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# LB11946

## Monolithic Digital IC PWM Current Control Stepping Motor Driver

### Overview

The LB11946 is a stepping motor driver IC that implements PWM current control bipolar drive with a fixed off time. This IC features 15 current setting levels using a fixed VREF voltage and support for micro-stepping drive from 1-2 phase excitation drive to 4W1-2 phase excitation drive. This device is optimal for driving stepping motors such as those used for carriage drive and paper feed in printers.

### Features

- PWM current control (with a fixed off time)
- Logic input serial-parallel converter (allows 1-2, W1-2, 2W1-2, and 4W1-2 phase excitation drive)
- Current attenuation switching function (with slow decay, fast decay, and mixed decay modes)
- Built-in upper and lower side diodes
- Simultaneous on state prevention function (through current prevention)
- Noise canceller function
- Thermal shutdown circuit
- Shutoff on low logic system voltage circuit
- Low-power mode control pin

### Specifications

Maximum Ratings at  $T_a = 25^\circ\text{C}$

| Parameter                   | Symbol     | Conditions                            | Ratings          | Unit             |
|-----------------------------|------------|---------------------------------------|------------------|------------------|
| Motor supply voltage        | $V_{BB}$   |                                       | 50               | V                |
| Peak output current         | $I_O$ peak | $t_w \leq 20\mu\text{S}$              | 1.2              | A                |
| Continuous output current   | $I_O$ max  |                                       | 1.0              | A                |
| Logic system supply voltage | $V_{CC}$   |                                       | 7.0              | V                |
| Logic input voltage range   | $V_{IN}$   |                                       | -0.3 to $V_{CC}$ | V                |
| Emitter output voltage      | VE         | $V_{CC} = 5\text{V}$ specifications   | 1.0              | V                |
|                             |            | $V_{CC} = 3.3\text{V}$ specifications | 0.5              | V                |
| Allowable power dissipation | $P_d$ max  | Independent IC                        | 3.0              | W                |
| Operating temperature       | $T_{opr}$  |                                       | -25 to +85       | $^\circ\text{C}$ |
| Storage temperature         | $T_{stg}$  |                                       | -55 to +150      | $^\circ\text{C}$ |

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

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## Recommended Operating Conditions at Ta = 25°C

| Parameter                   | Symbol           | Conditions                            | Ratings    | Unit |
|-----------------------------|------------------|---------------------------------------|------------|------|
| Motor supply voltage        | V <sub>BB</sub>  |                                       | 10 to 45   | V    |
| Logic system supply voltage | V <sub>CC</sub>  | V <sub>CC</sub> = 5V specifications   | 4.5 to 5.5 | V    |
|                             |                  | V <sub>CC</sub> = 3.3V specifications | 3.0 to 3.6 | V    |
| Reference voltage           | V <sub>REF</sub> | V <sub>CC</sub> = 5V specifications   | 0.0 to 3.0 | V    |
|                             |                  | V <sub>CC</sub> = 3.3V specifications | 0.0 to 1.0 | V    |

## Electrical Characteristics at Ta = 25°C, V<sub>CC</sub> = 5V, V<sub>BB</sub> = 42V, V<sub>REF</sub> = 1.52V

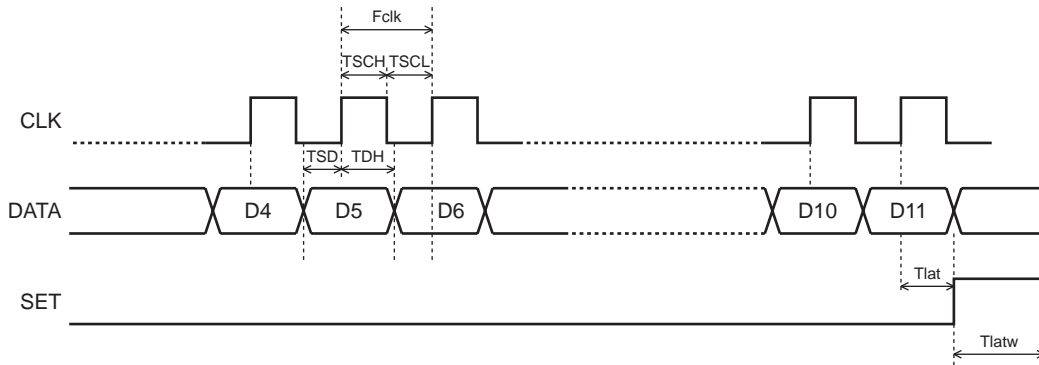
| Parameter                    | Symbol                 | Conditions                                                    | Ratings |      |       | Unit |
|------------------------------|------------------------|---------------------------------------------------------------|---------|------|-------|------|
|                              |                        |                                                               | min     | typ  | max   |      |
| <b>Output Block</b>          |                        |                                                               |         |      |       |      |
| Output stage supply current  | I <sub>BB ON</sub>     |                                                               | 0.9     | 1.3  | 1.7   | mA   |
|                              | I <sub>BB OFF</sub>    |                                                               | 0.52    | 0.7  | 1.05  | mA   |
| Output saturation voltage    | V <sub>O(sat) 1</sub>  | I <sub>O</sub> = +0.5A (sink)                                 |         | 1.1  | 1.4   | V    |
|                              | V <sub>O(sat) 2</sub>  | I <sub>O</sub> = +1.0A (sink)                                 |         | 1.4  | 1.7   | V    |
|                              | V <sub>O(sat) 3</sub>  | I <sub>O</sub> = -0.5A (source)                               |         | 1.9  | 2.2   | V    |
|                              | V <sub>O(sat) 4</sub>  | I <sub>O</sub> = -1.0A (source)                               |         | 2.2  | 2.5   | V    |
| Output leakage current       | I <sub>O1</sub> (leak) | V <sub>O</sub> = V <sub>BB</sub> (sink)                       |         |      | 50    | μA   |
|                              | I <sub>O2</sub> (leak) | V <sub>O</sub> = 0V (source)                                  | -50     |      |       | μA   |
| Output sustain voltage       | V <sub>SUS</sub>       | L = 15mH, I <sub>O</sub> = 1.0A, Design guarantee *           | 45      |      |       | V    |
| <b>Logic Block</b>           |                        |                                                               |         |      |       |      |
| Logic system supply current  | I <sub>CC ON</sub>     | D0 = 1, D1 = 1, D2 = 1, D3 = 1 When these data values are set | 24      | 35   | 46    | mA   |
|                              | I <sub>CC OFF1</sub>   | D0 = 0, D1 = 0, D2 = 0, D3 = 0                                | 22      | 32   | 42    | mA   |
|                              | I <sub>CC OFF2</sub>   | ST = LOW                                                      |         | 0.05 | 0.1   | mA   |
| Input voltage                | V <sub>IH</sub>        |                                                               | 2       |      |       | V    |
|                              | V <sub>IL</sub>        |                                                               |         |      | 0.8   | V    |
| Input current                | I <sub>IH</sub>        | V <sub>IH</sub> = 2 V                                         |         |      | 35    | μA   |
|                              | I <sub>IL</sub>        | V <sub>IL</sub> = 0.8 V                                       | 6       |      |       | μA   |
| Sense voltages               | V <sub>E</sub>         | D0 = 1, D1 = 1, D2 = 1, D3 = 1 When these data values are set | 0.470   | 0.50 | 0.525 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 1, D3 = 0                                | 0.445   | 0.48 | 0.505 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 0, D3 = 1                                | 0.425   | 0.46 | 0.485 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 0, D3 = 0                                | 0.410   | 0.43 | 0.465 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 1, D3 = 1                                | 0.385   | 0.41 | 0.435 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 1, D3 = 0                                | 0.365   | 0.39 | 0.415 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 0, D3 = 1                                | 0.345   | 0.37 | 0.385 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 0, D3 = 0                                | 0.325   | 0.35 | 0.365 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 1, D3 = 1                                | 0.280   | 0.30 | 0.325 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 1, D3 = 0                                | 0.240   | 0.26 | 0.285 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 0, D3 = 1                                | 0.195   | 0.22 | 0.235 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 0, D3 = 0                                | 0.155   | 0.17 | 0.190 | V    |
|                              |                        | D0 = 0, D1 = 0, D2 = 1, D3 = 1                                | 0.115   | 0.13 | 0.145 | V    |
|                              |                        | D0 = 0, D1 = 0, D2 = 1, D3 = 0                                | 0.075   | 0.09 | 0.100 | V    |
| Reference current            | I <sub>REF</sub>       | V <sub>REF</sub> = 1.5V                                       | -0.5    |      |       | μA   |
| CR pin current               | I <sub>CR</sub>        | CR = 1.0V                                                     | -1.6    | -1.2 | -0.8  | mA   |
| MD pin current               | I <sub>MD</sub>        | MD = 1.0V, CR = 4.0V                                          | -5.0    |      |       | μA   |
| Logic system on voltage      | V <sub>LSDON</sub>     |                                                               | 2.6     | 2.8  | 3.0   | V    |
| Logic system off voltage     | V <sub>LSDOFF</sub>    |                                                               | 2.45    | 2.65 | 2.85  | V    |
| LVSD hysteresis              | V <sub>LHIS</sub>      |                                                               | 0.03    | 0.15 | 0.35  | V    |
| Thermal shutdown temperature | T <sub>s</sub>         | Design guarantee *                                            |         | 170  |       | °C   |

\*Design guarantee: Design guarantee value, Do not measurement.

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## AC Electrical Characteristics at $V_{CC} = 5V$

| Parameter                            | Symbol | Conditions | Ratings |     |     | Unit    |
|--------------------------------------|--------|------------|---------|-----|-----|---------|
|                                      |        |            | min     | typ | max |         |
| Clock frequency                      | Fclk   |            |         | 200 | 550 | kHz     |
| Data setup time                      | TDS    |            | 0.9     | 2.5 |     | $\mu S$ |
| Data hold time                       | TDH    |            | 0.9     | 2.5 |     | $\mu S$ |
| Minimum clock high-level pulse width | TSCH   |            | 0.9     | 2.5 |     | $\mu S$ |
| Minimum clock low-level pulse width  | TSCL   |            | 0.9     | 2.5 |     | $\mu S$ |
| SET pin stipulated time              | Tlat   |            | 0.9     | 2.5 |     | $\mu S$ |
| SET pin signal pulse width           | Tlatw  |            | 1.9     | 5.0 |     | $\mu S$ |



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**Electrical Characteristics** at Ta = 25°C, VCC = 3.3V, VBB = 42V, VREF = 1.0V

(When measuring the sense voltage: VREF = 1.03V)

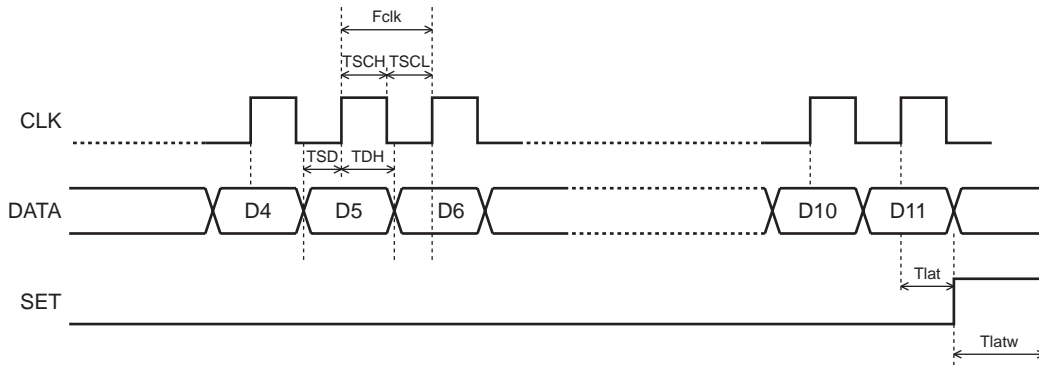
| Parameter                    | Symbol                 | Conditions                                                       | Ratings |       |       | Unit |
|------------------------------|------------------------|------------------------------------------------------------------|---------|-------|-------|------|
|                              |                        |                                                                  | min     | typ   | max   |      |
| <b>Output Block</b>          |                        |                                                                  |         |       |       |      |
| Output stage supply current  | I <sub>BB ON</sub>     |                                                                  | 0.9     | 1.3   | 1.7   | mA   |
|                              | I <sub>BB OFF</sub>    |                                                                  | 0.52    | 0.7   | 1.05  | mA   |
| Output saturation voltage    | V <sub>O(sat) 1</sub>  | I <sub>O</sub> = +0.5A (sink)                                    |         | 1.2   | 1.5   | V    |
|                              | V <sub>O(sat) 2</sub>  | I <sub>O</sub> = +1.0A (sink)                                    |         | 1.5   | 1.8   | V    |
|                              | V <sub>O(sat) 3</sub>  | I <sub>O</sub> = -0.5A (source)                                  |         | 2.0   | 2.3   | V    |
|                              | V <sub>O(sat) 4</sub>  | I <sub>O</sub> = -1.0A (source)                                  |         | 2.3   | 2.6   | V    |
| Output leakage current       | I <sub>O1 (leak)</sub> | V <sub>O</sub> = V <sub>BB</sub> (sink)                          |         |       | 50    | μA   |
|                              | I <sub>O2 (leak)</sub> | V <sub>O</sub> = 0V (source)                                     | -50     |       |       | μA   |
| Output sustain voltage       | V <sub>SUS</sub>       | L = 15mH I <sub>O</sub> -1.5A, Design guarantee *                | 45      |       |       | V    |
| <b>Logic Block</b>           |                        |                                                                  |         |       |       |      |
| Logic system supply current  | I <sub>CC ON</sub>     | D0 = 1, D1 = 1, D2 = 1, D3 = 1<br>When these data values are set | 21      | 30    | 39    | mA   |
|                              | I <sub>CC OFF1</sub>   | D0 = 0, D1 = 0, D2 = 0, D3 = 0                                   | 19      | 28    | 36.5  | mA   |
|                              | I <sub>CC OFF2</sub>   | ST = 0.8V                                                        |         | 0.03  | 0.1   | mA   |
| Input voltage                | V <sub>IH</sub>        |                                                                  | 2       |       |       | V    |
|                              | V <sub>IL</sub>        |                                                                  |         |       | 0.8   | V    |
| Input current                | I <sub>IH</sub>        | V <sub>IH</sub> = 2V                                             |         |       | 35    | μA   |
|                              | I <sub>IL</sub>        | V <sub>IL</sub> = 0.8V                                           | 6       |       |       | μA   |
| Sense voltages               | VE                     | D0 = 1, D1 = 1, D2 = 1, D3 = 1 VREF = 1.03V                      | 0.303   | 0.330 | 0.356 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 1, D3 = 0 VREF = 1.03V                      | 0.290   | 0.315 | 0.341 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 0, D3 = 1 VREF = 1.03V                      | 0.276   | 0.300 | 0.324 | V    |
|                              |                        | D0 = 1, D1 = 1, D2 = 0, D3 = 0 VREF = 1.03V                      | 0.263   | 0.286 | 0.309 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 1, D3 = 1 VREF = 1.03V                      | 0.250   | 0.272 | 0.294 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 1, D3 = 0 VREF = 1.03V                      | 0.236   | 0.257 | 0.278 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 0, D3 = 1 VREF = 1.03V                      | 0.223   | 0.243 | 0.263 | V    |
|                              |                        | D0 = 1, D1 = 0, D2 = 0, D3 = 0 VREF = 1.03V                      | 0.209   | 0.228 | 0.247 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 1, D3 = 1 VREF = 1.03V                      | 0.183   | 0.200 | 0.217 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 1, D3 = 0 VREF = 1.03V                      | 0.155   | 0.170 | 0.185 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 0, D3 = 1 VREF = 1.03V                      | 0.128   | 0.143 | 0.158 | V    |
|                              |                        | D0 = 0, D1 = 1, D2 = 0, D3 = 0 VREF = 1.03V                      | 0.102   | 0.114 | 0.126 | V    |
|                              |                        | D0 = 0, D1 = 0, D2 = 1, D3 = 1 VREF = 1.03V                      | 0.074   | 0.085 | 0.096 | V    |
|                              |                        | D0 = 0, D1 = 0, D2 = 1, D3 = 0 VREF = 1.03V                      | 0.047   | 0.057 | 0.067 | V    |
| Reference current            | I <sub>REF</sub>       | VREF = 1.0V                                                      | -0.5    |       |       | μA   |
| CR pin current               | I <sub>CR</sub>        | CR = 1.0V                                                        | -0.91   | -0.7  | -0.49 | mA   |
| MD pin current               | I <sub>MD</sub>        | MD = 1.0V, CR = 4.0V                                             | -5.0    |       |       | μA   |
| LVSD voltage                 | V <sub>LSDON</sub>     |                                                                  | 2.6     | 2.8   | 3.0   | V    |
| Logic system off voltage     | V <sub>LSDOFF</sub>    |                                                                  | 2.45    | 2.65  | 2.85  | V    |
| LVSD hysteresis              | V <sub>LHIS</sub>      |                                                                  | 0.03    | 0.15  | 0.35  | V    |
| Thermal shutdown temperature | T <sub>s</sub>         | Design guarantee *                                               |         | 170   |       | °C   |

\*Design guarantee: Design guarantee value, Do not measurement.

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## AC Electrical Characteristics at $V_{CC} = 3.3V$

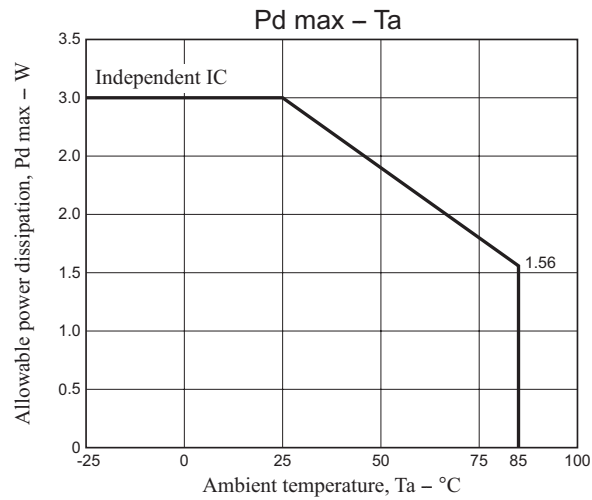
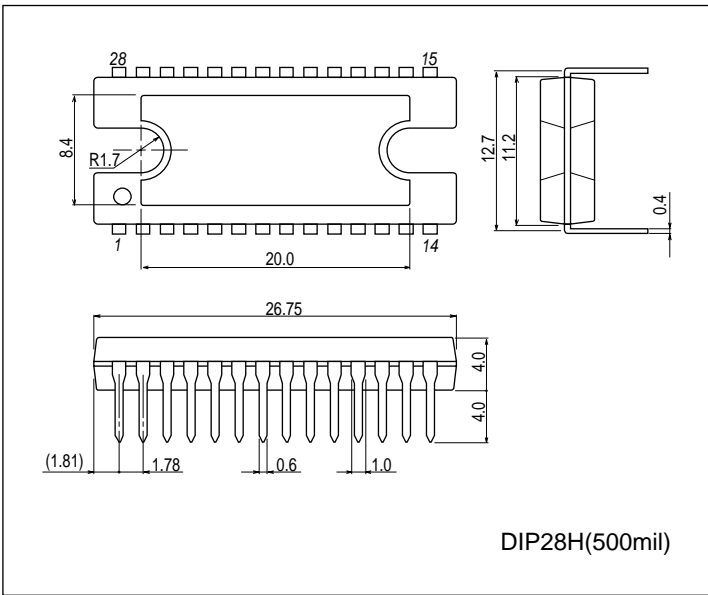
| Parameter                            | Symbol | Conditions | Ratings |     |     | Unit    |
|--------------------------------------|--------|------------|---------|-----|-----|---------|
|                                      |        |            | min     | typ | max |         |
| Clock frequency                      | Fclk   |            |         | 200 | 550 | kHz     |
| Data setup time                      | TDS    |            | 0.9     | 2.5 |     | $\mu S$ |
| Data hold time                       | TDH    |            | 0.9     | 2.5 |     | $\mu S$ |
| Minimum clock high-level pulse width | TSCH   |            | 0.9     | 2.5 |     | $\mu S$ |
| Minimum clock low-level pulse width  | TSCL   |            | 0.9     | 2.5 |     | $\mu S$ |
| SET pin stipulated time              | Tlat   |            | 0.9     | 2.5 |     | $\mu S$ |
| SET pin signal pulse width           | Tlatw  |            | 1.9     | 5.0 |     | $\mu S$ |



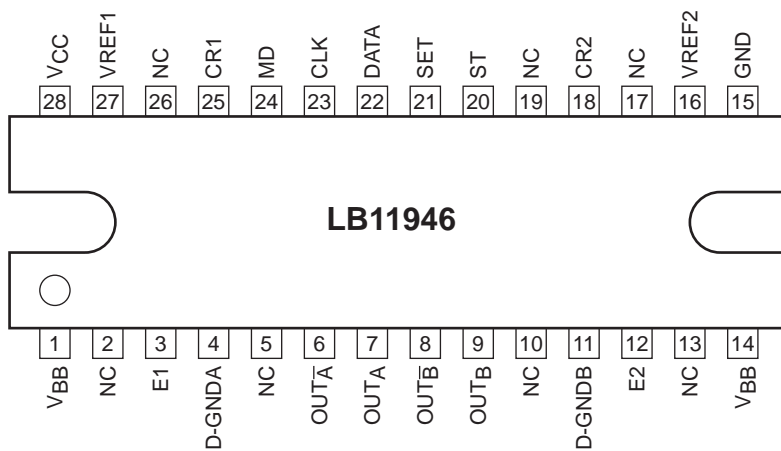
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## Package Dimensions

unit : mm (typ)  
3147C

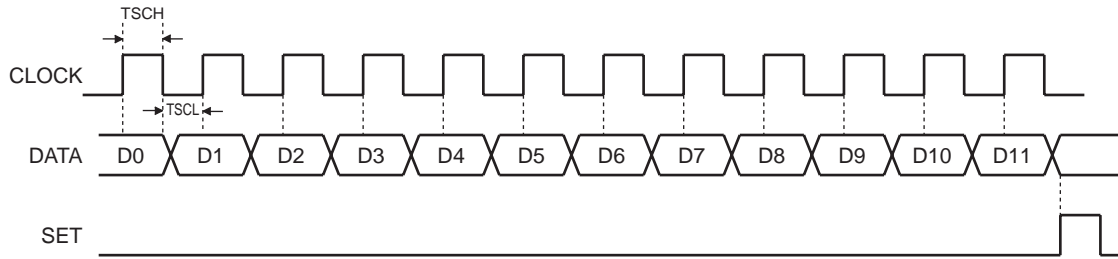


## Pin Assignment



Note: The D-GNDA and D-GNDB pins are the anode sides of the lower side diodes

Timing Chart



Serially Transferred Data Definition

| No. | IA4 | IA3 | IA2 | IA1 | DE1 | PH1 | IB4 | IB3 | IB2 | IB1 | DE2 | PH2 | Output mode      |                               |                  |                               | I/O ratio | DEC MODE |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------------|-------------------------------|------------------|-------------------------------|-----------|----------|
|     | D0  | D1  | D2  | D3  | D4  | D5  | D6  | D7  | D8  | D9  | D10 | D11 | OUT <sub>A</sub> | OUT <sub>A</sub> <sup>̄</sup> | OUT <sub>B</sub> | OUT <sub>B</sub> <sup>̄</sup> |           |          |
| 0   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | H                | L                             | H                | L                             | 100%      | SLOW     |
| 1   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | 0   | 1   | 1   | H                | L                             | H                | L                             | 96        | SLOW     |
| 2   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | H                | L                             | H                | L                             | 91        | SLOW     |
| 3   | 1   | 1   | 0   | 0   | 1   | 1   | 1   | 1   | 0   | 0   | 1   | 1   | H                | L                             | H                | L                             | 87        | SLOW     |
| 4   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | H                | L                             | H                | L                             | 83        | SLOW     |
| 5   | 1   | 0   | 1   | 0   | 1   | 1   | 1   | 0   | 1   | 0   | 1   | 1   | H                | L                             | H                | L                             | 78        | SLOW     |
| 6   | 1   | 0   | 0   | 1   | 1   | 1   | 1   | 0   | 0   | 1   | 1   | 1   | H                | L                             | H                | L                             | 74        | SLOW     |
| 7   | 1   | 0   | 0   | 0   | 1   | 1   | 1   | 0   | 0   | 0   | 1   | 1   | H                | L                             | H                | L                             | 70        | SLOW     |
| 8   | 0   | 1   | 1   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | H                | L                             | H                | L                             | 61        | SLOW     |
| 9   | 0   | 1   | 1   | 0   | 1   | 1   | 0   | 1   | 1   | 0   | 1   | 1   | H                | L                             | H                | L                             | 52        | SLOW     |
| 10  | 0   | 1   | 0   | 1   | 1   | 1   | 0   | 1   | 0   | 1   | 1   | 1   | H                | L                             | H                | L                             | 44        | SLOW     |
| 11  | 0   | 1   | 0   | 0   | 1   | 1   | 0   | 1   | 0   | 0   | 1   | 1   | H                | L                             | H                | L                             | 35        | SLOW     |
| 12  | 0   | 0   | 1   | 1   | 1   | 1   | 0   | 0   | 1   | 1   | 1   | 1   | H                | L                             | H                | L                             | 26        | SLOW     |
| 13  | 0   | 0   | 1   | 0   | 1   | 1   | 0   | 0   | 1   | 0   | 1   | 1   | H                | L                             | H                | L                             | 17        | SLOW     |
| 14  | 1   | 1   | 1   | 1   | 0   | 0   | 1   | 1   | 1   | 1   | 0   | 0   | L                | H                             | L                | H                             | 100       | FAST     |
| 15  | 1   | 1   | 1   | 0   | 0   | 0   | 1   | 1   | 1   | 0   | 0   | 0   | L                | H                             | L                | H                             | 96        | FAST     |
| 16  | 1   | 1   | 0   | 1   | 0   | 0   | 1   | 1   | 0   | 1   | 0   | 0   | L                | H                             | L                | H                             | 91        | FAST     |
| 17  | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 1   | 0   | 0   | 0   | 0   | L                | H                             | L                | H                             | 87        | FAST     |
| 18  | 1   | 0   | 1   | 1   | 0   | 0   | 1   | 0   | 1   | 1   | 0   | 0   | L                | H                             | L                | H                             | 83        | FAST     |
| 19  | 1   | 0   | 1   | 0   | 0   | 0   | 1   | 0   | 1   | 0   | 0   | 0   | L                | H                             | L                | H                             | 78        | FAST     |
| 20  | 1   | 0   | 0   | 1   | 0   | 0   | 1   | 0   | 0   | 1   | 0   | 0   | L                | H                             | L                | H                             | 74        | FAST     |
| 21  | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | L                | H                             | L                | H                             | 70        | FAST     |
| 22  | 0   | 1   | 1   | 1   | 0   | 0   | 0   | 1   | 1   | 1   | 0   | 0   | L                | H                             | L                | H                             | 61        | FAST     |
| 23  | 0   | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 1   | 0   | 0   | 0   | L                | H                             | L                | H                             | 52        | FAST     |
| 24  | 0   | 1   | 0   | 1   | 0   | 0   | 0   | 1   | 0   | 1   | 0   | 0   | L                | H                             | L                | H                             | 44        | FAST     |
| 25  | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   | L                | H                             | L                | H                             | 35        | FAST     |
| 26  | 0   | 0   | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 1   | 0   | 0   | L                | H                             | L                | H                             | 26        | FAST     |
| 27  | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | L                | H                             | L                | H                             | 17        | FAST     |
| 28  | 0   | 0   | 0   | 0   | *   | *   | 0   | 0   | 0   | 0   | *   | *   | OFF              | OFF                           | OFF              | OFF                           | 0         | -        |

Note \*: Either 0 or 1.

Note \*1: In mixed decay mode, set D4 and D10 to 0 and set the MD pin to a level in the range 1.5 to 4.0V.

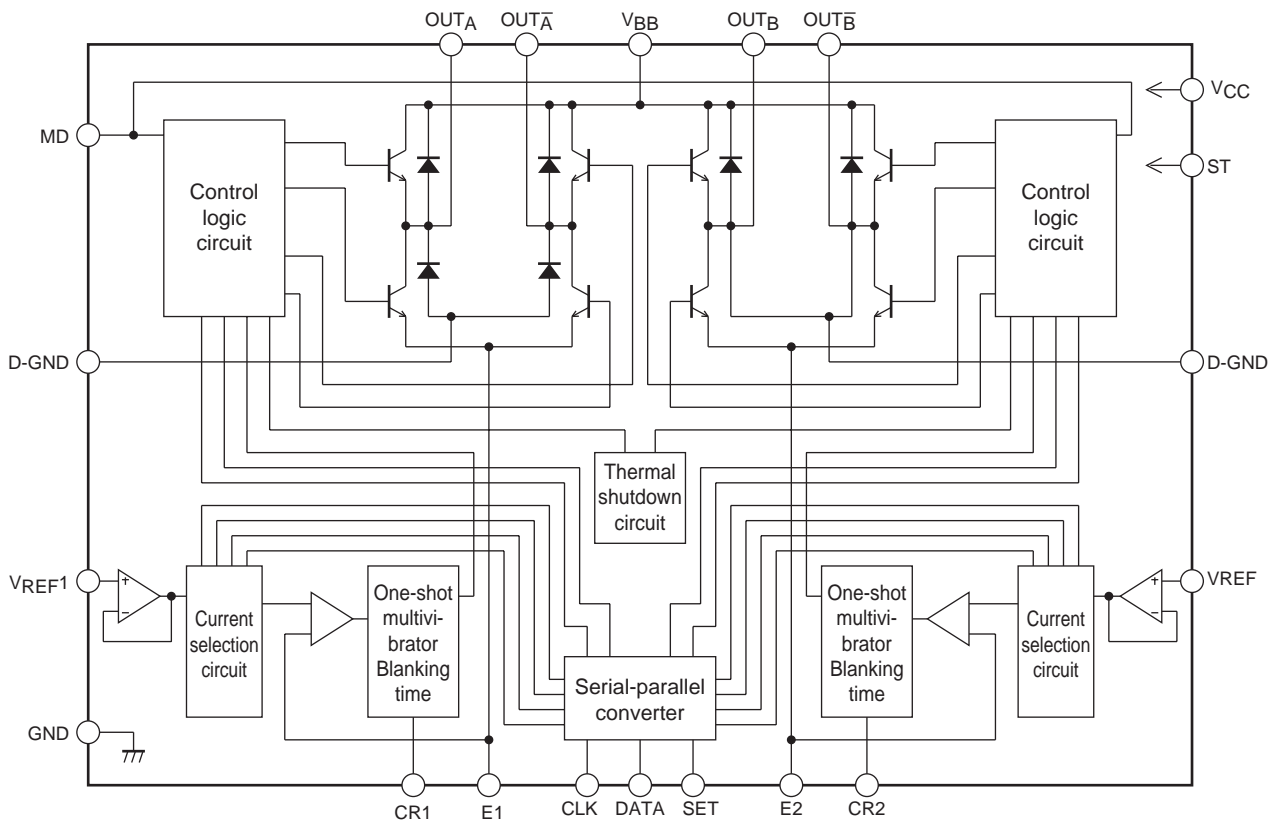
# LB11946

**Current Settings Truth Table** \* Items in parentheses are defined by the serial data.

| IA4 (D0) | IA3 (D1) | IA2 (D2) | IA1 (D3) | Set current Iout                      | Current ratio (%) |
|----------|----------|----------|----------|---------------------------------------|-------------------|
| 1        | 1        | 1        | 1        | $11.5/11.5 \times VREF/3.04RE = Iout$ | 100               |
| 1        | 1        | 1        | 0        | $11.0/11.5 \times VREF/3.04RE = Iout$ | 95.65             |
| 1        | 1        | 0        | 1        | $10.5/11.5 \times VREF/3.04RE = Iout$ | 91.30             |
| 1        | 1        | 0        | 0        | $10.0/11.5 \times VREF/3.04RE = Iout$ | 86.95             |
| 1        | 0        | 1        | 1        | $9.5/11.5 \times VREF/3.04RE = Iout$  | 82.61             |
| 1        | 0        | 1        | 0        | $9.0/11.5 \times VREF/3.04RE = Iout$  | 78.26             |
| 1        | 0        | 0        | 1        | $8.5/11.5 \times VREF/3.04RE = Iout$  | 73.91             |
| 1        | 0        | 0        | 0        | $8.0/11.5 \times VREF/3.04RE = Iout$  | 69.56             |
| 0        | 1        | 1        | 1        | $7.0/11.5 \times VREF/3.04RE = Iout$  | 60.87             |
| 0        | 1        | 1        | 0        | $6.0/11.5 \times VREF/3.04RE = Iout$  | 52.17             |
| 0        | 1        | 0        | 1        | $5.0/11.5 \times VREF/3.04RE = Iout$  | 43.48             |
| 0        | 1        | 0        | 0        | $4.0/11.5 \times VREF/3.04RE = Iout$  | 34.78             |
| 0        | 0        | 1        | 1        | $3.0/11.5 \times VREF/3.04RE = Iout$  | 26.08             |
| 0        | 0        | 1        | 0        | $2.0/11.5 \times VREF/3.04RE = Iout$  | 17.39             |

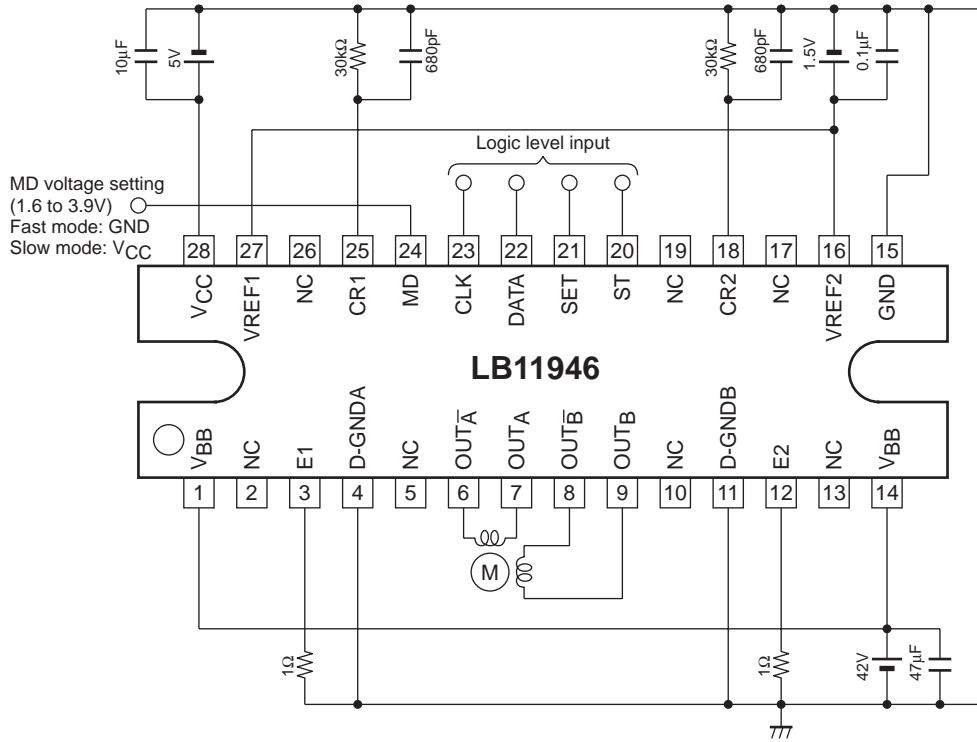
Note: The current ratios shown are calculated values.

## Block Diagram

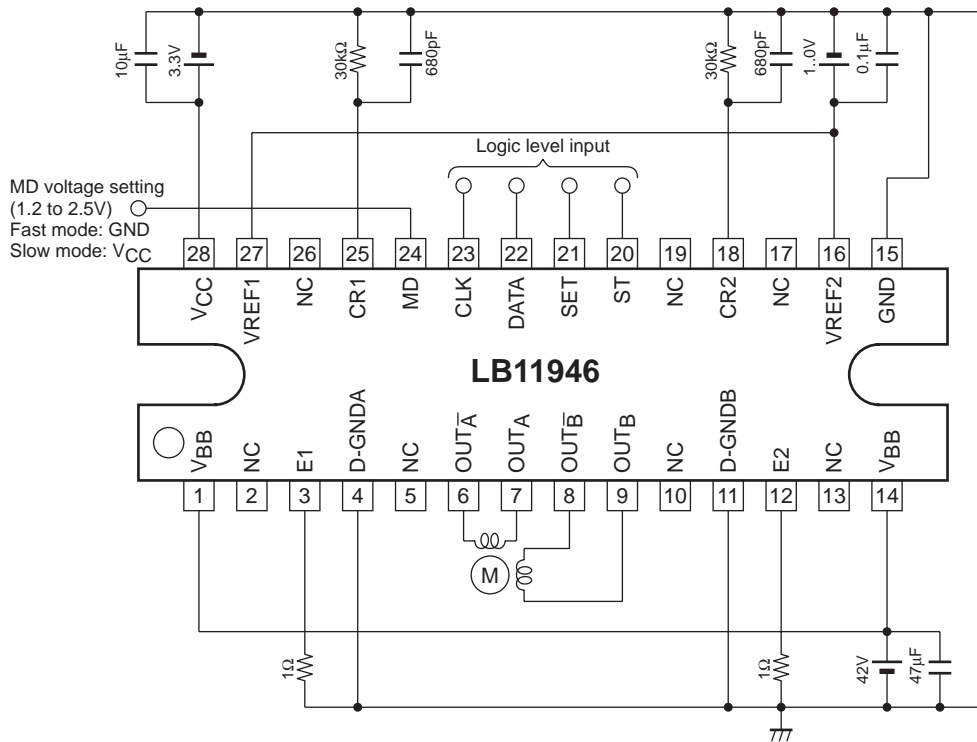


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## Sample Application Circuit at $V_{CC} = 5V$



## Sample Application Circuit at $V_{CC} = 3.3V$



**SLOW DECAY Current Path**

The reregenerative current at upper-side transistor switching operates

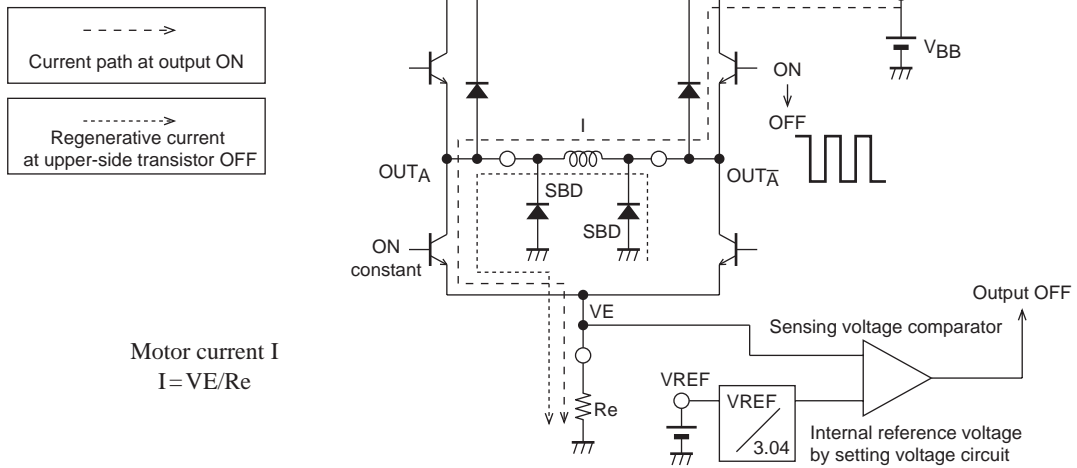


Fig.1

**FAST DECAY Current Path**

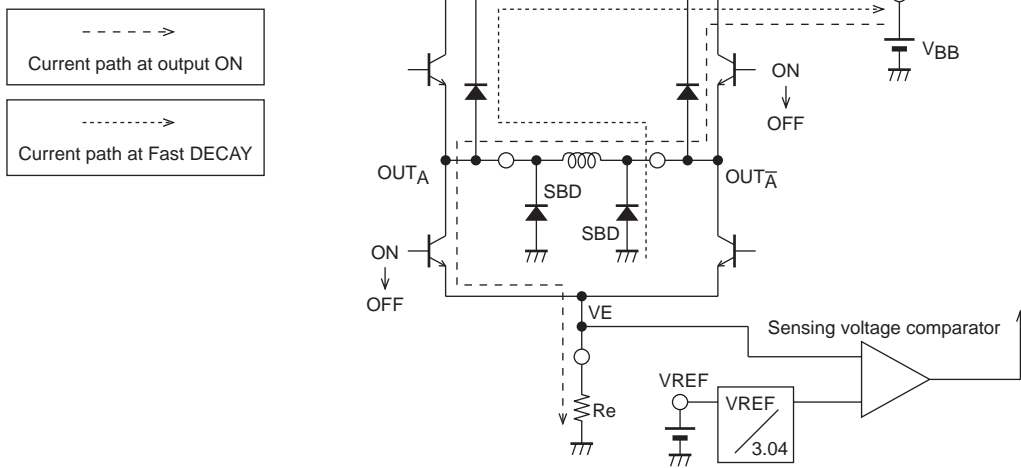


Fig.2

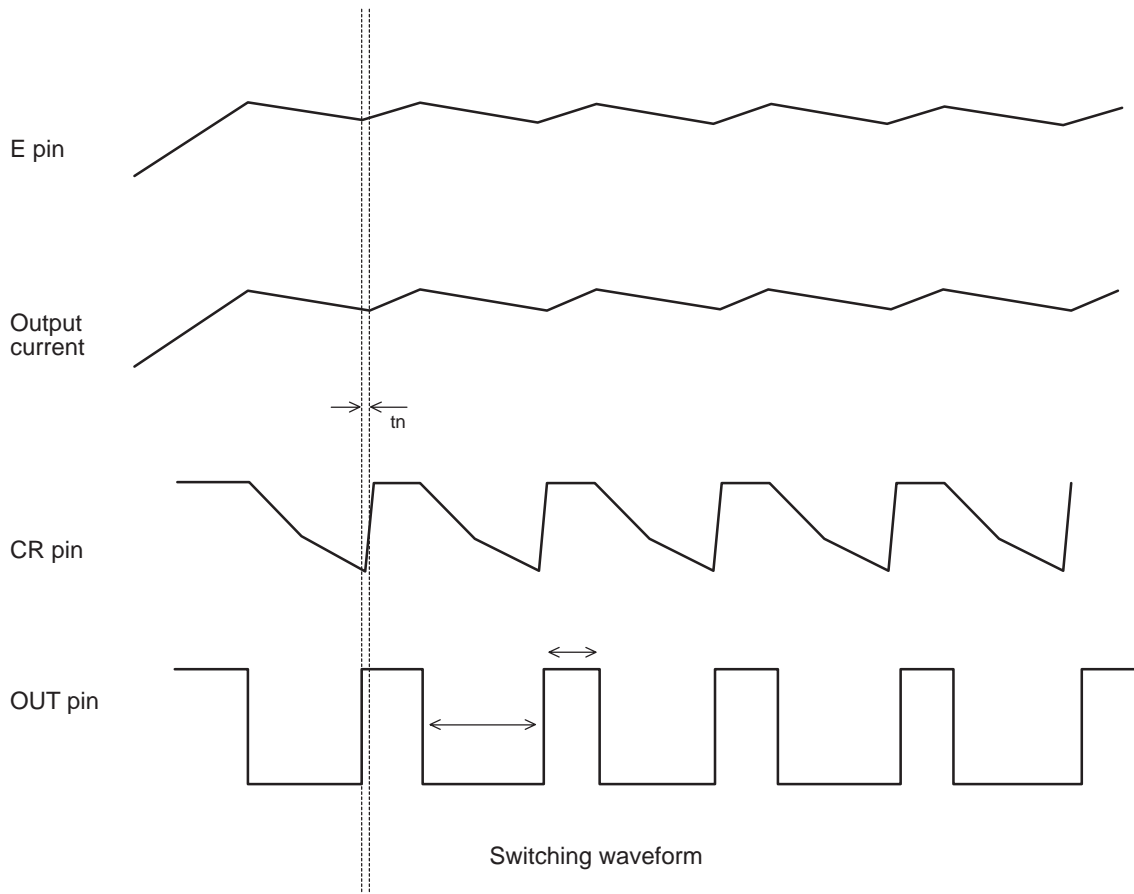
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## Switching Time Chart at PWM operation

SLOW DECAY (Upper-side Chopping)

Serial transmission data (D4, D10) = High

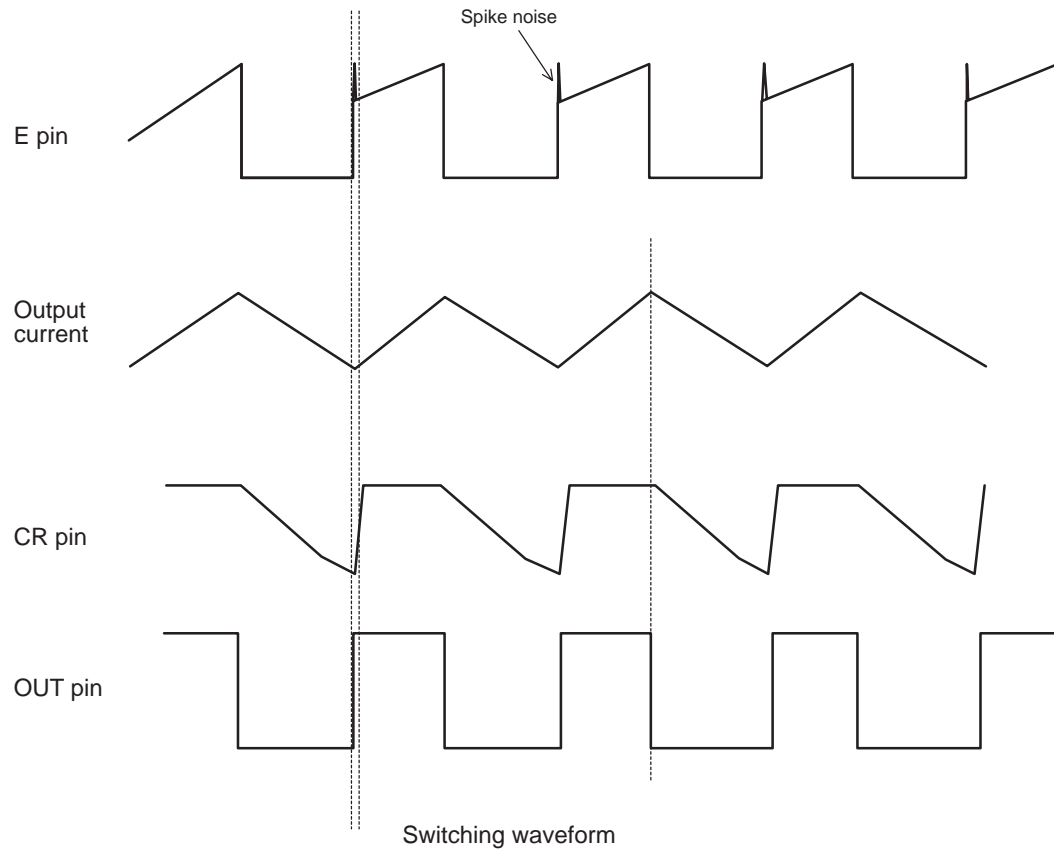
MD pin: Low setting



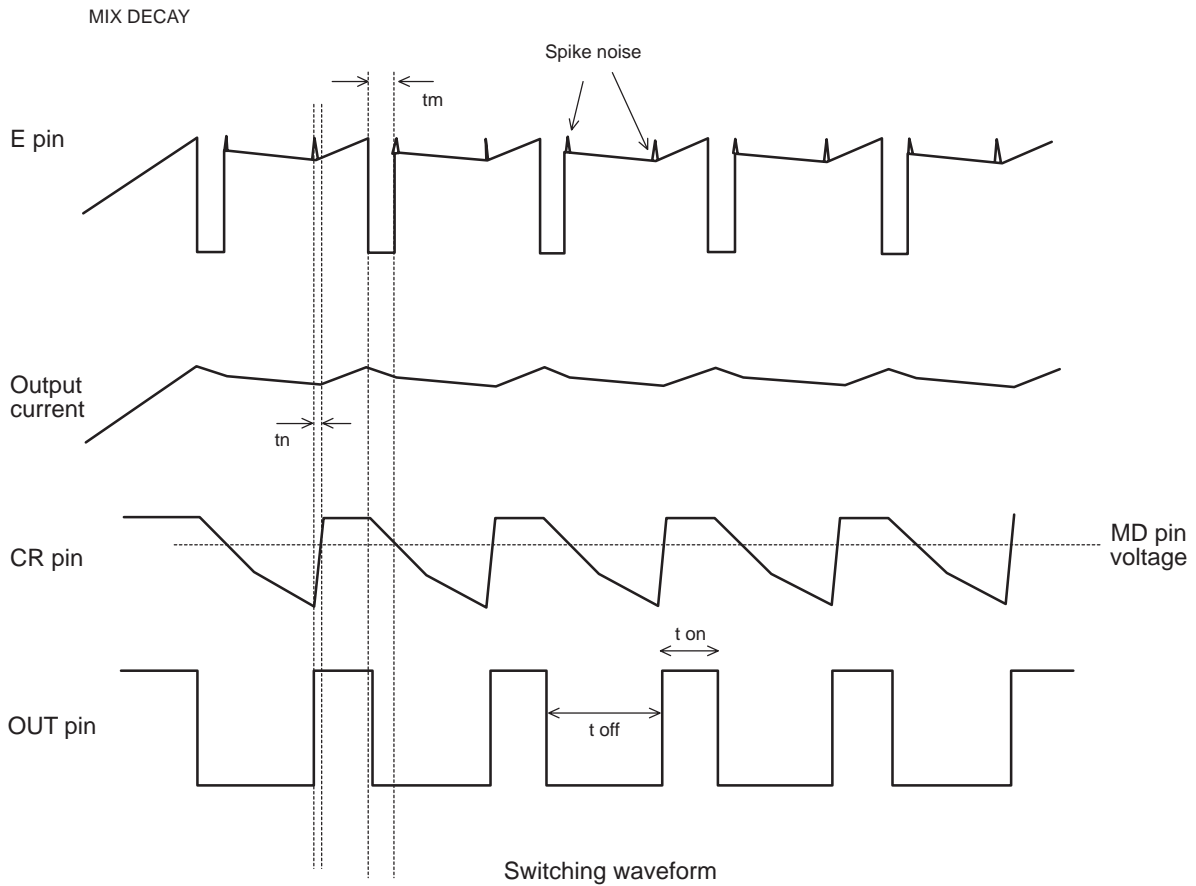
FAST DECAY

Serial transmission data (D4, D10) = Low

MD pin: Low setting



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## MIX DECADE logic setting

serial transmission data (D4, D10) = Low

MD pin: 1.6V to 3.0V at  $V_{CC} = 5V$  specification.

1.2V to 2.5V at  $V_{CC} = 3.3V$  specification.

t on: Output ON time

t off: Output OFF time

tm: FAST DECADE time at MIX DECADE mode

tn: Noise cancel time

The following operation by comparison between CR voltage and MD pin voltage in turning off time.

CR voltage > MD pin voltage: both sides chopping

CR voltage < MD pin voltage: upper side chopping

**Attached Documents**

1. Switching Off Time and Noise Canceller Time Calculations

Notes on the CR Pin Setting (switching off time and noise canceller time)

The noise canceller time ( $T_n$ ) and the switching off time ( $T_{off}$ ) are set using the following formulas.

(1) When  $V_{CC}$  is 5 V

Noise canceller time ( $T_n$ )

$$T_n \approx C \times R \times \ln \{(1.5 - RI) / (4.0 - RI)\} [s]$$

CR pin charge current: 1.25mA

Switching off time ( $T_{off}$ )

$$T_{off} \approx -C \times R \times \ln (1.5/4.8) [s]$$

Component value ranges

R: 5.6kΩ to 100kΩ

C: 470pF to 2000pF

(2) When  $V_{CC}$  is 3.3 V

Noise canceller time ( $T_n$ )

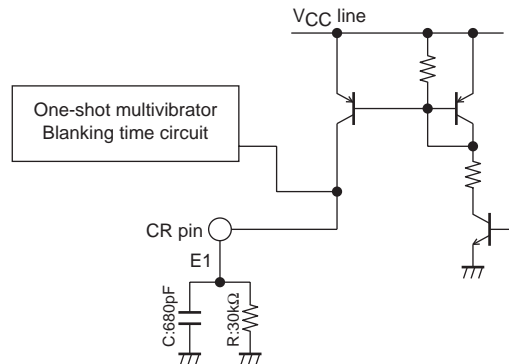
$$T_n \approx C \times R \times \ln \{(1.06 - RI) / (2.66 - RI)\} [s]$$

CR pin charge current: 0.7 mA

Switching off time ( $T_{off}$ )

$$T_{off} \approx -C \times R \times \ln (1.06 / 3.1) [s]$$

**CR Pin Internal Circuit Structure**



2. Notes on the MD Pin

(1) If slow decay mode is set up by setting the D4 and D10 bits in the input serial data to 1, the MD pin must be shorted to ground.

(2) If fast decay mode is set up by setting the D4 and D10 bits in the input serial data to 0, mixed decay mode can be set with the MD pin.

When the  $V_{CC} = 5V$  specifications are used the setting voltage range for mixed decay mode is 1.6 to 3.9V.

When the  $V_{CC} = 3.3V$  specifications are used the setting voltage range for mixed decay mode is 1.2 to 2.5V.

If mixed decay mode will not be used with the fast decay mode setting, either:

(a) Short the MD pin to ground to select fast decay mode, or

(b) Short the MD pin to  $V_{CC}$  to select slow decay mode.

## Usage Notes

### (1) Notes on the VREF pin

Since the VREF pin inputs the reference voltage used to set the current, applications must be designed so that noise does not occur at this pin.

### (2) Notes on the ground pins

Since this IC switches large currents, care is required with respect to the ground pins.

The PCB pattern in sections where large currents flow must be designed with low impedances and must be kept separate from the small-signal system.

In particular, the ground terminals of the E1 and E2 pin sense resistors ( $R_e$ ) and the external Schottky barrier diode ground terminals must be located as close as possible to the IC ground. The capacitors between  $V_{CC}$  and ground and between  $V_{BB}$  and ground must be as close as possible to the corresponding  $V_{CC}$  and  $V_{BB}$  pin in the pattern.

### (3) Power on sequence

When turning the power systems on

$V_{CC} \rightarrow$  logic level inputs (CLK, DATA, SET, and ST)  $\rightarrow$  VREF  $\rightarrow$   $V_{BB}$

When turning the power systems off



$V_{BB} \rightarrow$  VREF logic level inputs (CLK, DATA, SET, and ST)  $\rightarrow$   $V_{CC}$

Note that if the power supply for the logic level inputs is on when the  $V_{CC}$  power supply is off, a bias with an unstable state will be applied due to the protection diodes at the  $V_{CC}$  pins, and this can cause incorrect operation.

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