal Shut Down | —                                | 160 | —   | —                               | 130 | —   | °C   |

\*note3

This TSD function start temperature doesn't show the guaranteed max. temperature of the devices. The guranteed max. temperature is Tj max. which is shown in "9. ABSOLUTE MAXIMUM RATING". The TSD function is a thermal protection in case the temperature of the devices goes up above Tjmax because of wrong use.

And these TSD temperature are the target temperatures for circuit design, not the guaranteed temperatures. (The TSD function of all the devices is not checked by a test in high temperature.)

Standby function

|         | Logic control |  | Drive channel |        |        |       |          |         |
|---------|---------------|--|---------------|--------|--------|-------|----------|---------|
|         | MU1           |  | Loading       | Slide1 | Slide2 | Focus | Tracking | Spindle |
| SELECT2 | H             |  | On            | On     | On     | On    | On       | On      |
| SELECT1 | L/Open        |  | Off           | Off    | Off    | Off   | Off      | Off     |

This IC has MUTE terminal (MU1).  
 It is possible to control ON / OFF of the channel by external logic inputs.  
 In case of SELECT1, the bias of all circuit becomes OFF.  
 Therefore, this mode is available in order to reduce the power dissipation when the waiting mode.  
 In case of SELECT2, the bias of all channel becomes ON.

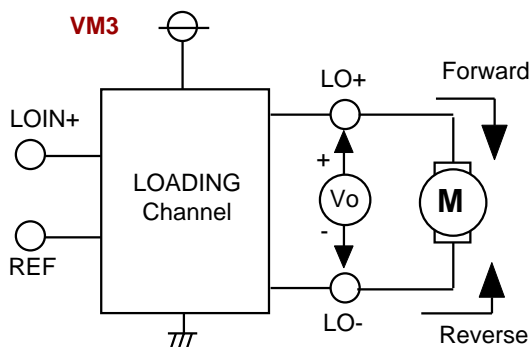
Brake select function

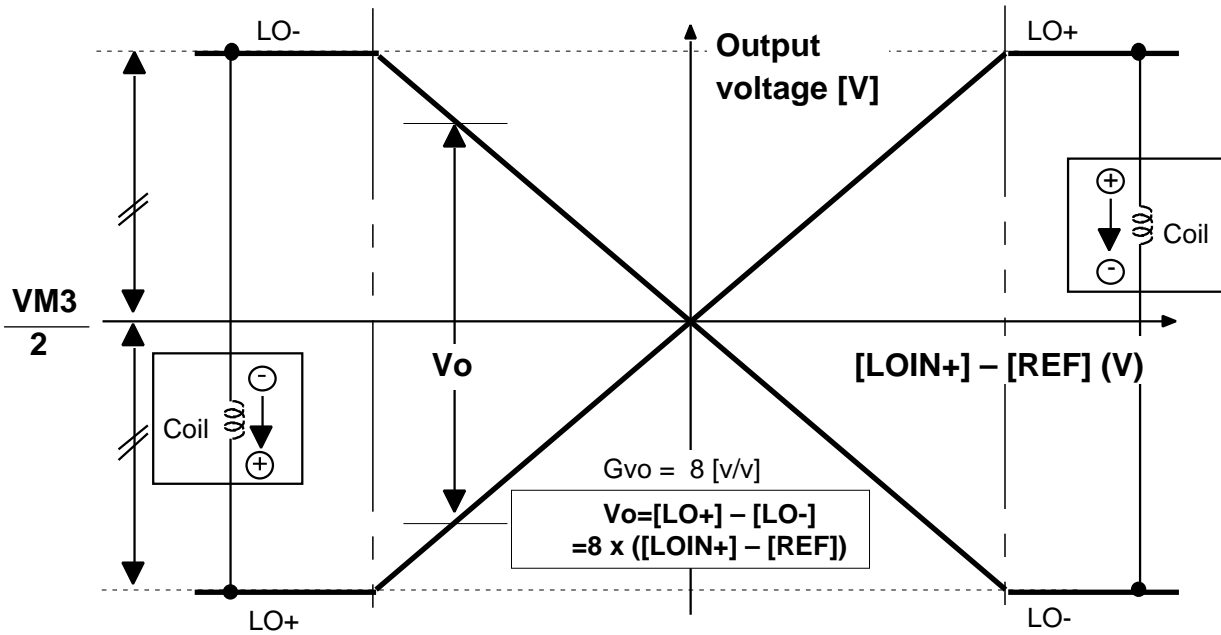
| BRS      | SPIN < REF    | REF < SPIN |
|----------|---------------|------------|
| Hi       | Reverse Brake | Forward    |
| L / Open | Short Brake   | Forward    |

This IC has BRS terminal (BRS).  
 It is possible for a braking timing of Spindle drive to select which the short brake or the reverse brake by BRS.  
 It should select the short brake in case of high speed system and please change to the reverse brake when the rotation speed becomes enough low. It is available when the SPIN voltage is low than the reference voltage.

Loading channel

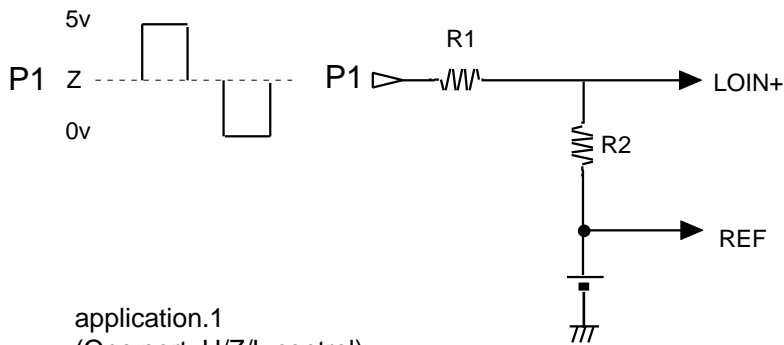
The loading channel is the circuit of BTL voltage drive. This circuit has the referential input. Output swing is determined with  $V_{in} \times 8$ . Also, it is possible for this channel to use for the slide motor, the focus coil and the tracking coil.  
 The input terminal is high impedance. It is possible to do variable a gain by external resistor.  
 In case of one MCU port, if use three state port, it is possible for this channel to have the stop function.





application.1 (MCU : One port H/Z/L control)

| Logic control P1    | Situation of loading channel | Output voltage swing   |
|---------------------|------------------------------|--|
| 5v                  | Forward rotation             | $V_o = \frac{8 \times (5[V] - REF[V]) \times R_2}{R_1 + R_2}$  |
| Z<br>(Hi impedance) | Short brake --> Stop         | $V_o = 0 [V]$  |
| 0                   | Reverse rotation             | $V_o = \frac{-8 \times (5[V] - REF[V]) \times R_2}{R_1 + R_2}$ |





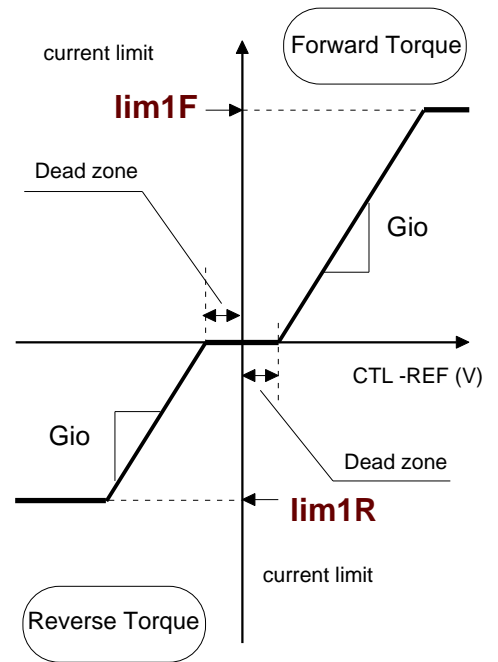
SPINDLE channel

The relationship between the differential voltage between SPIN and REF and the torque is shown in right Figure. The voltage gain[Gvo] is 1.0 [V/V].

The current gain[Gio] is 2.0[A/V] (at sensing resistor : 0.5 ohm, and R1= ,R2=0ohm) in forward torque directions, and the dead zone is from 0mV to 80mV (at R1= ,R2=0ohm) .

The coil current gain under the reverse torque is the same with in forward torque directions. And the limitation function gets on when the differential voltage of VM1(12V) to RSP is 0.5V.

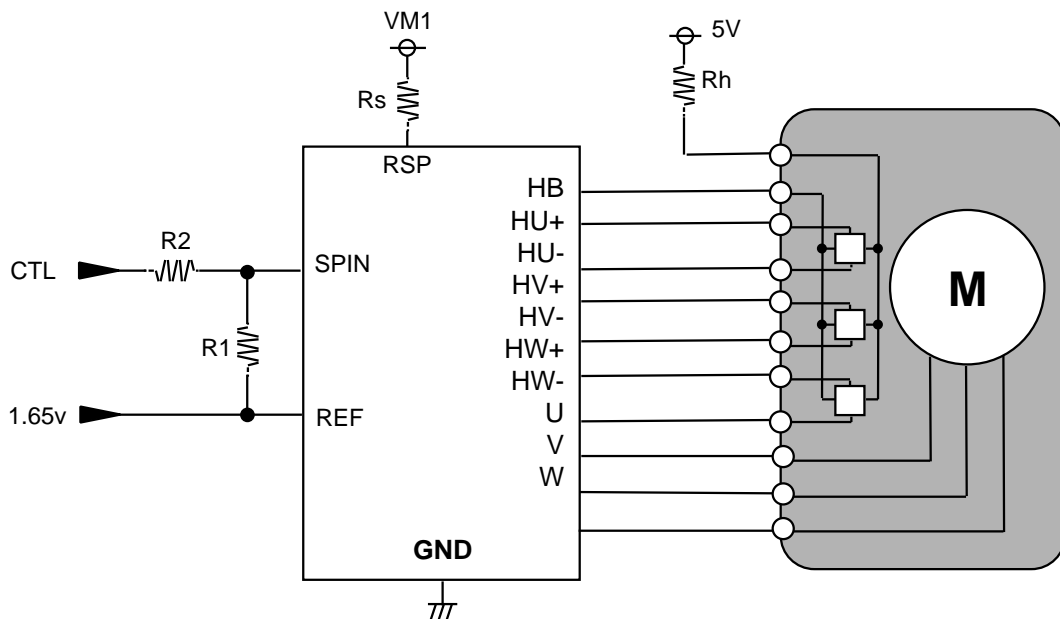
Therefore current-gain-control and current-limit of this IC is determined with sensing resistor value, and more detail control can be determined with setting a gain-resistor outter this IC as below.



The example of current-gain and current-limit of SPINDLE.

| Rs [ Ω ] | Ilim1F [A] | Ilim1R [A] | Gio* [A/V]   |       |           |
|----------|------------|------------|--------------|-------|-----------|
|          |            |            | R1= R2=0 ohm | R1=R2 | R1=2 • R2 |
| 0.50     | 1.00       | 0.56       | 2.00         | 1.00  | 0.66      |
| 0.75     | 0.66       | 0.37       | 1.33         | 0.66  | 0.44      |
| 1.00     | 0.50       | 0.28       | 1.00         | 0.50  | 0.33      |

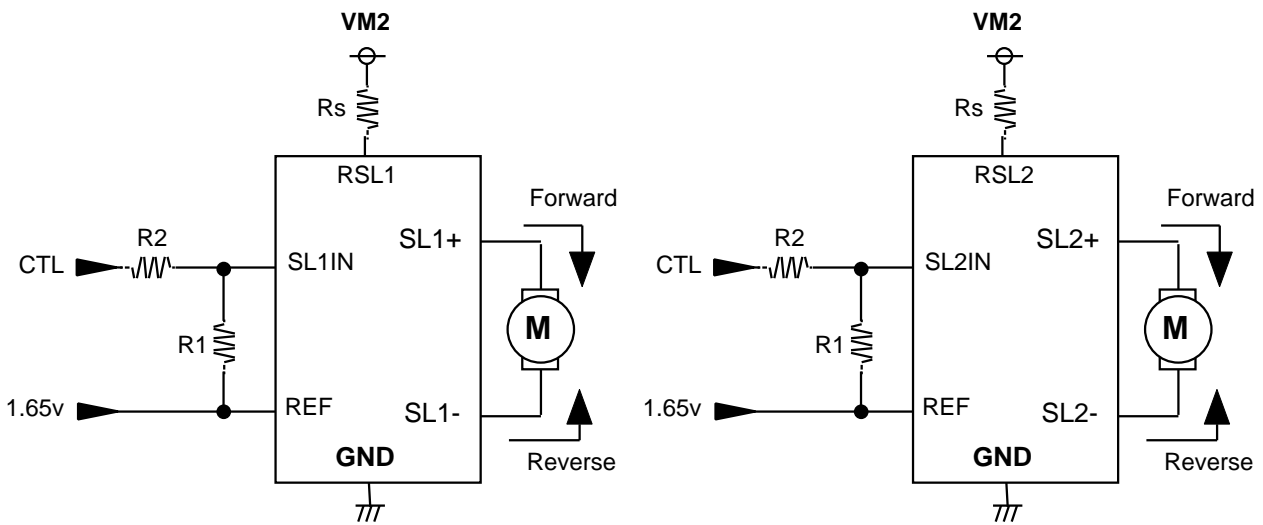
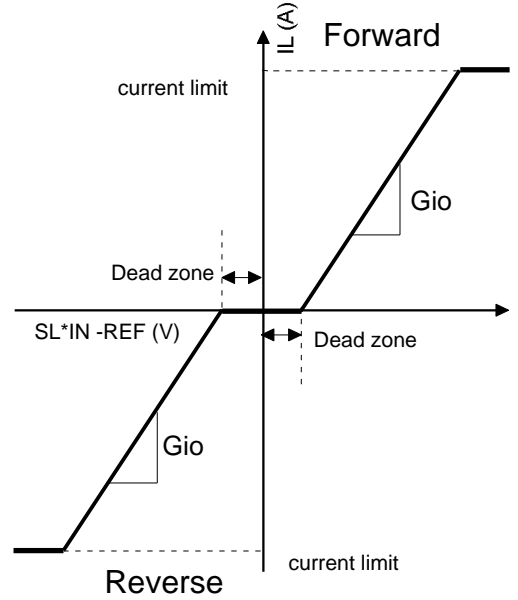
$$G_{io}^* = R_1 / [(R_1 + R_2) \cdot R_s] \text{ [A/V]}$$



SLIDE channel

The relationship between the differential voltage between SLIN and REF and the torque is shown in right Figure. The voltage gain[Gvo] is 1.0 [V/V]. The current gain is 2.0[A/V] (at sensing resistor : 0.5 ohm and R1= ,R2=0ohm) in forward torque directions, and the dead zone is from 0mV to 80mV (at R1= ,R2=0ohm)).

The coil current gain under the reverse torque is the same with in forward torque directions. And the limitation function gets on when the differential voltage of VM2(12V) to RSL is 0.5V. Therefore current-gain-control and current-limit of this IC is determined with sensing resistor value.



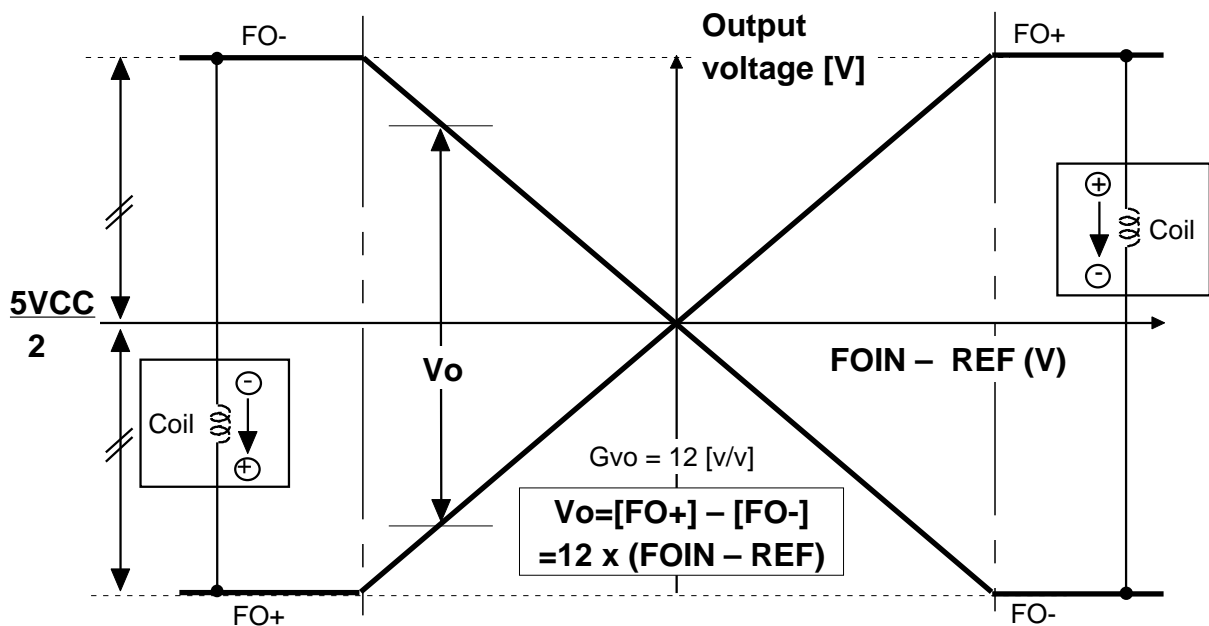
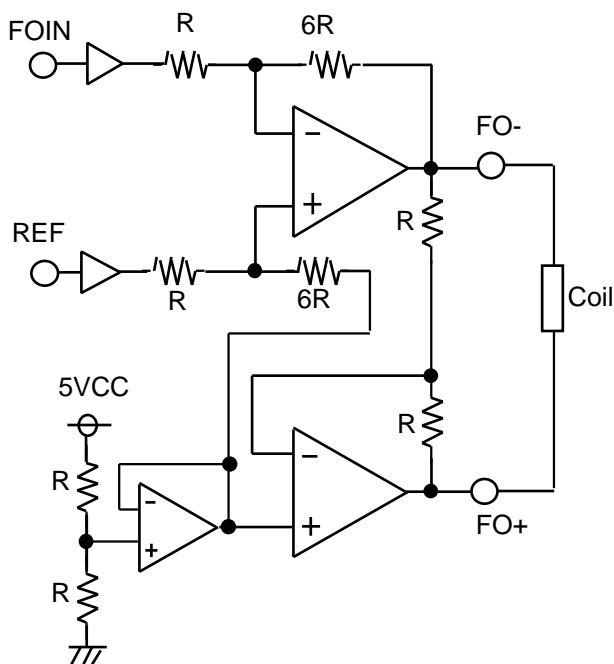
The example of current-gain and current-limit of SLIDE.

| Rs [ Ω ] | Ilim [A] | Gio* [A/V]   |       |           |
|----------|----------|--------------|-------|-----------|
|          |          | R1= R2=0 ohm | R1=R2 | R1=2 • R2 |
| 0.50     | 1.00     | 2.00         | 1.00  | 0.66      |
| 0.75     | 0.66     | 1.33         | 0.66  | 0.44      |
| 1.00     | 0.50     | 1.00         | 0.50  | 0.33      |

$$Gio^* = R1 / [(R1+R2) \cdot Rs] [A/V]$$

FOCUS / TRACKING channel

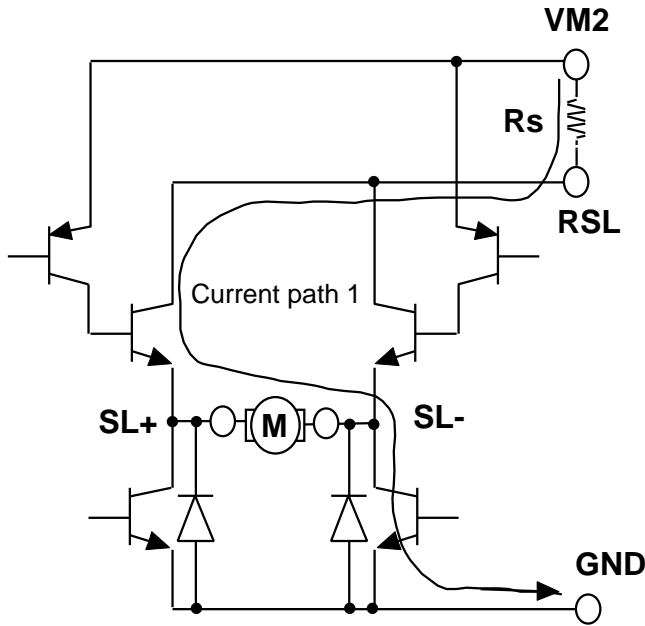
The focus and tracking channel is the voltage control drive using BTL .  
 The focus and tracking is the same composition.  
 The relationship between the differential voltage between FOIN and REF and the output voltage is shown in below Figure.  
 The voltage gain [Gvo] is 5.0 [V/V].



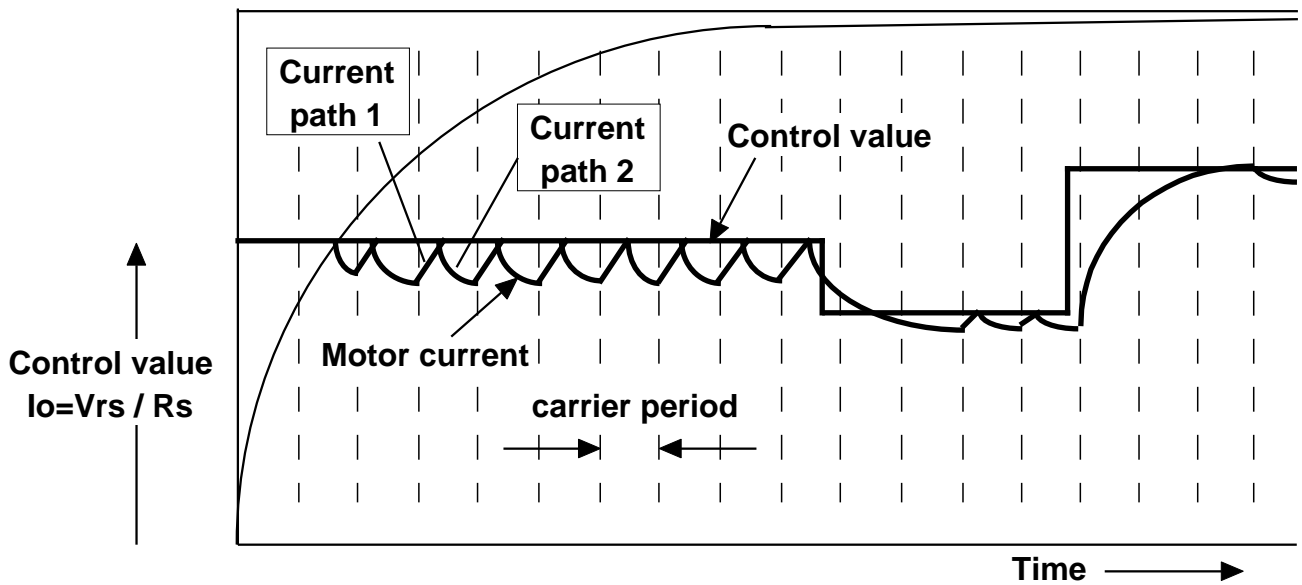
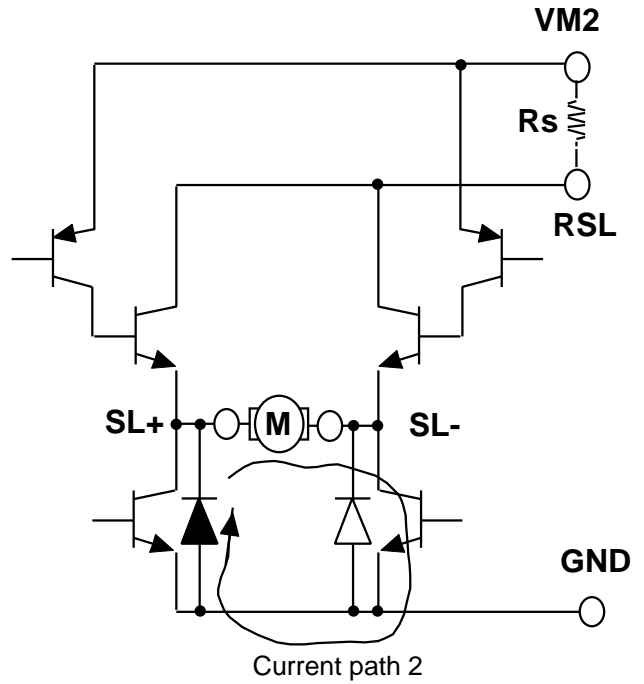
Direct PWM operation

The spindle and the slide channel is controlled by the direct PWM control.  
 Also, built-in the current limit circuit. This IC controls the motor current directly.

FORWARD Current path timing 1.



FORWARD Current path timing 2.



PWM carrier frequency setting

PWM carrier frequency is decided by charging and discharging the capacitor that is connected to OSC terminal outer IC. Examination of the relationship the capacitor connected to OSC terminal and PWM carrier frequency is given in following table.

|                         |           |           |           |           |            |            |            |
|-------------------------|-----------|-----------|-----------|-----------|------------|------------|------------|
| Capacitor [pF]          | 820       | 750       | 330       | 220       | 180        | 130        | 110        |
| Carrier Frequency [KHz] | <b>28</b> | <b>30</b> | <b>65</b> | <b>90</b> | <b>110</b> | <b>140</b> | <b>160</b> |

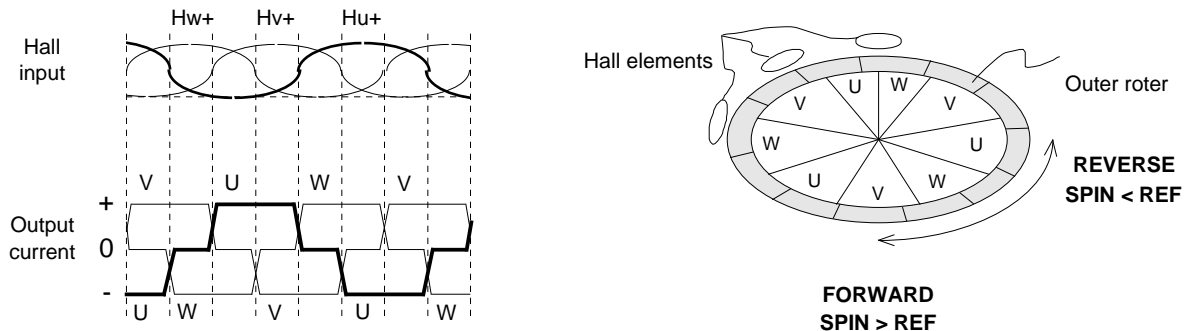
\*note) This PWM carrier frequency is TYP value.

Recommendation of SHORT BRAKE MODE at SPINDLE DRIVE

This IC has two brake mode, PWM-BRAKE-MODE and SHORT-BRAKE-MODE. In this IC recommendation, SHORT-BRAKE-MODE is superior to PWM-BRAKE-MODE to reducing the power dissipation and to avoid braking down of this IC. (By excessive reverse torque current in braking a motor with PWM-BRAKE from high-speed-rotation with being excessive Back-EMF, this IC could be broken.)

The relationship between hall-amplifier-input and output-current-commutation at SPINDLE DRIVE

The relationship between the hall elements and the motor output current is shown in bellow Figure.



#### FG function at SPINDLE DRIVE

The FG terminal outputs the square pulse signal synchronizing with the Hall inputs [Hv+, Hv-] timing. And, the FG terminal is open-collector output.

#### Phase delay circuit at SLIDE

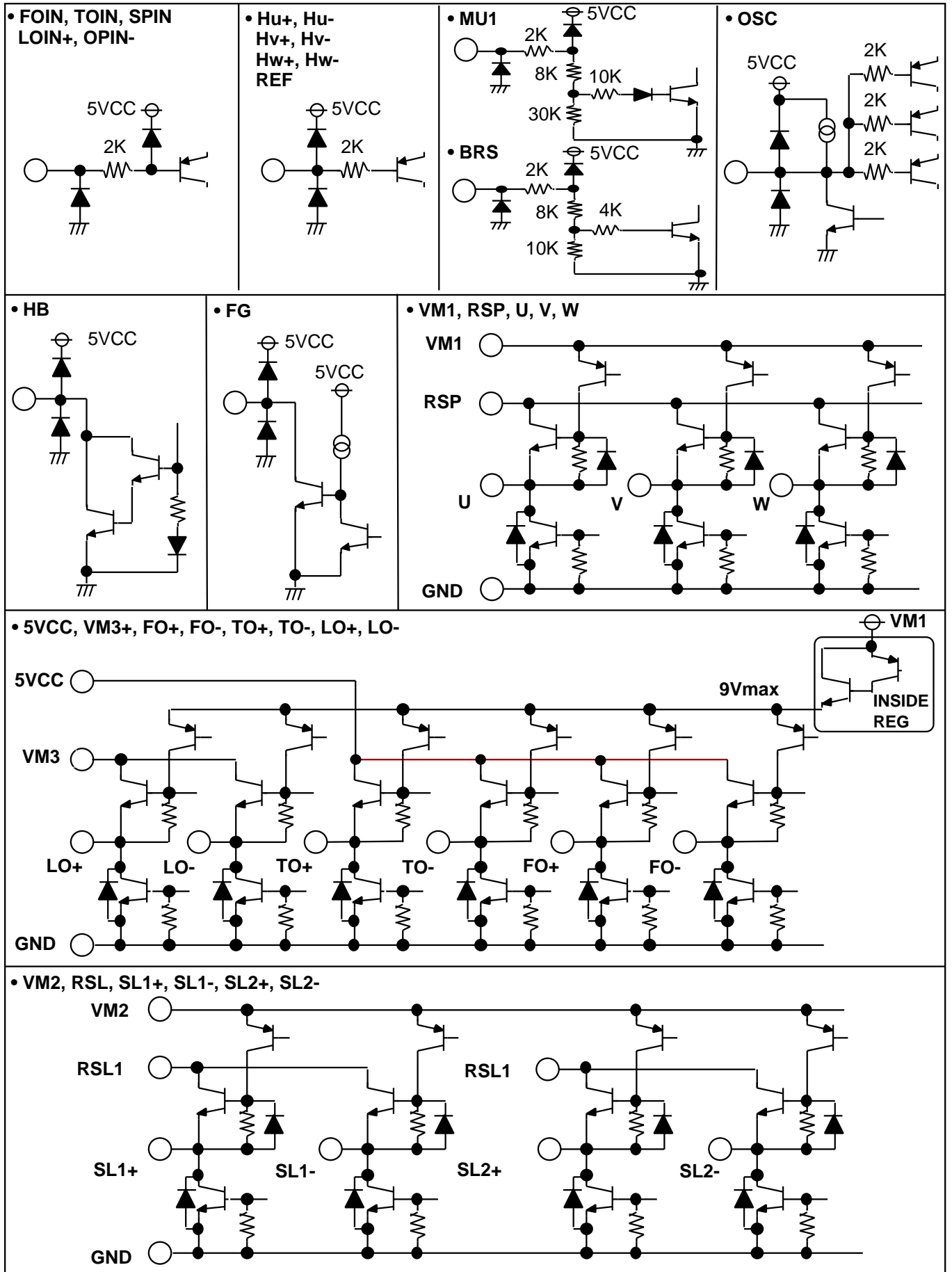
Phase delay circuit is built in the IC to detect an output spike current, when the motor current direction is switching.

In switching the motor current direction, Phase delay circuit switch-off all output transistor of H-bridge for 3 $\mu$ sec.

#### Output current setting at SLIDE

In this IC, since output transistor is NPN-type transistor, motor coil current (Io) is larger than sensing resistance current about 10mA (TYP.) according to base current of output transistor. Therefore please design output current with considering these base current.

I/O circuit



[The boards for thermal derating evaluation]

Board material  
Glass-epoxy FR-4

Size  
70x70mm

thickness  
t=1.6mm

1 and 2 layers

material : copper

thickness : t=18μm

1st layer [TOP view]

2nd layer [BACK view]

N-type board

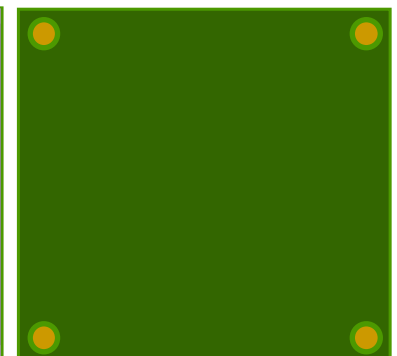
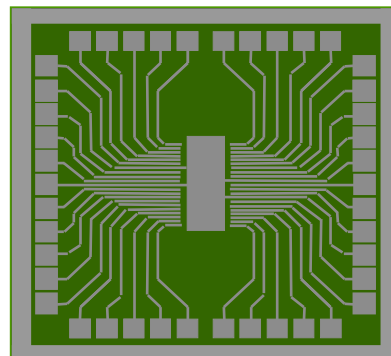
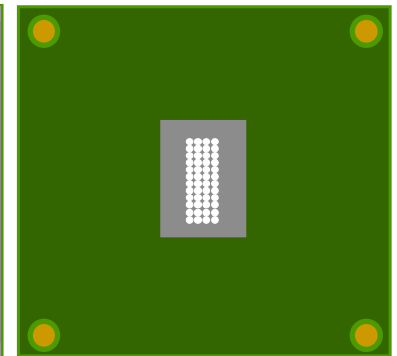
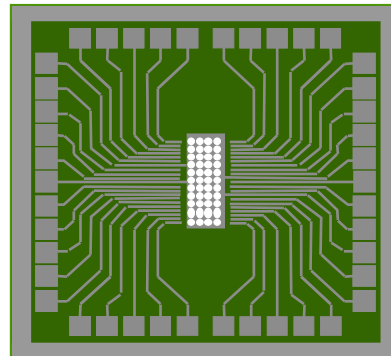
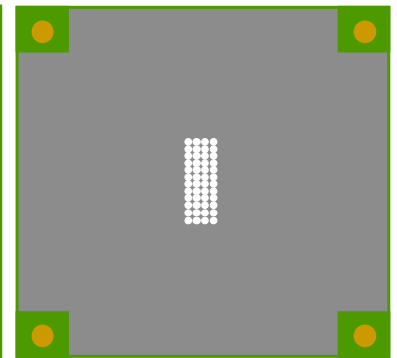
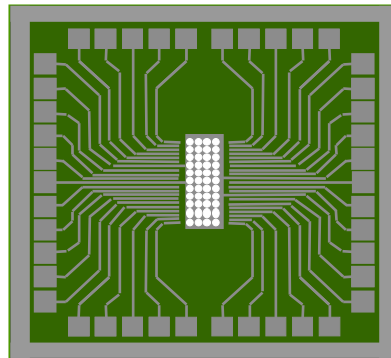
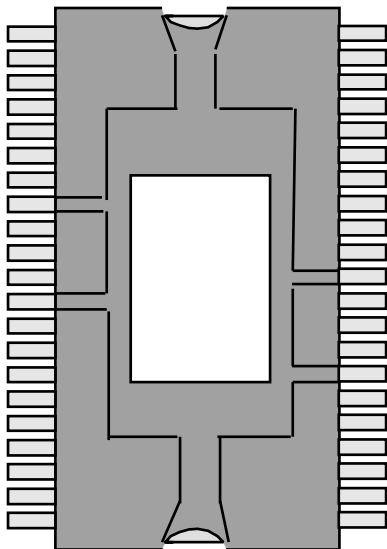
[2 layer]

O-type board

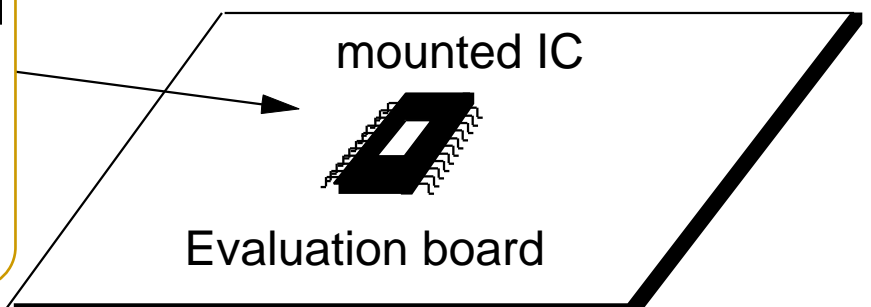
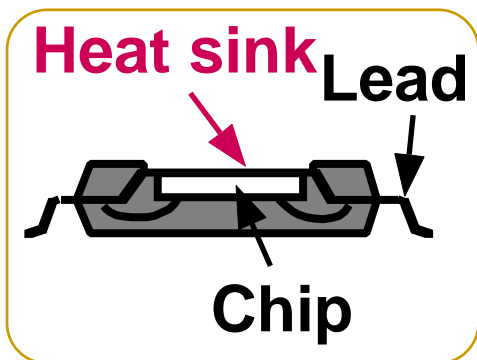
[2 layer]

P-type board

[1 layer]

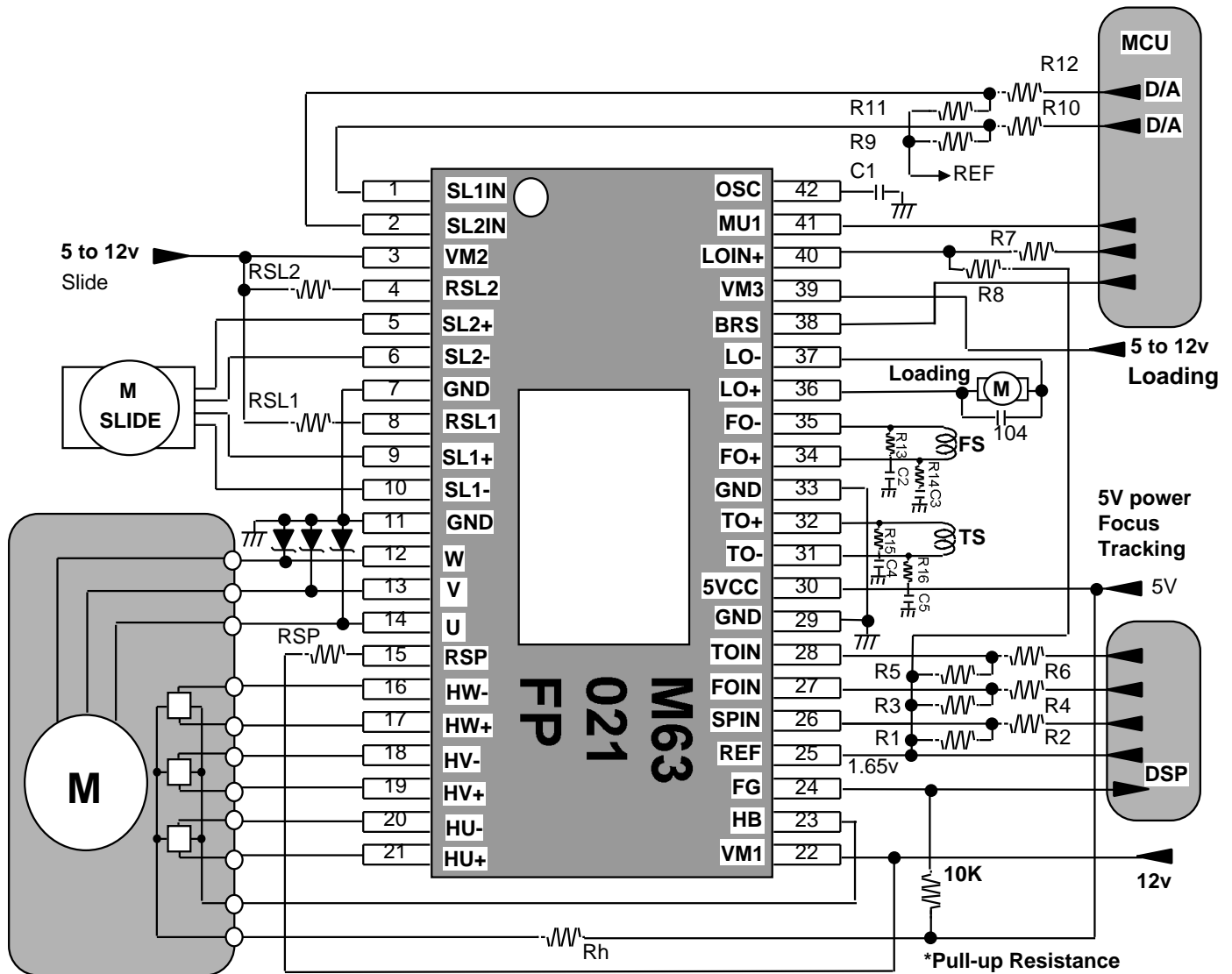


POWER-SSOP 42P9R-B





[APPLICATION CIRCUIT no.1]



<Example>

| External Parts         | Typ  | Unit | Note                                      |
|------------------------|------|------|---|
| RSP                    | 0.33 |      | Ilim1F=1.5A, Ilim1R=1.0A, Gain=3.0A/V     |
| RSL1,RSL2              | 2    |      | Ilim=0.5A, Gain=1A/V                      |
| Rh                     | 200  |      |   |
| R1, R2, R3, R4, R5, R6 | 10K  |      | This is difficult for your specification. |
| R7, R8                 | 10K  |      | This is difficult for your specification. |
| C1                     | 330p | F    | Fosc=65KHz                                |
| R9, R10, R11, R12      | 10K  |      | This is difficult for your specification. |
| D1, D2, D3             | -    | V    | Recommend VF<0.5V at IL=1.0A              |
| R13, R14, R15, R16     | 22   |      |   |
| C2,C3,C4,C5            | 10n  | F    |   |