Ordering number: EN3519A

Monolithic Digital IC

# LB1860,1860M,1861,1861M

## Variable Speed Fan Motor Driver

## Overview

The LB1860 series ICs are drivers for two-phase unipolar drive DC brushless fan motors. They have functions such as driving, lock protection, restart and speed control.

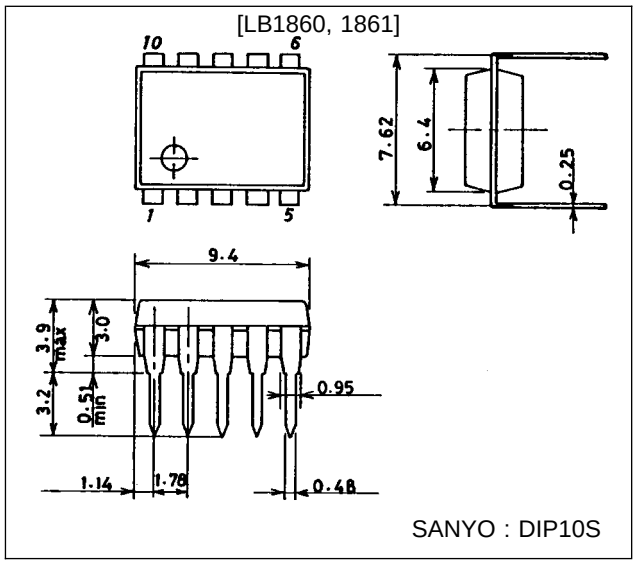
## Features and Functions

- Two-speed mode select function requiring less external component additions: Full speed and Low speed. Or, thermistor-controlled continuous variable-speed function according to ambient operation temperatures.
  → Motor starts rotating at a low speed.
- Motor lock protection and automatic return circuit built in
- Output transistors: Output current $I_O$ = 1.5 A, output circuit protection Zener diodes (LB1860: M-Vz = 57 V/ LB1861: M-Vz = 32 V)
  → Enables low-level noise protection with chip capacitor.
- Built-in thermal shutdown circuit
- Built-in rotation detect function
  (Drive mode: "L", Stop mode: "H")
- The LB1860 series can be operated from either 12 V or 24 V power supply by changing an external resistor.
  (Strong protection against power supply surge)
- Connectable direct to a Hall element

## Package Dimensions

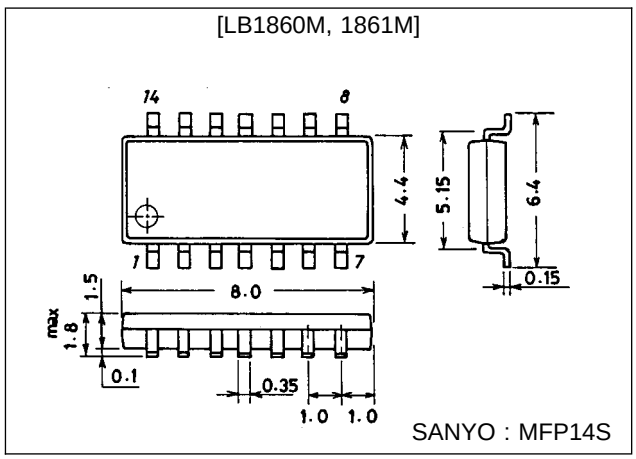
unit: mm

### 3098B-DIP10S




unit: mm

### 3111-MFP14S



# Specifications

## Absolute Maximum Ratings at Ta = 25 °C, ( ): LB1860M, LB1861M

| Parameter | Symbol | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Maximum input current | $I_{CC}$ max | t ≦ 20 ms | 200 | mA |
| Output supply voltage | $V_{OUT}$ | | Internal | V |
| Output current | $I_{OUT}$ | | 1.5 | A |
| RD flow-in current | $I_{RD}$ | | 10 | mA |
| RD supply voltage | $V_{RD}$ | | 50 | V |
| Allowable power dissipation | Pd1 max | | 1.1 | W |
| | Pd2 max | Mounted on 20 × 15 × 1.5 mm glass epoxy board | (0.8) | W |
| Operating temperature | Topr | | –30 to +80 | °C |
| Storage temperature | Tstg | | –55 to +125 | °C |

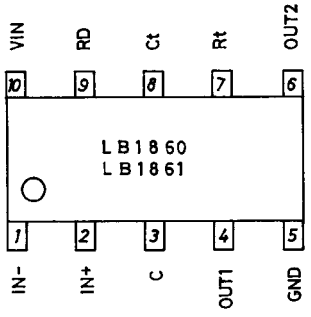
## Allowable Operating Ranges at Ta = 25 °C

| Parameter | Symbol | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Input current range | $I_{CC}$ | | 6.0 to 50 | mA |
| Common-mode input voltage range | $V_{ICM}$ | | 0 to $V_{IN}$ –1.5 | V |

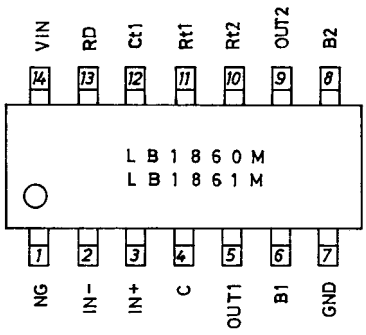
## Electrical Characteristics at Ta = 25 °C, $I_{CC}$ = 10 mA

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Output limiting voltage | $V_{OLM}1$ | LB1860, 1860M: $I_O$ = 0.1 A | 54 | 57 | 60 | V |
| | | LB1861, 1861M: $I_O$ = 0.1 A | 30 | 32 | 34 | V |
| Output saturation voltage | $V_{O\ sat1}$ | $I_O$ = 0.5 A | | 0.95 | 1.2 | V |
| | $V_{O\ sat2}$ | $I_O$ = 1.0 A | | 1.15 | 1.5 | V |
| | $V_{O\ sat3}$ | $I_O$ = 1.5 A | | 1.4 | 2.0 | V |
| Input voltage | $V_{IN}$ | $I_{CC}$ = 7.0 mA | 6.4 | 6.7 | 7.0 | V |
| Amp input offset voltage | $V_{OFF}$ | | –7.0 | 0 | 7.0 | mV |
| Amp input bias current | $I_{BA}$ | | –250 | | | nA |
| RD output saturation voltage | $V_{RD}$ (sat) | $I_{RD}$ = 5 mA | | 0.15 | 0.3 | V |
| C flow-out current | $I_C1$ | C = GND | 2.7 | 3.9 | 5.0 | µA |
| C discharge current | $I_C2$ | C = $V_{IN}$ | 0.35 | 0.50 | 0.65 | µA |
| Comparator input threshold voltage | $V_{TH}1$ | | 0.77 | 0.8 $V_{IN}$ | 0.83 | V |
| | $V_{TH}2$ | | 0.44 | 0.47 $V_{IN}$ | 0.50 | V |
| Ct discharge voltage | Vct | | 0.18 | 0.2 $V_{IN}$ | 0.22 | V |
| Rt input current | $I_{RT}$ | $V_{RT}$ = GND | –440 | –350 | –240 | µA |
| Rt comparator voltage | $V_{RT}$ | $R_T$ = OPEN | 0.59 | 0.62 $V_{IN}$ | 0.65 | V |
| Thermal protection circuit operating voltage | TSD | Design target | | 180 | | °C |
| Thermal protection circuit hysteresis | ΔTSD | Design target | | 40 | | °C |

## Pin Assignments

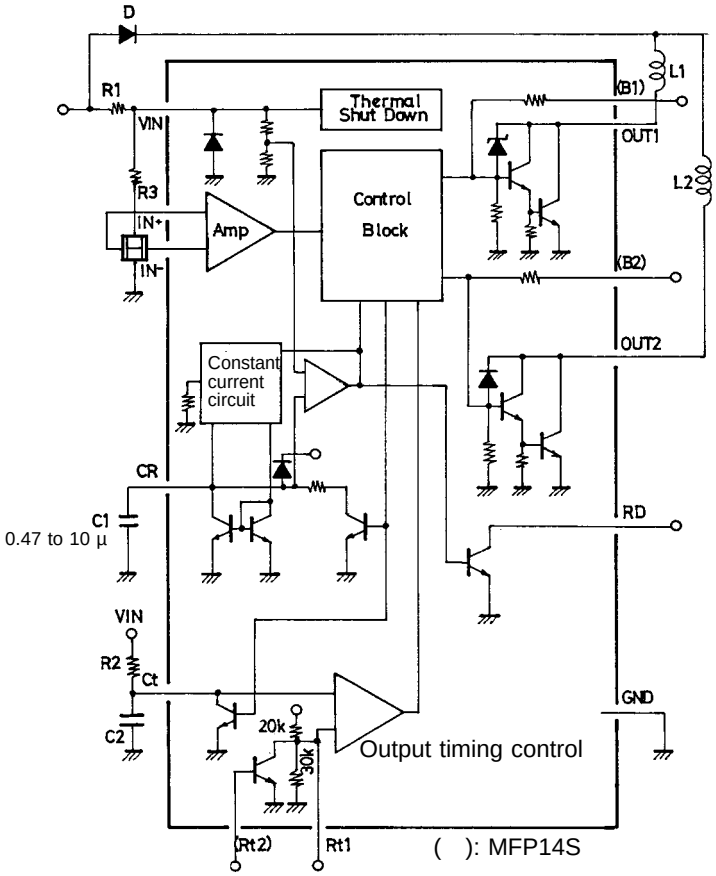



Top view




Top view

## Block Diagram and Application Circuit




Unit (resistance: Ω, capacitance: F)

**Figure 1**

## Truth Table

( ): LB1860M, 1861M

| $IN^+$ | $IN^-$ | Ct | Rt1 | Rt2 | CR | OUT1 | OUT2 | RD | Mode |
|---|---|---|---|---|---|---|---|---|---|
| H | L | H | L | — | L | H | L | L | Full speed |
| L | H | H | L | — | L | L | H | L | Full speed |
| (H) | (L) | — | — | (H) | (L) | (H) | (L) | (L) | (Full speed) |
| (L) | (H) | — | — | (H) | (L) | (L) | (H) | (L) | (Full speed) |
| — | — | L | H | L | L | H | H | L | Low speed |
| — | — | — | — | — | H | H | H | H | Lock protection |

## Designer's Notes

(1) Variable-speed circuit (Rt and Ct pins) — Refer to the application circuit diagram

- The time constant gained by external components C2 and R2 is used to set the length of an 'off' operation time period after phase switching. This means that the variable-speed operations can be performed by changing the 'on' operation time of each phase through the duty control.
- The sawtooth waveform signals are generated by the C2-R2 time constant. The voltage of this signal (Ct pin voltage) increases from 1.3 V to 4.0 V (Vct) at each phase switching. That is, during this period, the driver becomes inactive ($t_{off}$), in which output circuit is turned off.
- If $V_{CC} \geqq 4.0$ V, the driver IC remains active ($t_{on}$) until the next phase switching. During this period, output circuit is turned on.
- If the active drive time of each phase is assumed to '$t_o$', the following relation can be established:

$$t_o = t_{off} + t_{on}$$

$t_{off}$: Fixed constant; $t_{on}$: Rotation speed proportional constant

$$t_{off} = 0.69 \cdot C2 \cdot R2 \quad \text{..... ①}$$

- From this relation, it can be observed that the '$t_o$' and '$t_{on}$' are in proportional relation with each other, and that the '$t_{on}/t_o$' equals the 'on' time duty. As a result, a certain rotation speed can be fixed despite the fact that rotation speed exclusively depends on each motor.
- At the start, the '$t_{on}$' value becomes longer while the '$t_{off}$' value remains unchanged. This means that the '$t_{off}/t_o$' duty becomes small enough compared to normal rotation mode. Therefore, the same start torque as that of the full speed rotation can be obtained because the 'on' operation time duty increases. This enables the motor to start at a very low speed.

(2) Supply voltage ($V_{IN}$ pin)

- The LB1860 has the internal parallel regulator which supplies power to the Hall amplifier circuit and the control block. Therefore, the driver ICs are not affected by power source fluctuations and kickbacks from the motor. They maintain the stable operations even if noise signals such as surge are generated.
- Set the resistance R1 between $V_{CC}$ and $V_{IN}$ so that the $I_{CC}$ current of 6 mA to 50 mA can flow onto the $V_{IN}$ pin within the supply voltage range of a fan motor.
- $V_{IN}$ is 6.7 V typ at $I_{CC}$ = 7 mA.
- The current flowing into $V_{IN}$ is calculated using the equation shown below.

$$I_{CC} = \frac{V_{CC} - V_{IN}}{R1} \quad \cdots\cdots\cdots\cdots \text{②}$$

- Consideration given to surge voltage
- The maximum allowable current at $V_{IN}$ pin is 200 mA. Therefore, the pin is designed to withstand abnormal positive voltage of:

$$Vsurge = V_{IN} + R1 \times 200\ mA \quad \cdots\cdots\cdots\cdots \text{③}$$

(3) Hall input pin voltage (Pins $IN^-$, $IN^+$)

- Set the voltage levels of the input pin for the Hall element output and the Hall element output voltage to within the range of 0 V to $V_{IN}$ – 1.5 V.
- The gain between the hall input pin and the output pin is 100 dB or greater. The offset voltage of the hall input amp is ±7 mV, therefore, the hall element output must be set with the offset voltage (±7 mV) considered.

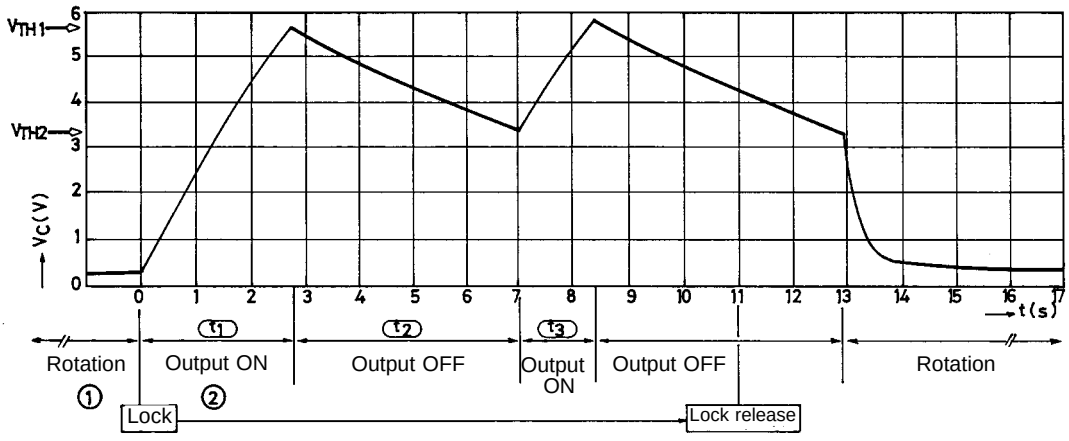
(4) Output transistor (Pins OUT1, OUT2)

- Output current $I_O$ = 1.5 A max
- Output saturation voltage $V_O$ sat = 1.15 V/1.0 A typ
- Output limiting voltage $V_{OLM}$ = 57 V typ (LB1860, 1860M)
  $V_{OLM}$ = 32 V typ (LB1861,1861M)
- Since the LB1860 series have a protect zener diode between collector and base, the kickback voltage induced by the coil is cut at $V_{OLM}$ = 57 V (32 V). When external capacitors are connected between OUT and GND, the capacitance should not exceed 10 µF.

(5) Output protection function (C pin)

- Capacitor pin used in forming an automatic return circuit.
- If rotation is stopped due to overload, the pin voltage level increases and then forces the output to become inactive. In this case, after proper load adjustment, the output returns to the 'drive' mode from the 'stop' mode automatically. By changing the capacitor value, the lock detect time period can be set.

| | | | |
|---|---|---|---|
| For C marked with 1 µF | Lock detect time | | Approximately 2 sec. |
| | Lock protect time | (output ON) | Approximately 1 sec. |
| | | (output OFF) | Approximately 6 sec. |




Automatic Return Circuit C Pin Voltage

① When a fan is rotating, the capacitor is charged at 4 μA (typ) and discharged through the C with pulses according to the rotational speed.

② When a fan is locked, no discharge occurs through the C and the C voltage rises, turning OFF the output at $0.8 \times V_{IN}$.

③ When the output is turned OFF, discharge occurs through the C at 0.5 μA (typ). If the lock is not released when the C voltage drops to $V_{TH}2$, the capacitor is charged to $V_{TH}1$ again. (At this moment, the output is turned ON.) These operations ② and ③ repeated at a cycle of approximately $t_{on} : t_{off} = 1:6$ protect a motor.

④ If the lock is released when the C voltage drops to $V_{TH}2$, the output is turned ON, starting rotation.

(6) Rotation detect signal (RD pin)

- Open collector output (Drive mode: "L", Stop mode: "H")

(7) Radio noise reducing (Pins B1, B2)

- Base pin of Darlington connection output transistor
- If radio noises need to be processed properly, the following actions should be taken:
  - ① Connect a capacitor of 0.01 μ to 0.1 μF between B1 and B2.
  - ② Connect a capacitor of 0.001 μ to 0.01 μF between OUT and B.

  If output causes oscillation, add a resistor of 200 Ω to 1 kΩ in series with a capacitor.

(8) Thermal shutdown function

- Shutdown the driver output in case of coil short-circuiting and abnormal IC heating.

## Thermistor-controlled Application Circuit Example

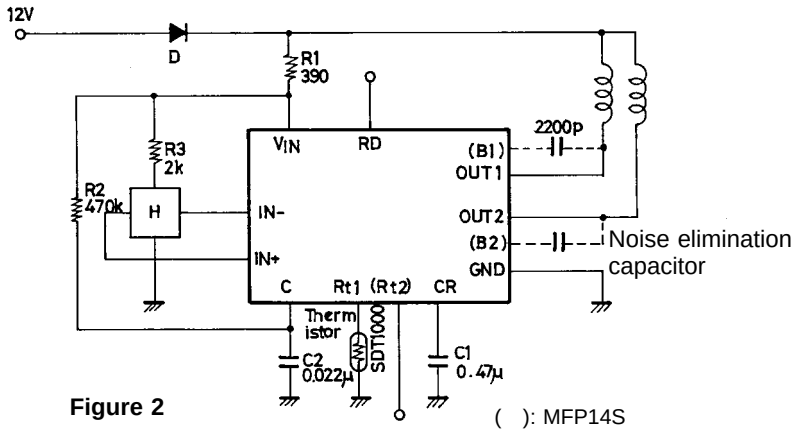



**Figure 2**

( ): MFP14S

Unit (resistance: Ω, capacitance: F)

Use of a thermistor enables motor speed to be sensitive to the operating ambient temperature.

The Rt pin voltage at Ta = 20 °C has 1.42 ms of '$t_{off}$' as calculated in expression 4 with the application constant of Figure 2. However, the Rt pin voltage at Ta = 40 °C is reduced into less than the Vct (= 1.3 V) level, which results in a 0 of '$t_{off}$'. This means the 100% duty.

$$t = -C2 \cdot R2 \cdot 1n \frac{(V_{IN} - V_{Rt})}{V_{IN} - V_{Ct}} \quad \text{..... ④}$$

## Output Timing Chart

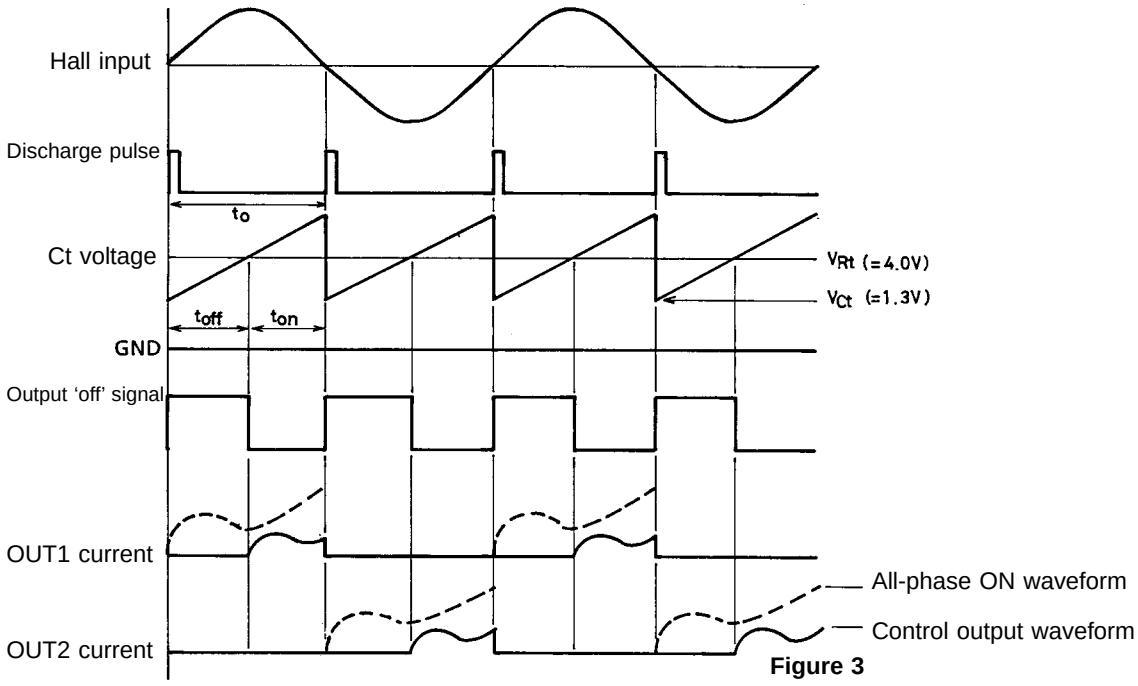
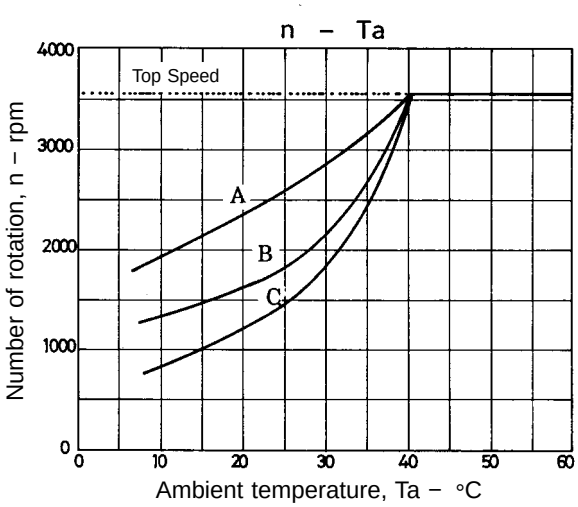



**Figure 3**

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