PRELIMINARY

White LED Driver with Automatic Dimming Control

■ GENERAL DESCRIPTION

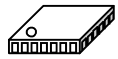
The **NJU6053** is a white LED driver with an automatic dimming control. It contains an output driver, a PWM controller, a luminance sensor control (power supply for sensor & A/D converter), a step-up DC/DC converter, a serial interface, etc.

The **NJU6053** can turn three independent lighting circuits on/off separately or simultaneously with instruction.

The output driver ensures a 40mA maximum capability which allows the connection of 12 white LEDs (4 series x 3 parallels). Depending on the ambient light sensed with an external luminance sensor, the PWM controller controls PWM duty in 8 steps preselected out of 64 steps. In addition, the frequency of the DC/DC converter is high so that it permits the use of small, low-profile inductors and capacitors to minimize the footprint in space-conscious applications.

All of these benefits make the **NJU6053** suitable for the battery-powered portable applications such as a cellular phone, a camcorder, PDA, etc.

■ PACKAGE OUTLINE

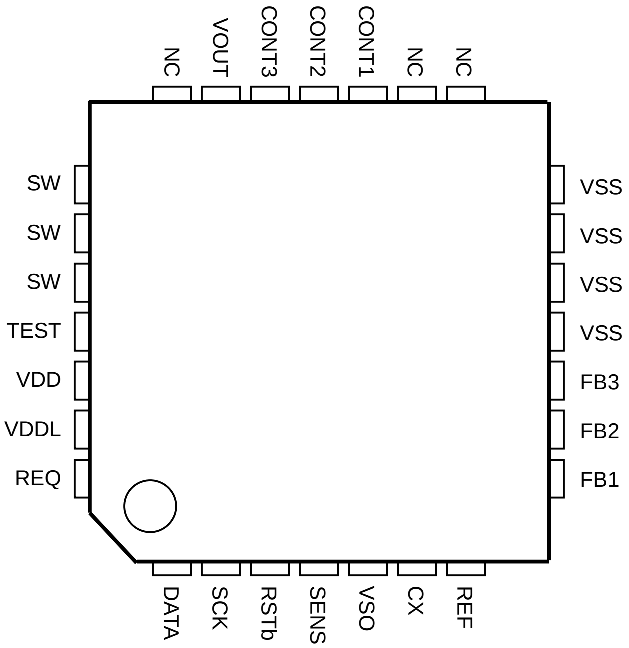


NJU6053KP4

■ FEATURES

- Drives up to 12 white LEDs (4 series x 3 parallels)
- Controls 3 outputs separately
  V_{SW} = 18.0V(Max), I_{OUT} = 40mA
- Built-in PWM Dimming Control
  (Selectable 8 out of 64 steps)
- Built-in Luminance Sensor Control (Power Supply for Sensor & A/D converter)
  (No MPU-access required after initial setting)
- Built-in Temperature Compensation Circuit to Suppress the Characteristic Degradation of LEDs
- Uses Small Inductor and Capacitors
- 1.8V to 3.6V Operating Voltage for Logic Circuits (V_{DDL})
- 3.0V to 5.5V Operating Voltage for Step-up Circuits (V_{DD})
- CMOS Technology
- Package : QFN28

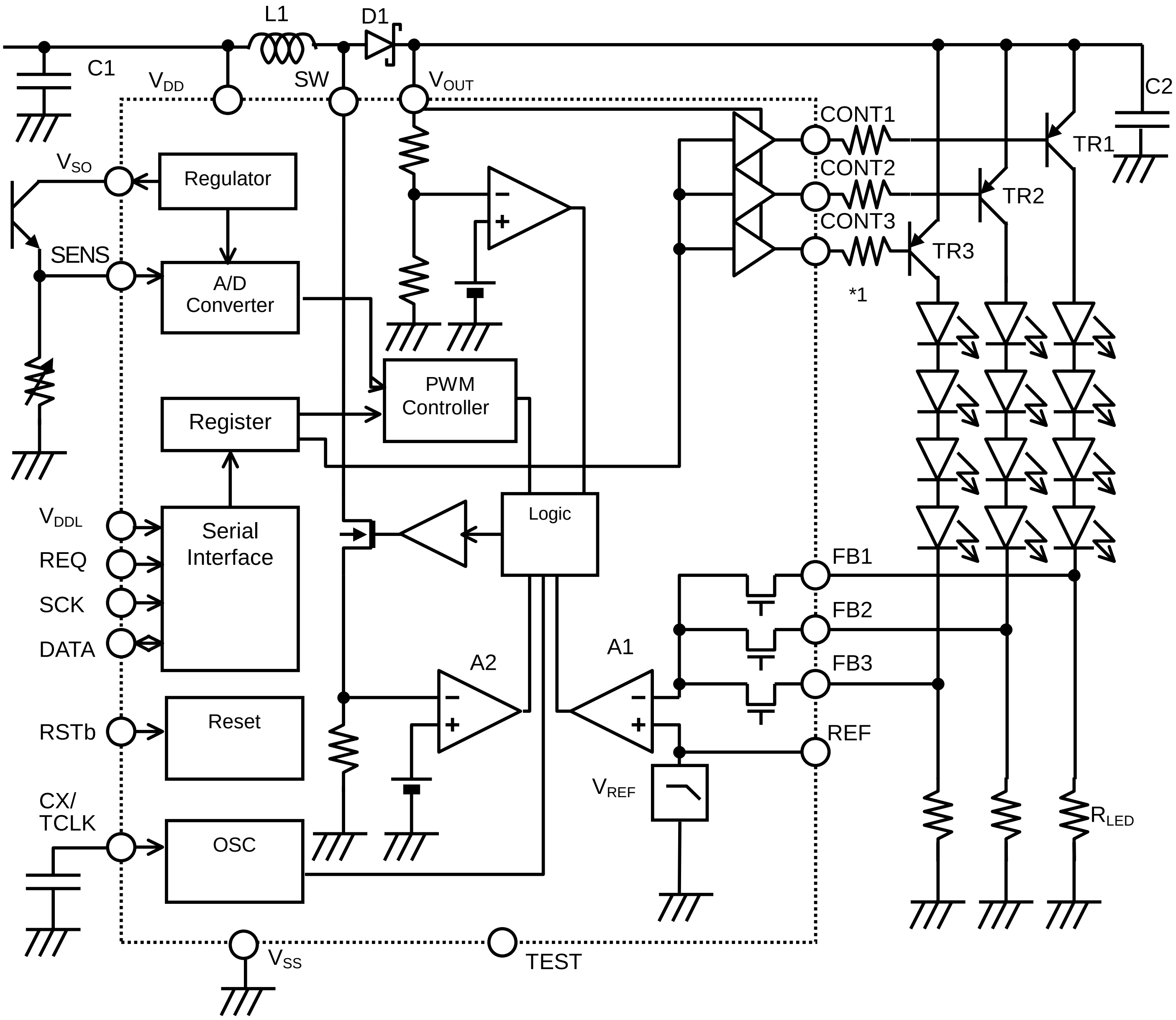
■ QFN28 PIN CONNECTIONS (TOP VIEW)



■ PIN DESCRIPTION

No.	Symbol	Type	Description
26	V_{DD}	Power	**V_{DD} Power Supply** - Power supply for step-up voltage
27	V_{DDL}	Power	**V_{DDL} Power Supply** - Power supply for logic voltage - Relation: 1.8V ≤ V_{DDL} ≤ V_{DD} should be maintained.
22,23, 24	SW	Input	**Switch** - All these terminals should be connected together.
2	SCK	Input	**Shift Clock** - Serial data is latched on the rising edge of SCK.
1	DATA	Input / Output	**Serial Data**
25	TEST	Output	**Test** - This terminal must be open.
28	REQ	Input	**Data Request** “L” : Writing command data “H”: Reading sensor data
4	SENS	Input	**Luminance Sensor Connection**
3	RSTb	Input	**Reset** - Active “L”.
20	V_{OUT}	Power	**Output** - This terminal is connected to LED anode.
8,9,10	FB1 to 3	Input	**Feedback**
11,12, 13,14	V_{SS}	Power	**Ground** - All these terminals should be connected together.
6	CX/TCLK	Input	**Oscillator Capacitor Connection / External Clock Input**
5	V_{SO}	Output	**V_{SO} Power Supply** - Power supply for luminance sensor - 2.4V typical
7	REF	Input	**Reference Voltage** - This terminal must be open.
17,18, 19	CONT1 to 3	Output	**LED control**
15,16, 21	NC	-	**Non Connection** - These terminals must be open.

■ BLOCK DIAGRAM



Note : Either the NPN or PNP transistor can be used to switch outputs. If the PNP transistor is used, in order to limit the current coming into the **NJU6053**, a resistor should be inserted between the CONT pin and the base of PNP transistor. The resistance should make the base current equal to I_{LED}/h_{EF}, otherwise, if the base current is much larger than I_{LED}/h_{EF}, efficiency of the **NJU6053** will go down, if the base current is smaller than I_{LED}/h_{EF}, the LED current cannot reach the desired value.

■ FUNCTIONAL DESCRIPTONS

(1) LED CURRENT CONTROL

The **NJU6053** incorporates the LED current control circuit to regulate the LED current (I_{LED}), which is programmed by the feedback resistor (R_{LED}) connected between the FB and V_{SS} terminals. The reference voltage V_{REF} is internally regulated to 0.6V typical and connected to the positive input of the built-in comparator A1. Formula (1) is used to choose the value of the R_{LED}, as shown below.

$$R_{LED} = V_{REF} / I_{LED} \qquad \text{--- Formula (1)}$$

$$V_{REF}=0.6\text{V (typ.)}$$

Referring to the block diagram is recommended for understanding the operation of the LED current control. The I_{LED} is the constant current programmed by the R_{LED}. When the feedback voltage on the FB terminal reaches above the reference voltage V_{REF} on the REF terminal (i.e., I_{LED} is above the level programmed by R_{LED}), the output capacitor C2 delivers the I_{LED}. Once the feedback voltage drops below the reference voltage (i.e., I_{LED} drops below the level programmed by R_{LED}), the comparator A1 detects it and turns on the internal MOS switch, then the current of the inductor L1 begins increasing. When this switch current reaches 720mA and the comparator A2 detects it, or when the predetermined switch-on-period expires, the MOS switch is turned off. The L1 then delivers current to the output through the diode D1 as the inductor current drops. After that, the MOS switch is turned on again and the switch current increases up to 720mA. This switching cycle continues until the I_{LED} reaches the level programmed by the R_{LED}, then the I_{LED} is maintained constant.

When the feedback voltage is less than 1/2*V_{REF}, the current limit of the MOS switch is reduced to 550mA typical. This action reduces the average inductor-current, minimizes the power dissipation and protects the IC against high current at start-up.

The total forward-voltage of the LEDs must be greater than the power supply voltage V_{DD}, otherwise the LEDs remain lighting up, being out of control.

(2) OUTPUT SWITCH CIRCUIT

With built-in LED control and feedback circuits, **NJU6053** can control LEDs on/off with software. But the maximum total output current can not exceed 40 mA.

NJU6053 can turn LEDs in string on or off respectively via LED control pins, but can not make LED dimming control for individual lighting circuit. Corresponding to the lighted LEDs, one of three feedback pins (FB1 to FB3) become active. For details of relationship between the lighted LED and feedback pin, refer to (6) Serial Interface.

(3) OSCILLATOR

The built-in oscillator incorporates a reference power supply, so its frequency is independent from the V_{DD}. The frequency is varied by the external capacitor CX, as shown in Figure 7.

(4) LUMINANCE SENSOR CONTROL

The luminance sensor control circuits consist of the power supply for sensor and the A/D converter. The A/D converter senses the voltage on the SENS terminal and selects 1 out of 8 registers (PWM REGISTER 0–7). And the data in the selected register is reflected to the PWM duty (PWM dimming control). The contents of the registers can be programmed through the serial interface, in other words, the dimming control is user-settable.

The voltage sense and the register selection are updated at regular intervals, and the interval period is set by the “DIVIDE” bits. The selected register is held by setting “1” at the “HOLD” bit of the command data.

(5) PWM DIMMING CONTROL

By setting the duty data at “PWM REGISTER” bits, 8 out of 64 registers are assigned to the PWM REGISTER 0-7. The PWM duty is changed depending on the register selected by the SENS voltage. The relation between the PWM REGISTER and its duty is shown below.

TABLE 1 PWM DUTY vs. PWM REGISTER

REGISTER	DUTY	REGISTER	DUTY	REGISTER	DUTY	REGISTER	DUTY
0,0,0,0,0,0	OFF	0,1,0,0,0,0	26.56%	1,0,0,0,0,0	51.56%	1,1,0,0,0,0	76.56%
0,0,0,0,0,1	3.13%	0,1,0,0,0,1	28.13%	1,0,0,0,0,1	53.13%	1,1,0,0,0,1	78.13%
0,0,0,0,1,0	4.69%	0,1,0,0,1,0	29.69%	1,0,0,0,1,0	54.69%	1,1,0,0,1,0	79.69%
0,0,0,0,1,1	6.25%	0,1,0,0,1,1	31.25%	1,0,0,0,1,1	56.25%	1,1,0,0,1,1	81.25%
0,0,0,1,0,0	7.81%	0,1,0,1,0,0	32.81%	1,0,0,1,0,0	57.81%	1,1,0,1,0,0	82.81%
0,0,0,1,0,1	9.38%	0,1,0,1,0,1	34.38%	1,0,0,1,0,1	59.38%	1,1,0,1,0,1	84.38%
0,0,0,1,1,0	10.94%	0,1,0,1,1,0	35.94%	1,0,0,1,1,0	60.94%	1,1,0,1,1,0	85.94%
0,0,0,1,1,1	12.50%	0,1,0,1,1,1	37.50%	1,0,0,1,1,1	62.50%	1,1,0,1,1,1	87.50%
0,0,1,0,0,0	14.06%	0,1,1,0,0,0	39.06%	1,0,1,0,0,0	64.06%	1,1,1,0,0,0	89.06%
0,0,1,0,0,1	15.63%	0,1,1,0,0,1	40.63%	1,0,1,0,0,1	65.63%	1,1,1,0,0,1	90.63%
0,0,1,0,1,0	17.19%	0,1,1,0,1,0	42.19%	1,0,1,0,1,0	67.19%	1,1,1,0,1,0	92.19%
0,0,1,0,1,1	18.75%	0,1,1,0,1,1	43.75%	1,0,1,0,1,1	68.75%	1,1,1,0,1,1	93.75%
0,0,1,1,0,0	20.31%	0,1,1,1,0,0	45.31%	1,0,1,1,0,0	70.31%	1,1,1,1,0,0	95.31%
0,0,1,1,0,1	21.88%	0,1,1,1,0,1	46.88%	1,0,1,1,0,1	71.88%	1,1,1,1,0,1	96.88%
0,0,1,1,1,0	23.44%	0,1,1,1,1,0	48.44%	1,0,1,1,1,0	73.44%	1,1,1,1,1,0	98.44%
0,0,1,1,1,1	25.00%	0,1,1,1,1,1	50.00%	1,0,1,1,1,1	75.00%	1,1,1,1,1,1	100.00%

The relation between the PWM REGISTER and SENS voltage is reversed by the “REV” bit, as follows.

TABLE 2 REV vs. PWM REGISTER

REV	PWM REGISTER
0	PWM REGISTER0
	PWM REGISTER1
	PWM REGISTER2
	PWM REGISTER3
	PWM REGISTER4
	PWM REGISTER5
	PWM REGISTER6
	PWM REGISTER7
1	PWM REGISTER7
	PWM REGISTER6
	PWM REGISTER5
	PWM REGISTER4
	PWM REGISTER3
	PWM REGISTER2
	PWM REGISTER1
	PWM REGISTER0

Note 1) For the information on the relation between PWM duty and LED current (ILED), refer to “(10-1) PWM DUTY and LED CURRENT“.

Note 2) For the information on the relation between SENS voltage and PWM REGISTER, refer to “DC ELECTRICAL CHARACTERISTICS”.

(6) SERIAL INTERFACE

(6-1) SERIAL DATA WRITE

The serial data is latched into the shift register on the rising edge of the serial clock (SCK), and determined on the rising edge of the data request (REQ). The serial data format should be the MSB first.

For COMMAND data transmission, the command data 1 (CMD1) and the command data 2 (CMD2) should be continuous. The CMD1 is first, then the CMD2. If only 1-byte data is transferred, this data is recognized as the CMD1. Do not transmit more than 2 bytes data, because the 3rd and 4th data are used only for maker test and the data after the 4th data will be ignored. If it's absolute necessary to send more than 2 bytes data in the user's application, only value (0,0,0,0,0,0,0,0) for the 3rd and 4th data can be accepted.

For DUTY data transmission, 8 bytes for PWM REGISTER 0-7 should be continuous. The order is : PWM REGISTER 0, 1, 2, 3, 4, 5, 6 and 7. If 7bytes or less are transferred, all bytes are accepted. And if 9 bytes or more, the 9th and later are ignored.

Note that the data should be in 8*n bits (n=integer number), otherwise it may cause malfunctions. And the SCK should be “0” when the REQ is changed.

SERIAL DATA FORMAT

TABLE 3-1 Command Data 1

B7	B6	B5	B4	B3	B2	B1	B0
0	SOFF	BRIGHT			STBY	HOLD	REV

TABLE 3-2 Command Data 2

B7	B6	B5	B4	B3	B2	B1	B0
0	FB	INV	C1	C2	C3	DIVIDE	

TABLE 3-3 Duty Data

B7	B6	B5	B4	B3	B2	B1	B0
1	*	PWM REGISTER					

* : ”Don’t care”

FIGURE 1 COMMAND DATA TRANSMISSION

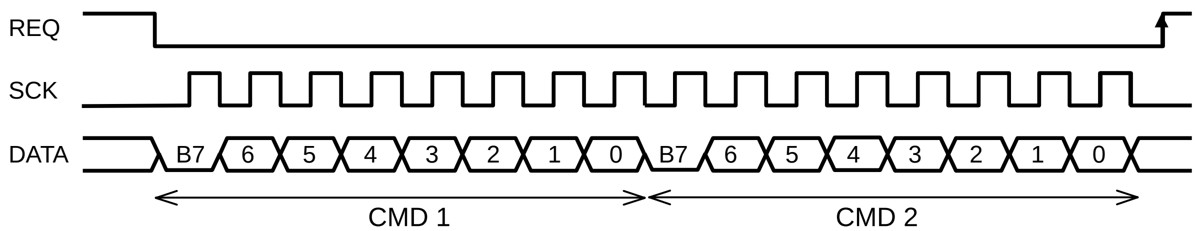
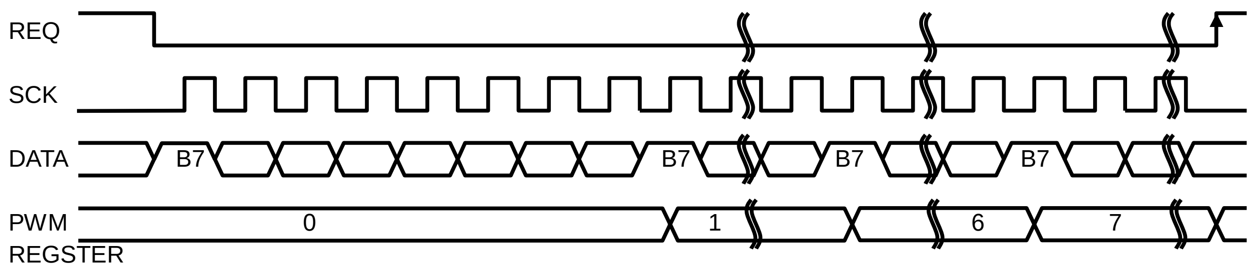


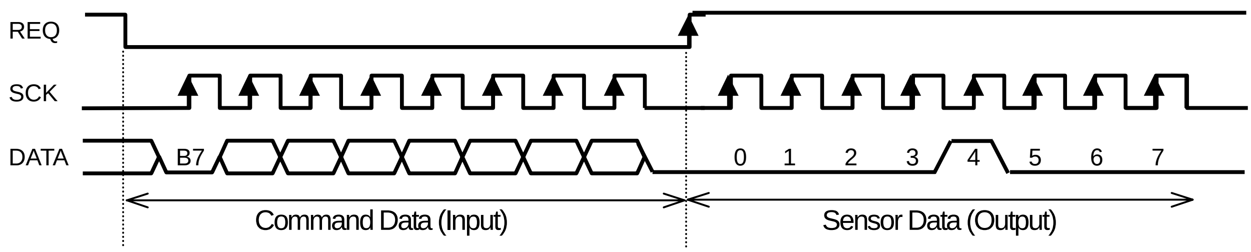
FIGURE 2 DUTY DATA TRANSMISSION



(6-2) SENSOR DATA READ

The DATA terminal becomes output state by setting the REQ terminal to “1” after the command data transmission. And the sensor data is read out, synchronizing with the SCK. The bit number corresponding to a selected register is “1” and the others are “0”, as shown below.

FIGURE 3 SENSOR DATA READ (REV=0, PWM REGISTER4 selected)



(6-3) SOFF and BRIGHT

By setting “1” at the SOFF bit, the luminance sensor control is disabled and the PWM duty is controlled by the BRIGHT bits, as shown below.

TABLE 4 SOFF and BRIGHT

SOFF	BRIGHT	REV	PWMREGISTER
0	-	0	PWM REGISTER0
			PWM REGISTER1
			PWM REGISTER2
			PWM REGISTER3
			PWM REGISTER4
			PWM REGISTER5
			PWM REGISTER6
			PWM REGISTER7
1	0,0,0	-	PWM REGISTER0
	0,0,1		PWM REGISTER1
	0,1,0		PWM REGISTER2
	0,1,1		PWM REGISTER3
	1,0,0		PWM REGISTER4
	1,0,1		PWM REGISTER5
	1,1,0		PWM REGISTER6
	1,1,1		PWM REGISTER7

Note 1) When SOFF=”0”, luminance sensor control is enabled and PWM REGISTER is selected according to SENS voltage.

Note 2) For the information on the relation between SENS voltage and PWM REGISTER, refer to “DC ELECTRICAL CHARACTERISTICS”.

(6-4) STBY

By setting “1” at the STBY bit, the **NJU6053** goes into the standby mode, as follows.

- DC/DC converter, oscillator, reference voltage generator, and power supply for sensor are halted.
- The contents of PWM REGISTER are maintained.
- Luminance sensor control circuit is initialized.

(6-5) HOLD

By setting “1” at the HOLD bit, the selected PWM REGISTER is held and the luminance sensor control cannot be used. In other words, this setting works so that the luminance of the LEDs doesn’t change even if the SENS voltage changes. The selection is initialized to the PWM REGISTER 0 by the reset. And when the standby is released, the selection is initialized to the PWM REGISTER 0 at REV=“0” or the PWM REGISTER 7 at REV=“1”.

(6-6) REV

By setting “1” at the REV bit, the correspondence between the PWM REGISTER and SENS voltage is reversed.

TABLE 5 REV

REV	PWM REGISTER
0	PWM REGISTER0
	PWM REGISTER1
	PWM REGISTER2
	PWM REGISTER3
	PWM REGISTER4
	PWM REGISTER5
	PWM REGISTER6
	PWM REGISTER7
1	PWM REGISTER7
	PWM REGISTER6
	PWM REGISTER5
	PWM REGISTER4
	PWM REGISTER3
	PWM REGISTER2
	PWM REGISTER1
	PWM REGISTER0

(6-7) DIVIDE

By setting the DIVIDE bits, the sensor-sampling-time (t_{SENS}) and PWM frequency (f_{PWM}) are changed. Note that these parameters are varied depending on the oscillation frequency (F_{OSC}). The formula (2) gives the sensor-sampling-time.

$$tsens = \frac{2^{(17+N)}}{fosc} \text{ (sec)} \quad \text{--- Formula (2)}$$

TABLE 6 SENSOR SAMPLING TIME

DIVIDE	N	Fosc			
		100KHz	200KHz	400KHz	800KHz
0,0	0	**1.311 sec**	0.655 sec	0.328 sec	0.164 sec
0,1	1	2.621 sec	**1.311 sec**	0.655 sec	0.328 sec
1,0	2	5.243 sec	2.621 sec	**1.311 sec**	0.655 sec
1,1	3	10.486 sec	5.243 sec	2.621 sec	**1.311 sec**

And, the formula (3) gives the PWM frequency.

$$fpwm = \frac{1}{64} \bullet \frac{fosc}{2^{(3+N)}} \text{ (Hz)} \quad \text{--- Formula (3)}$$

TABLE 7 PWM FREQUENCY

DIVIDE	N	Fosc			
		100KHz	200KHz	400KHz	800KHz
0,0	0	**195.3 Hz**	390.6 Hz	781.3 Hz	1562.5 Hz
0,1	1	97.7 Hz	**195.3 Hz**	390.6 Hz	781.3 Hz
1,0	2	48.8 Hz	97.7 Hz	**195.3 Hz**	390.6 Hz
1,1	3	24.4 Hz	48.8 Hz	97.7 Hz	**195.3 Hz**

NOTE) PWM frequencies written in bold or neighbors are recommended, otherwise it might cause LED flickering.

(6-8) C1, C2, C3

If set C1 bit of command data to 1, CONT1 pin becomes “H” level, FB1 pin will be active.
If set C2 bit of command data to 1, CONT2 pin becomes “H” level, FB2 pin will be active.
If set C3 bit of command data to 1, CONT3 pin becomes “H” level, FB3 pin will be active.
If set more than one bit of command data’s C1, C2, and C3 bits to 1, only the feedback pin with the smaller pin number will be active.

(6-9) INV

If set the INV bit of command data to 1, the output at CONT pins will be reversed.

Command data				Output			
INV	C1	C2	C3	CONT1	CONT2	CONT3	FB pin
0	0	0	0	L	L	L	FB1
0	0	0	1	L	L	H	FB3
0	0	1	0	L	H	L	FB2
0	0	1	1	L	H	H	FB2
0	1	0	0	H	L	L	FB1
0	1	0	1	H	L	H	FB1
0	1	1	0	H	H	L	FB1
0	1	1	1	H	H	H	FB1
1	0	0	0	H	H	H	FB1
1	0	0	1	H	H	L	FB3
1	0	1	0	H	L	H	FB2
1	0	1	1	H	L	L	FB2
1	1	0	0	L	H	H	FB1
1	1	0	1	L	H	L	FB1
1	1	1	0	L	L	H	FB1
1	1	1	1	L	L	L	FB1

(7) LEVEL SHIFTER

The level shifter allows the communication with the MPU working at the power supply voltage lower than the V_{DD}. Apply the MPU power-supply-voltage on the V_{DDL} terminal. The voltage range is: $1.8V \leq V_{DDL} \leq 3.6V$.

(8) RESET

By setting the RSTb pin to "L", the **NJU6053** is initialized into the following default status.

TABLE 8 RESET

1.	REV	: (0)	Refer to Table 5
2.	HOLD	: (0)	Sensor sampling is enabled
3.	STBY	: (0)	Standby Off
4.	BRIGHT	: (0,0,0)	
5.	SOFF	: (0)	Luminance sensor control is enabled
6.	DIVIDE	: (0,0)	
7.	C1,C2,C3	: (0,0,0)	
8.	INV	: (0)	
9.	PWM REGISTER 0	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
10.	PWM REGISTER 1	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
11.	PWM REGISTER 2	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
12.	PWM REGISTER 3	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
13.	PWM REGISTER 4	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
14.	PWM REGISTER 5	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
15.	PWM REGISTER 6	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)
16.	PWM REGISTER 7	: (0,0,0,0,0,0)	DUTY 0% (LED OFF)

(9) TEMPERATURE COMPENSATION

The reference voltage (V_{REF}) generator has temperature compensation, which suppresses the characteristic degradation of LEDs at high temperatures. Refer to "I_{LED} vs. Temperature" shown in the "DC Electrical Characteristics".

(10) APPLICATIONS INFORMATION

(10-1) PWM DUTY and LED CURRENT

The average LED current is programmed with the single resistor R_{LED} and the PWM duty, as shown in Formula (4).

$$I_{LED(avg)} = I_{LED(max)} \cdot \frac{DUTY}{100} \qquad \text{--- Formula (4)}$$

$$I_{LED(max)} = \frac{V_{REF}}{R_{LED}}$$

(10-2) INDUCTOR SELECTION

Formula (5) is used to choose an optimum inductor, as shown below:

$$L = \frac{2\left(\frac{V_{OUT}}{\eta} - V_{IN}\right) \cdot I_{LED}}{I_{LIMIT}^2 \cdot f_{OSC}} \qquad \text{--- Formula (5)}$$

η : Power conversion efficiency (= 0.7 to 0.8)

The power supply voltage V_{IN} may fluctuate in battery-powered applications. For this reason, the minimum voltage should be applied to the V_{IN} in Formula (5).

The **NJU6053** has about 200ns of delay time (T_{DELAY}), which is defined as the period from the reach of the current limit 720mA to the MOS-switch-off. The T_{DELAY} may cause an overshoot-inductor-current, which is called the peak current $I_{L,PEAK}$, and calculated by Formula (6). Therefore, it is recommended that an inductor with a rating twice of the $I_{L,PEAK}$ and a low DCR (DC resistance) be used for high efficiency.

$$I_{L,PEAK} = I_{LIMIT} + \left(\frac{V_{IN(max)} - V_{DS}}{L} \right) \cdot T_{DELAY} \qquad \text{--- Formula (6)}$$

V_{DS} : Drain-Source voltage of the MOS switch (=I_{LIMIT}*R_{ON})
$V_{IN(max)}$: Maximum of V_{IN} Voltage

(10-3) DIODE SELECTION

A Schottky diode with a low forward-voltage-drop and a fast switching-speed is ideal. And the diode must have a rating greater than the output voltage and the output current in the system.

(10-4) CAPACITOR SELECTION

A low ESR (Equivalent Series Resistance) capacitor should be used at the output to minimize output ripples. A multi-layer ceramic capacitor is the best selection for the **NJU6053** application because of not only the low ESR but its small package. A ceramic capacitor as the input decoupling-capacitor is also recommended and should be placed as close to the **NJU6053** as possible

(10-5) SELECTION OF SWITCHING TRANSISTOR

Either the NPN or PNP transistor can be used to switch outputs. If the PNP transistor is used, in order to limit the current coming into the **NJU6053**, a resistor should be inserted between the CONT pin and the base of PNP transistor. The resistance should make the base current equal to I_{LED}/h_{EF}, otherwise, if the base current is much larger than I_{LED}/h_{EF}, efficiency of the **NJU6053** will go down, if the base current is smaller than I_{LED}/h_{EF}, LED current cannot reach the desired value.

■ ABSOLUTE MAXIMUM RATINGS

Ta=25°C

PARAMETERS	SYMBOL	CONDITIONS	RATINGS	UNIT	NOTE
V_{DD} Power Supply	V_{DD}		-0.3 to +6	V	
V_{DDL} Power Supply	V_{DDL}		-0.3 to V_{DD}	V	
Input Voltage	V_{IN1}	CX/TCLK, REF, FB,SENS terminals	-0.3 to V_{DD}+0.3	V	
Input Voltage	V_{IN2}	REQ, DATA, SCK, RSTb terminals	-0.3 to V_{DDL}+0.3	V	
Switch Voltage	V_{SW}	SW terminal	+18.0	V	3
Power Dissipation	Pd		T.B.D.	mW	4
Operating Temperature	T_{opr}		-40 to +85	°C	
Storage Temperature	T_{stg}		-55 to +125	°C	

NOTE1) All voltages are relative to V_{SS} = 0V reference.

NOTE2) Do not exceed the absolute maximum ratings, otherwise the stress may cause a permanent damage to the IC. It is also recommended that the IC be used in the range specified in the DC electrical characteristics, or the electrical stress may cause mulfunctions and affect the reliability.

NOTE3) The switch voltage V_{SW} is the highest voltage in the system. This voltage must not exceed the absolute maximum rating.

$$V_{SW} = V_F(LED) \times N(LED) + V_F(D1) + V_{REF}$$

V_F(LED) :Forward Voltage of LED
N(LED) :The Number of LEDs
V_F(D1) :Forward Voltage of Diode D1

For instance,
when V_F(LED) = 3.6V, N(LED)=4pcs, V_F(D1)=0.3V, V_{REF}=0.6V(TYP),
V_{SW}= 3.6V x 4 + 0.3V + 0.6V = 15.3V.

NOTE4) Mounted on the glass epoxy board (50mm x 50mm x 1.6mm)

■ DC ELECTRICAL CHARACTERISTICS

V_{DDL}=1.8V to 3.6V, V_{DD}=3.0V to 5.5V, Ta= -40 to 85°C

PARAMETERS	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT	NOTE
V_{DD} Power Supply	V_{DD}		3.0		5.5	V	
V_{DDL} Power Supply	V_{DDL}		1.8		3.6	V	
Output Current	I_{OUT}			40		mA	1
Reference Voltage	V_{REF}	Ta=25°C DC/DC Converter OFF	0.558	0.60	0.642	V	2
Operating Current	I_{OPR}	fosc=350kHz		1.0	1.4	mA	3
Standby Current	I_{STBY}				1	μA	4
V_{SO} Power Supply	V_{SO}		2.23	2.4	2.57	V	5
PWM REGISTER0 Selected Voltage	V_{D0}	SENS terminal, REV=0	0		0.0055V_{SO}	V	
PWM REGISTER1 Selected Voltage	V_{D1}	SENS terminal, REV=0	0.015V_{SO}		0.0185V_{SO}	V	
PWM REGISTER2 Selected Voltage	V_{D2}	SENS terminal, REV=0	0.030V_{SO}		0.040V_{SO}	V	
PWM REGISTER3 Selected Voltage	V_{D3}	SENS terminal, REV=0	0.060V_{SO}		0.090V_{SO}	V	
PWM REGISTER4 Selected Voltage	V_{D4}	SENS terminal, REV=0	0.110V_{SO}		0.180V_{SO}	V	
PWM REGISTER5 Selected Voltage	V_{D5}	SENS terminal, REV=0	0.220V_{SO}		0.360V_{SO}	V	
PWM REGISTER6 Selected Voltage	V_{D6}	SENS terminal, REV=0	0.440V_{SO}		0.720V_{SO}	V	
PWM REGISTER7 Selected Voltage	V_{D7}	SENS terminal, REV=0	0.880V_{SO}		V_{SO}	V	
Input "L" Level	V_{IL}	SCK, DATA, REQ, RSTb, terminals	0		0.2V_{DDL}	V	
Input "H" Level	V_{IH}	SCK, DATA, REQ, RSTb terminals	0.8V_{DDL}		V_{DDL}	V	
Output "L" Level (1)	V_{OL1}	DATA terminals V_{DDL}=1.8V, I_{OL}=0.4mA			0.2V_{DDL}	V	
Output "L" Level (2)	V_{OL2}	CONT terminals V_{OUT}=15V, I_{OL}=0.5mA			1	V	
Output "H" Level (1)	V_{OH1}	DATA terminals V_{DDL}=1.8V, I_{OH}= - 0.04mA	0.8V_{DDL}			V	
Output "H" Level (2)	V_{OH2}	CONT terminals V_{OUT}=15V, I_{OH}= - 0.5mA	14			V	
Oscillation Frequency	f_{OSC}	V_{DD}=3V, CX=82pF	245	350	455	kHz	
Oscillation Duty	D_{OSC}	V_{DD}=3V, CX=82pF	77	82	87	%	6
Switch Current Limit	I_{LIMIT}	SW terminal V_{DD}=4.2V, V_{FB}>V_{REF}/2, Ta=25°C	610	720	825	mA	
Switch On Voltage	V_{DS}(on)	SW terminal V_{DD}=4.2V, I_{SW}=720mA, Ta=25°C		1	1.4	V	
Over Voltage Protection	V_{OVP}	V_{OUT} terminal		17.5		V	

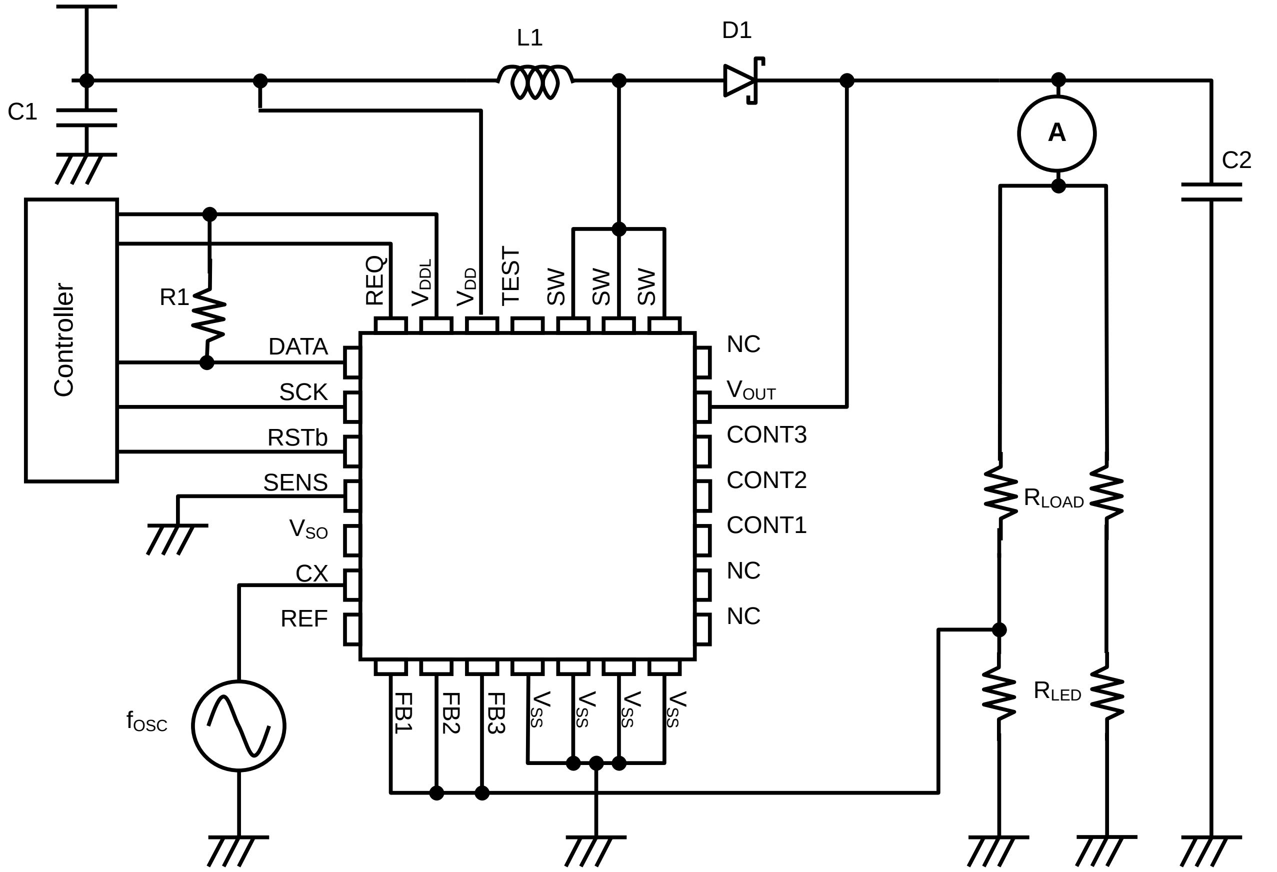
NOTE1) Output Current Test Conditions

- TEST Command

	B7	B6	B5	B4	B3	B2	B1	B0
Command Data 1	0	1	1	1	1	0	0	0
Command Data 2	0	0	0	0	0	0	0	0
Command Data 3	0	1	0	0	0	0	0	0

- TEST Circuit

V_{DD}	:5V
D1	:Schottky diode
L1	:10uH
C1	:4.7uF
C2	:1 uF
R_{LED}	:30Ω
R_{LOAD}	:750Ω
R1	:100kΩ
f_{OSC}	:350kHz / Duty 82%



NOTE2) TEMPERATURE COMPENSATION

The reference voltage (V_{REF}) generator has temperature compensation, which suppresses the characteristic-degradation of LEDs at high temperatures. The V_{REF} is regulated to 0.6V typical in the temperature range up to 45°C, and gradually decreases as the ambient temperature rises in the range higher than 45°C.

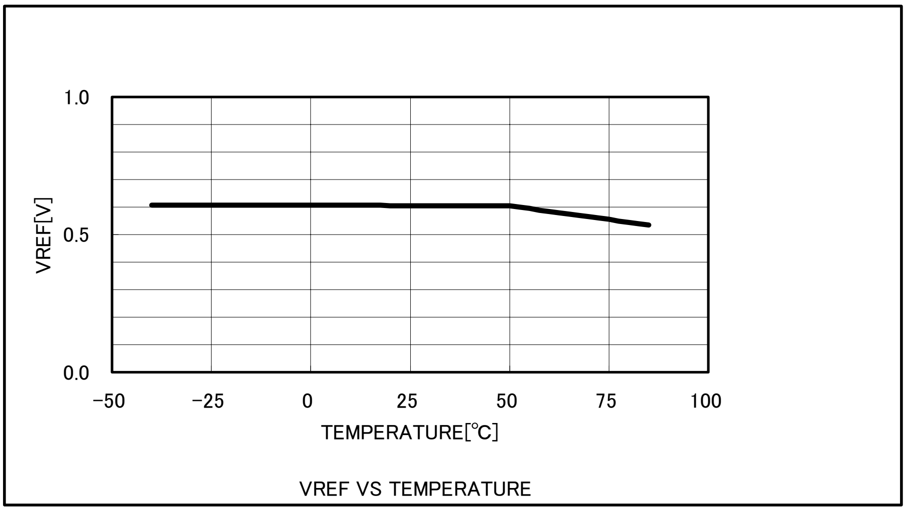


FIGURE 4 VREF vs. TEMPERATURE

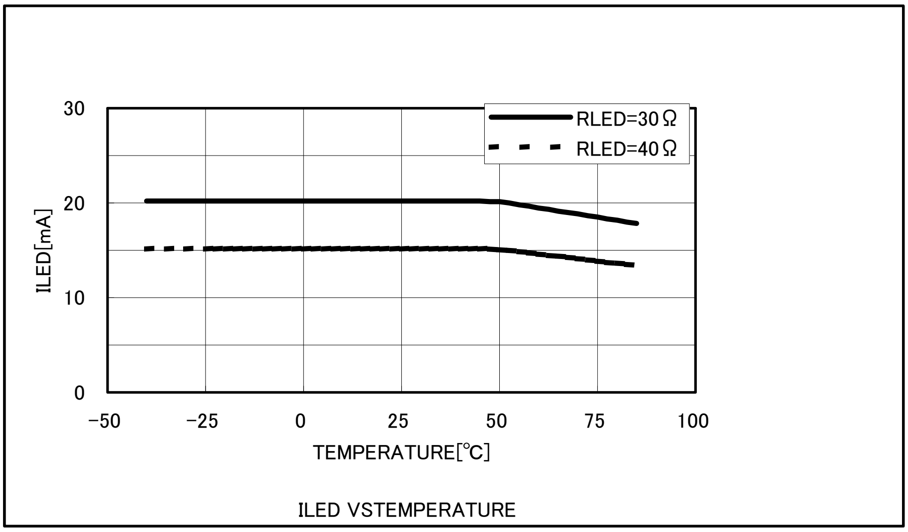


FIGURE 5 ILED vs. TEMPERATURE

NOTE3) Operating Current Test Conditions

- TEST Command

	B7	B6	B5	B4	B3	B2	B1	B0
Command Data 1	0	1	1	1	1	0	0	0
Command Data 2	0	0	0	0	0	0	0	0
Command Data 3	0	1	0	0	0	0	0	0

NOTE4) Standby Current

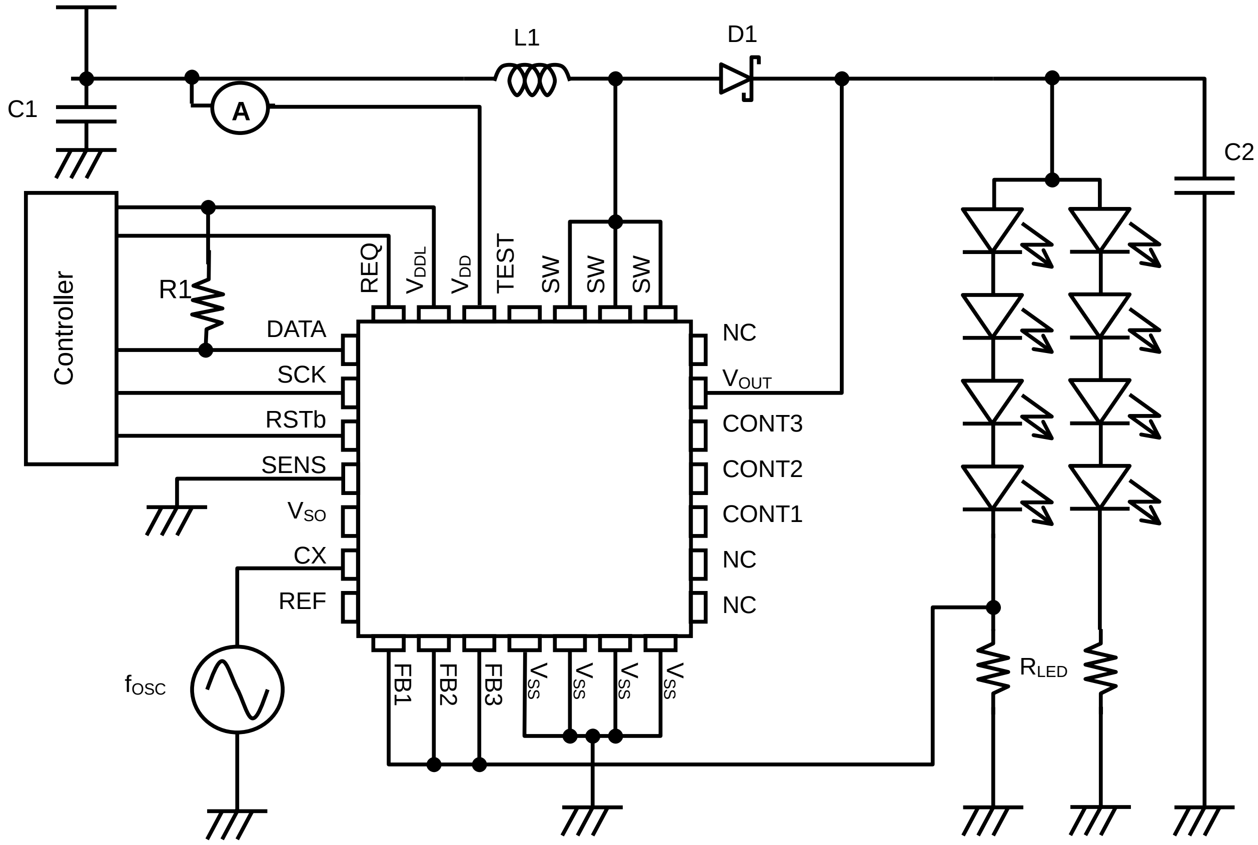
- TEST Command

	B7	B6	B5	B4	B3	B2	B1	B0
Command Data 1	0	*	*	*	*	1	*	*
Command Data 2	0	0	0	0	0	0	0	0
Command Data 3	0	1	0	0	0	0	0	0

* : "Don't care"

- TEST Circuit (Operating Current, Standby Ciurrent)

LED	:V_F=3.6V, I_{LED}=20mA
D1	:Schottky diode
L1	:10uH
C1	:4.7uF
C2	:1 uF
R_{LED}	:30Ω
R1	:100kΩ
f_{OSC}	:350kHz / Duty 82%



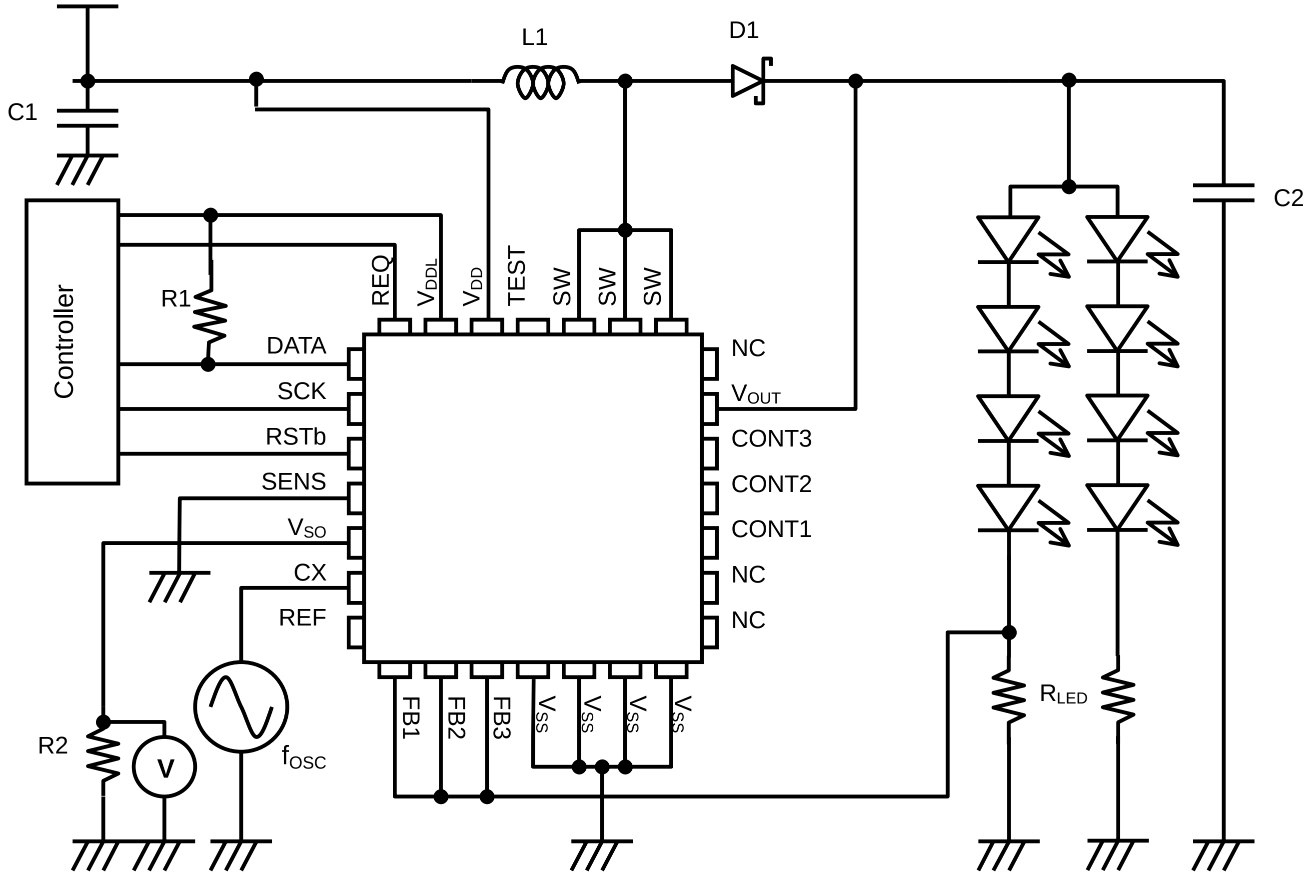
NOTE5) V_{SO} Power Supply Test Condition

- TEST Command

	B7	B6	B5	B4	B3	B2	B1	B0
Command Data 1	0	1	1	1	1	0	0	0
Command Data 2	0	1	0	0	0	0	0	0
Command Data 3	0	1	0	0	0	0	0	0
Command Data 4	0	0	0	0	0	1	0	0

- TEST Circuit

LED :V_F=3.6V, I_{LED}=20mA
D1 :Schottky diode
L1 :10uH
C1 :4.7uF
C2 :1uF
R_{LED} :30Ω
R1 :100kΩ
R2 :1kΩ
f_{OSC} :350kHz / Duty 82%



NOTE6) OSCILLATOR

The built-in oscillator incorporates a reference power supply, so its frequency is independent from the V_{DD}. The frequency is varied by the external capacitor CX, as shown below.

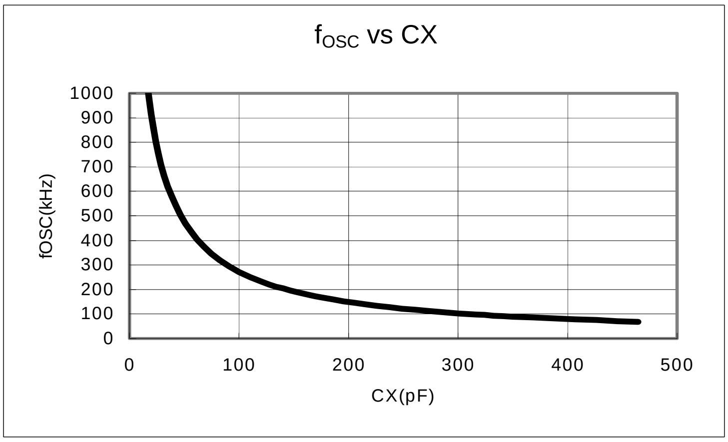


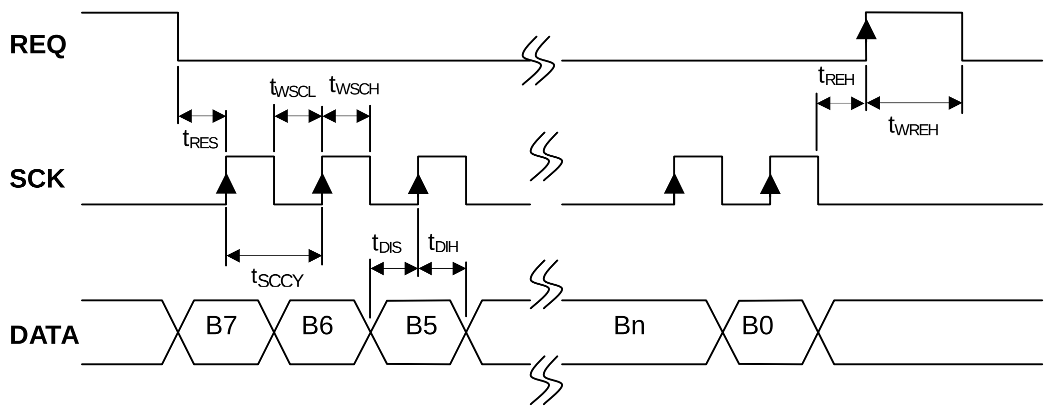
Figure 7 fOSC vs. CX
(Reference but not guaranteed)

AC ELECTRICAL CHARACTERISTICS

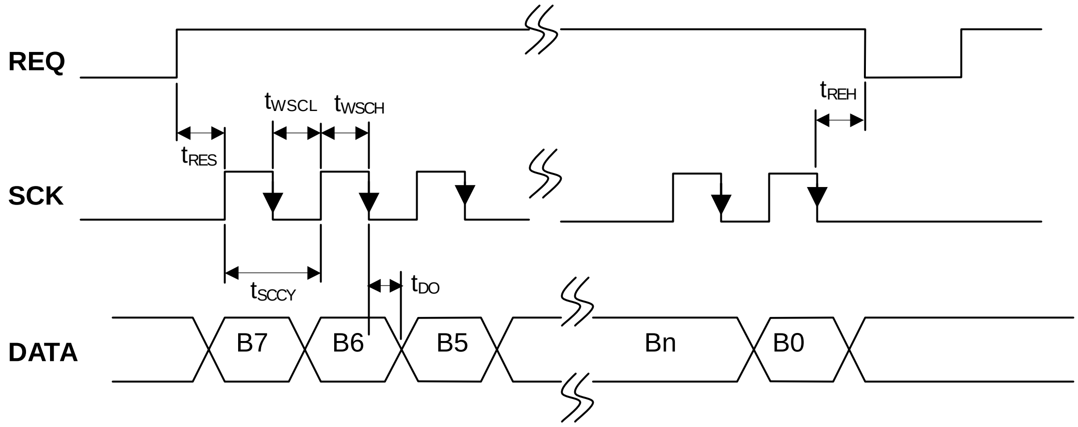
V_{DDL}=1.8V to 3.6V, V_{DD}=3.0V to 5.5V, Ta= -40 to 85°C

PARAMETERS		SYMBOL	MIN	TYP	MAX	UNIT	NOTE
SCK Clock Cycle		t_{SCCY}	1.0	-	-	µs	
SCK Clock Width	"High" Level	t_{WSCH}	400	-	-	ns	
	"Low" Level	t_{WSCL}	400	-	-	ns	
REQ Hold Time		t_{REH}	800	-	-	ns	
Data Set-Up Time		t_{DIS}	400	-	-	ns	
Data Hold Time		t_{DIH}	400	-	-	ns	
Output Data Delay Time CL=20pF		t_{D0}	-	-	200	ns	
CONT Output Delay Time CL=20pF, V_{OUT}=15V		t_{C0}	-	-	400	ns	
REQ Set-Up Time		t_{RES}	400	-	-	ns	
REQ High Level Width		t_{WREH}	800	-	-	ns	
REQ,SCK,DATA Rising Time		t_r	-	-	100	ns	
REQ,SCK,DATA Falling Time		t_f	-	-	100	ns	
RSTb Pulse Width		t_{RSL}	1.0	-	-	µs	

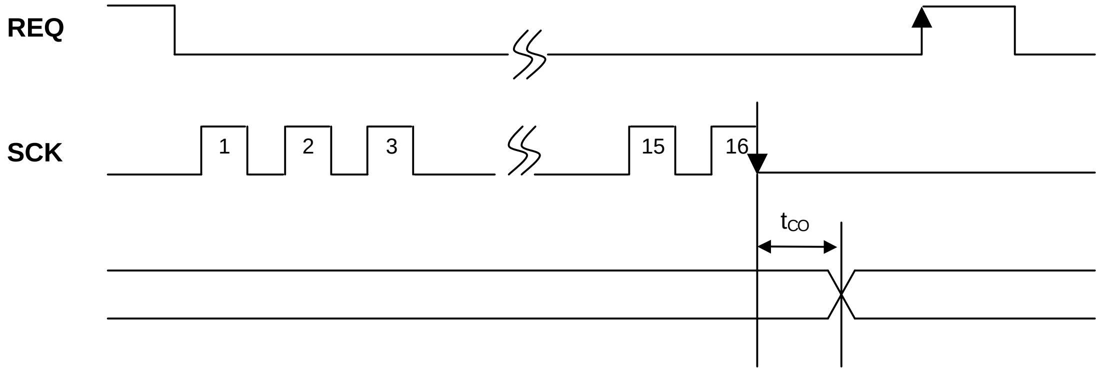
Serial Input Timing



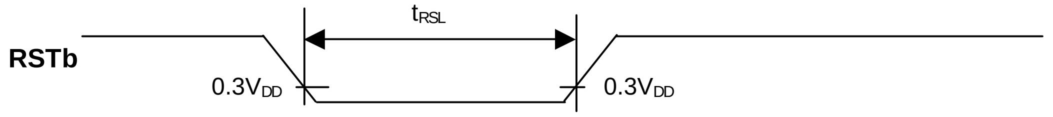
Serial Output Timing



CONT Output Delay Time

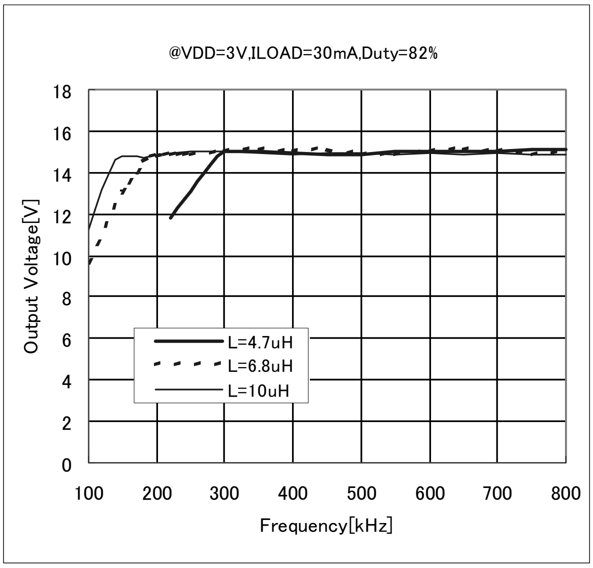


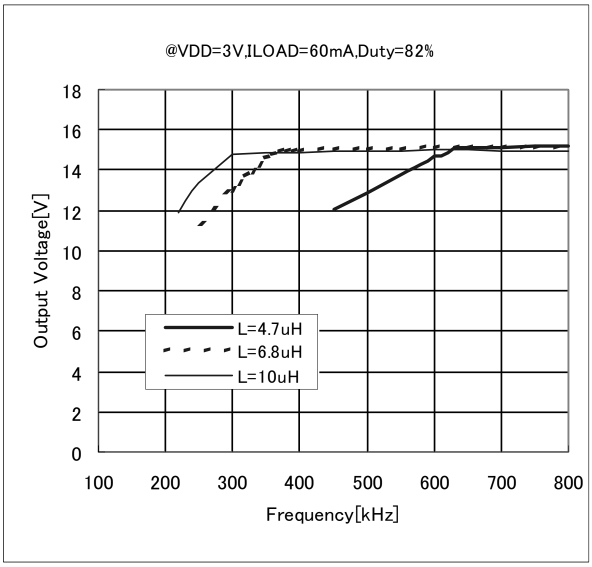
Reset Input Timing

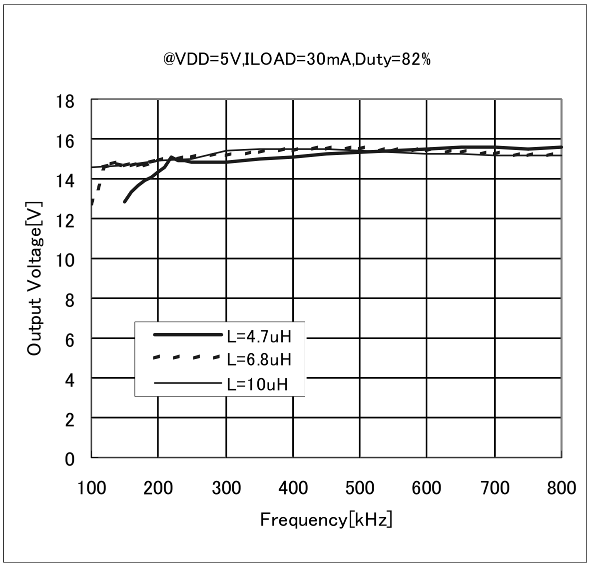


■ TYPICAL PERFORMANCE

1. Oscillation Frequency







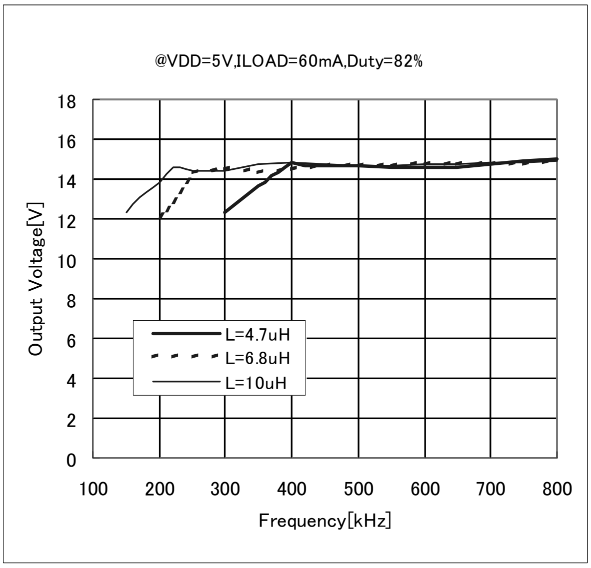
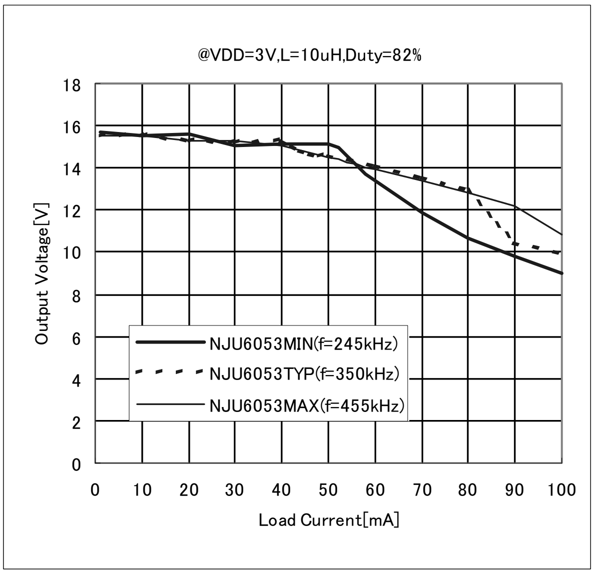


Figure 8 Output Voltage vs. Frequency

2. Load Current



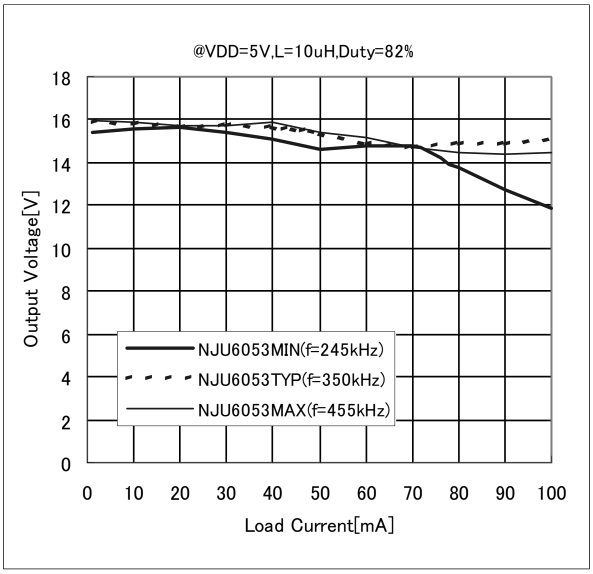
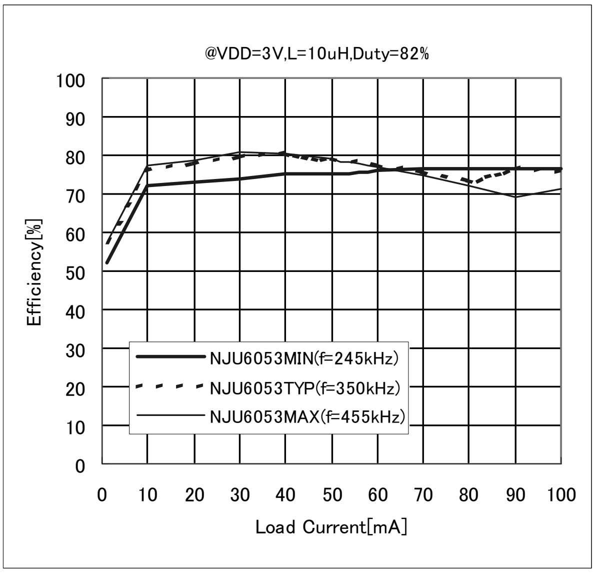


Figure 9 Output Voltage vs. Load Current



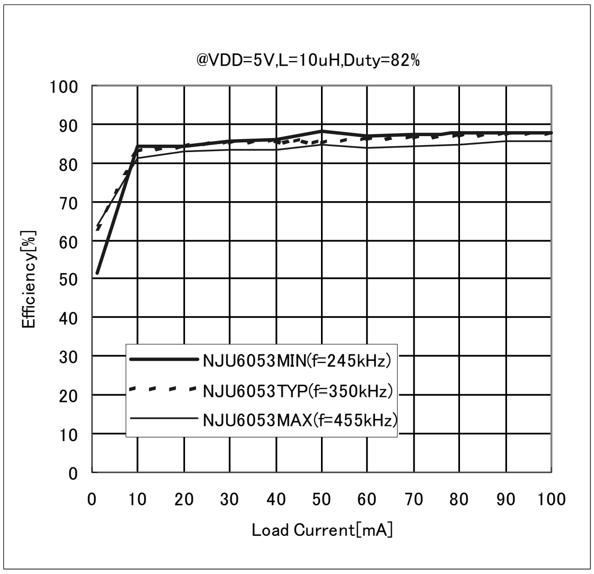


Figure 10 Efficiency vs. Load Current

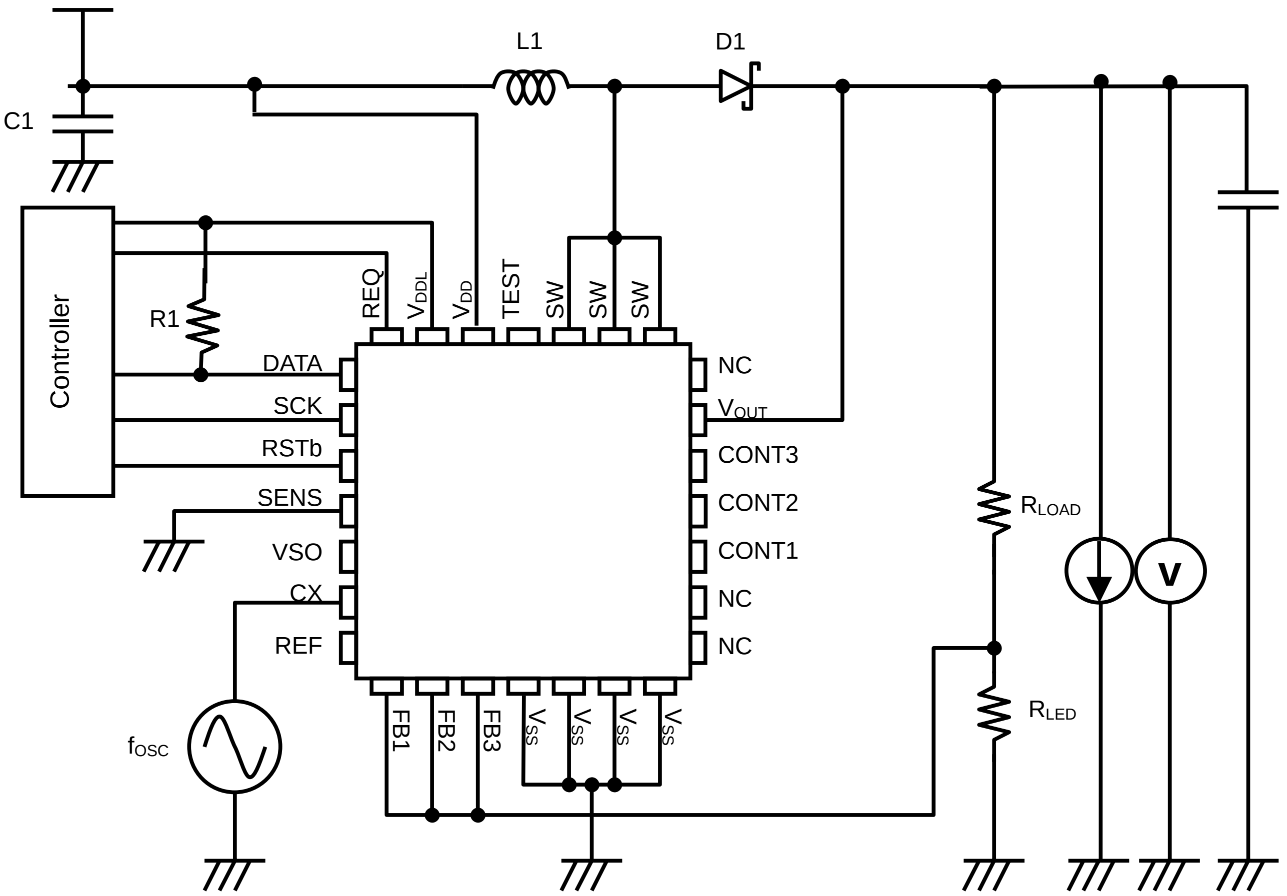
3. Typical Performance TEST Circuit

- TEST Command

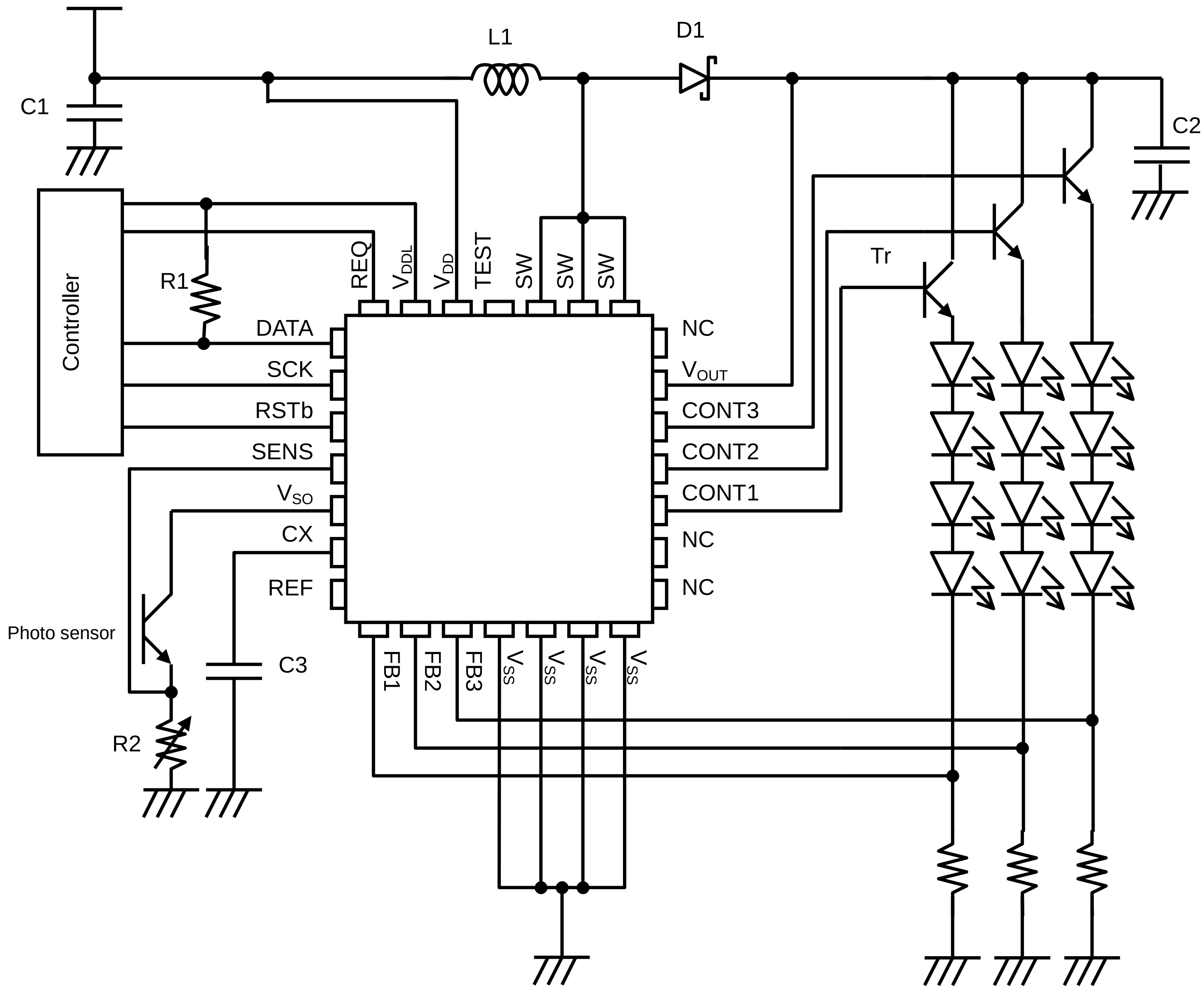
	B7	B6	B5	B4	B3	B2	B1	B0
Command Data 1	0	1	1	1	1	0	0	0
Command Data 2	0	0	0	0	0	0	0	0
Command Data 3	0	1	0	0	0	0	0	0

- TEST Circuit

D1	:Schottky diode
L1	:10uH
C1	:4.7uF
C2	:1uF
R_{LED}	:4.2kΩ
R_{LOAD}	:100kΩ
R1	:100kΩ



■ TYPICAL APPLICATION CIRCUIT



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