eFuse Application Circuit (with Thermal Shutdown)

Design guide

RD241A-DGUIDE-01

Toshiba Electronic Devices & Storage Corporation

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1. Introduction

This design guide document describes the design methodology of the eFuse Application Circuit (with Thermal Shutdown).

In recent years, various protective functions have become important in various consumer devices such as notebook PCs, game machines, storage devices, servers, etc. This document describes the Protection Circuit (hereafter referred to as "this design"), which is ideal for these applications, it is built using the eFuse IC (electronic fuse) and the over temperature detection IC Thermoflagger™.

eFuse IC (electronic fuse) operates when excessive current flows and has a fast current interruption function compared to the conventional fuse. In addition, it can be used repeatedly because it doesn't get destroyed by a single event of overcurrent. Various other protection functions, such as overvoltage protection, are also built in.

Thermoflagger™ (Over temperature detection IC) detects abnormally high temperature in the electronic devices in conjunction with a PTC thermistor. By arranging several PTC thermistors and connecting them to the Thermoflagger™, a wide range of abnormal temperatures can be detected at a low-cost. Featuring low current consumption operation, this product contributes to power saving.

This Design consists of a module board and a base board.

The module board consists of an eFuse IC (TCKE905ANA) with overcurrent protection and an over temperature detection IC Thermoflagger™ (TCTH021BE). In case of overcurrent detection, the eFuse IC cuts off the current. If the temperature of the PTC thermistor connected to the over temperature detection IC Thermoflagger™ rises due to abnormal heating, the Thermoflagger™ will output an over temperature detection signal and then this signal is sent to the eFuse IC which cuts off the current. In addition to eFuse IC functions, this design can be used to create a compact circuit that cuts off the output current when over temperature is detected at several points on the BOARD.

The base board is used for evaluating the module board. It is equipped with the N-ch power MOSFETs TPHR8504PL1, the MOSFET gate driver ICs TCK402G, the transistors with bias resistors for signal-control, the one-gate logic ICs TC7PZ17FU, and the CMOS logic ICs 74HC123D.

The base board is also used in the reference design of the Power Multiplexer Circuit.

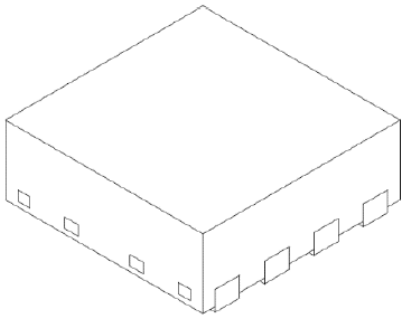
2. Main Components Used

2.1. eFuse IC TCKE905ANA

The main features of TCKE905ANA are as follows. Please click here for more information.

- High input voltage: V_{IN} = 25.0V (Max.)
- Low on-resistance: R_{ON} = 34mΩ (Typ.)
- Adjustable overcurrent limit: 0.5A to 4.0A
- Overvoltage clamp: TCKE905ANA: V_{OVC} = 5.7V (Typ.)
- Adjustable slew rate control by external capacitance for inrush current reduction
- Adjustable under voltage lockout by external resistor
- Thermal shutdown
- Small package
  WSON8 (2.0mm x 2.0mm (Typ.), t: 0.8mm (Max.))
- IEC62368-1 certification scheduled

Appearance and Terminal Layout



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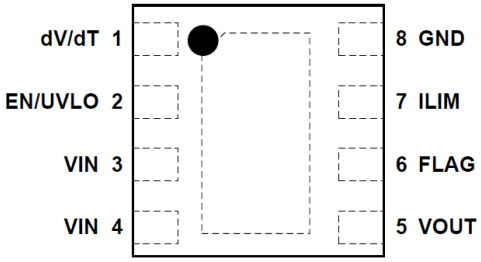


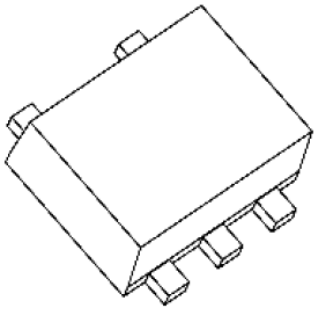
2.2. Thermoflagger™ (Over Temperature Detection IC) TCTH021BE

In this design it is used for over temperature detection. Please click here here for more information.

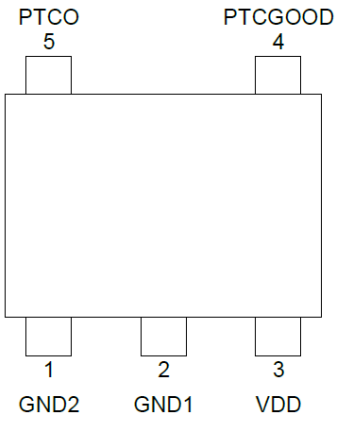
The main features of TCTH021BE are as follows.

- PTCO output current: I_{PTCO} = 10μA (Typ.)
- High PTCO output current accuracy: ±8% (V_{DD} = 3.3V, 25°C)
- Low Current Consumption: I_{DD} = 11.3μA (Typ.)
- FLAG signal output (PTCGOOD): Open-drain type
- Standard package: ESV (SOT-553) (1.6mm x 1.6mm x 0.55mm)

Appearance and Terminal Layout



ESV



2.3. MOSFET

This design uses the following MOSFETs. Click the part number for details.

Product Number	Application	Package	V_{DSS}	V_{GSS}	$R_{DS(ON)}$ (Max.)
SSM3K35MFV	For LED control	VESM	20V	+/-10V	4Ω@4.0V
SSM3J35AMFV	For LED control	VESM	-20V	+/-10V	1.1Ω@-4.5V

2.4. L-MOS Logic IC

This design uses the following L-MOS logic IC. Click the part number for details.

Product Number	Package	Function	Vcc
TC7SH34FU	USV	Non-Inverting Buffer	2.0V to 5.5V

2.5. Zener Diode

This design uses the following Zener diode. Click the part number for details.

Product Number	Package	V_Z (V) (Typ.)	VESD
CEZ6V8	US2H	6.8V@I_Z = 10mA	±30kV

3. Specifications and Block Diagram

3.1. Specifications

Table 3.1 and Table 3.2 list the main specifications of this circuit.

Table 3.1 Module Board Specifications

Board Name	Input Voltage	Rated Output Current
eFuse Application Circuit (with Thermal Shutdown)	Min. 2.7V Typ. 5V Max. 6V	1.1A (Typ.), up to 4A with appropriate resistor setting

Table 3.2 Base Board Specifications

Input/Output	Description
Input	VINA input (VINA 2.7V to 6V) VINB input (not used) Drive power supply (VDD 5V to 12V)
Output	Output load A to D (LOAD-A to LOAD-D, each Load can have both resistive load and capacitive load, Max current is 4A for the module board of this design) FLAG output (H-level (approximately 5V) is output when VINA is input)

3.2. Block Diagrams

3.2.1. Module Board Block Diagram

Fig. 3.1 shows the block diagram of the module board.

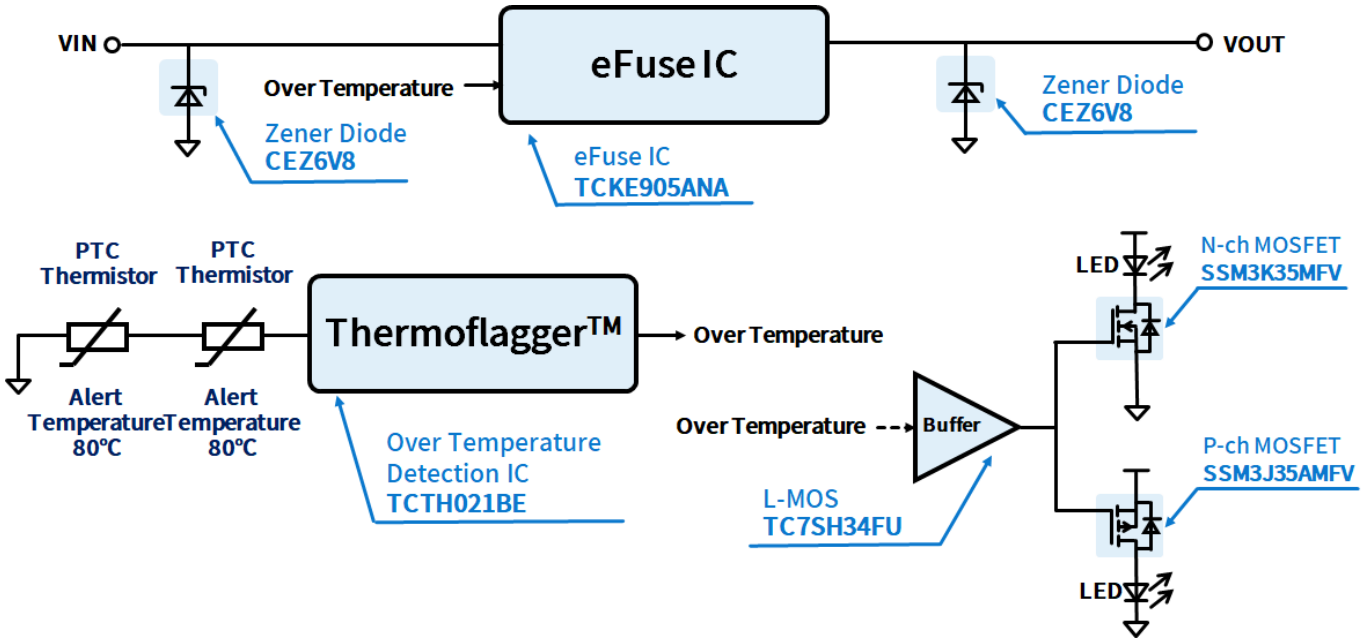


Fig. 3.1 Module Board Block Diagram

3.2.2. Base Board Block Diagram

Fig. 3.2 shows the block diagram of the base board.

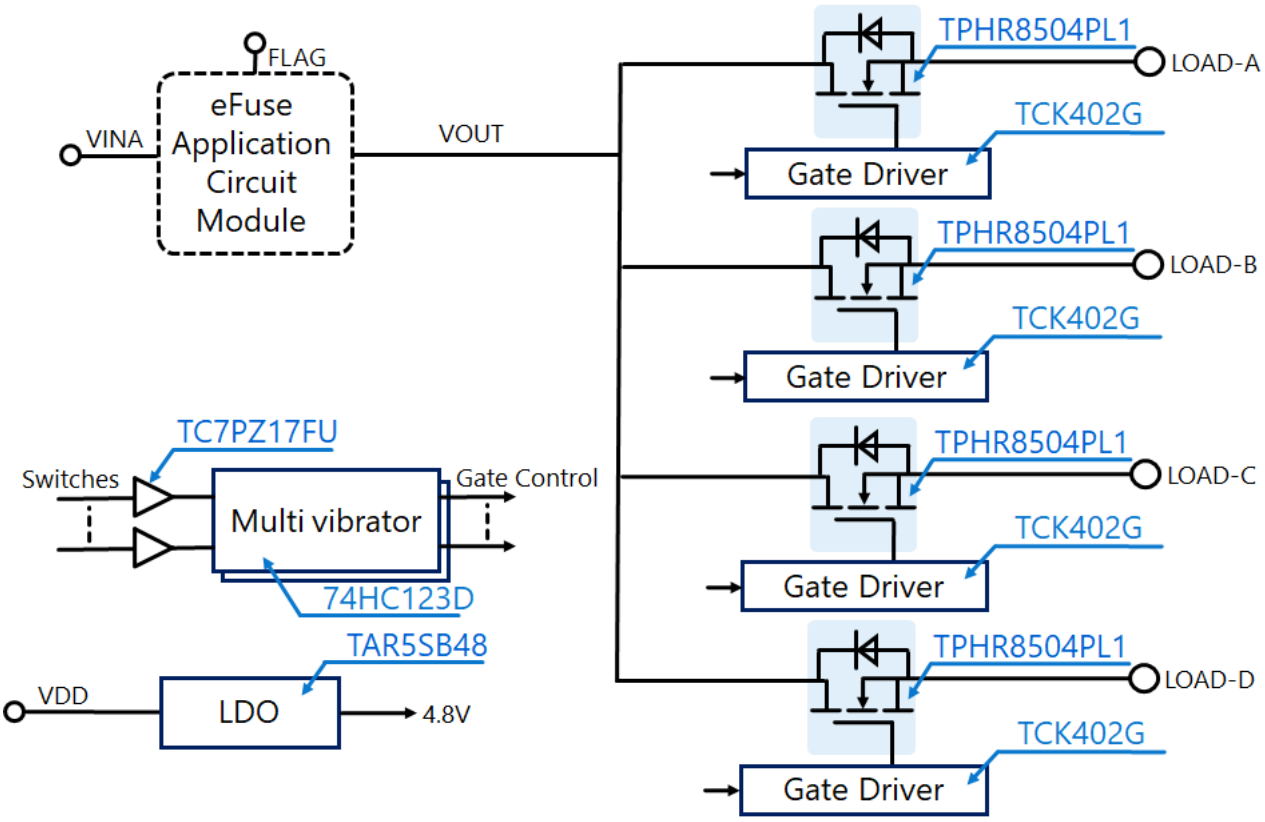


Fig. 3.2 Base Board Block Diagram

4. Circuit Design

4.1. Module Board

The circuit of the module board (eFuse Application Circuit (with Thermal Shutdown)) is shown below.

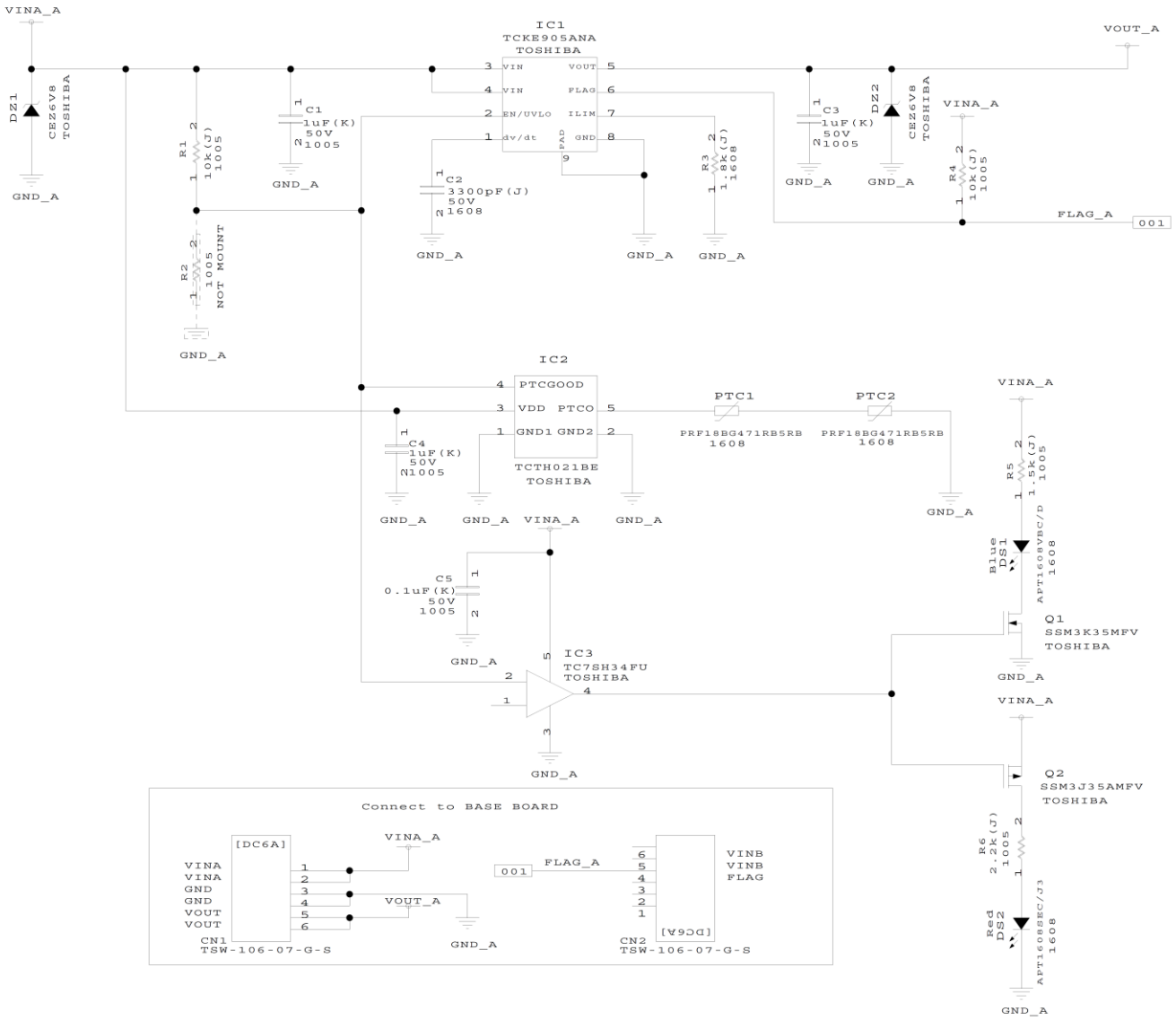


Fig. 4.1 Module Board Circuit Diagram

4.1.1. Over Temperature Detection

TCTH021BE (IC2) outputs a constant current of 10μA (Typ.) from PTCO terminal. When the voltage of the resistor connected to PTCO terminal becomes 0.50V (Typ.) or higher, PTCGOOD terminal changes from High level to Low level.

In this design, if the temperature of any of the two PTC thermistors (PTC1, PTC2) connected to PTCO terminal of TCTH021BE (IC2) becomes more than approximately 80°C, then the PTCGOOD terminal of TCTH021BE (IC2) changes from High level to Low level. The PTCGOOD terminal is connected to the EN/UVLO terminal of TCKE905ANA (IC1) and the input of TC7SH34FU (IC3). And when the PTCGOOD terminal becomes Low level, the VOUT output of TCKE905ANA (IC1) is cut off, the MOSFET SSM3K35MFV (Q1) is turned off, the MOSFET SSM3J35AMFV (Q2) is turned on, the blue LED (DS1) is turned off, and the red LED (DS2) is turned on.

4.1.2. Overcurrent Detection

Current can be limited by connecting a resistor to ILIM terminal of TCKE905ANA (IC1).

In this design, VIN current limit is set as shown below.

$$I_{INLIM}\ A = \frac{1985}{R_{ILIM}\ \Omega} + 0.04 = \frac{1985}{1800} + 0.04 \cong 1.1A$$

When a current of approximately 1.1A or more flows from the output VOUT, the overcurrent protective function is activated to cut off the output, and FLAG terminal of TCKE905ANA (IC1) changes from High level to Low level.

4.1.3. Setting the Slew Rate

The slew rate of VOUT can be set by connecting a capacitor to dV/dT terminal of TCKE905ANA (IC1).

In this desig, VOUT slew rate of TCKE905ANA (IC1) is set as shown below.

$$\mathrm{SR_{ON}\ V\ /\ ms} = \frac{42000}{\mathrm{C_{dV/dT}\ pF}} = \frac{42000}{3300} \cong 12.7\mathrm{V/ms}$$

4.2. Base Board

4.2.1. All Circuits on the Base Board

All circuits on the base board are shown below.

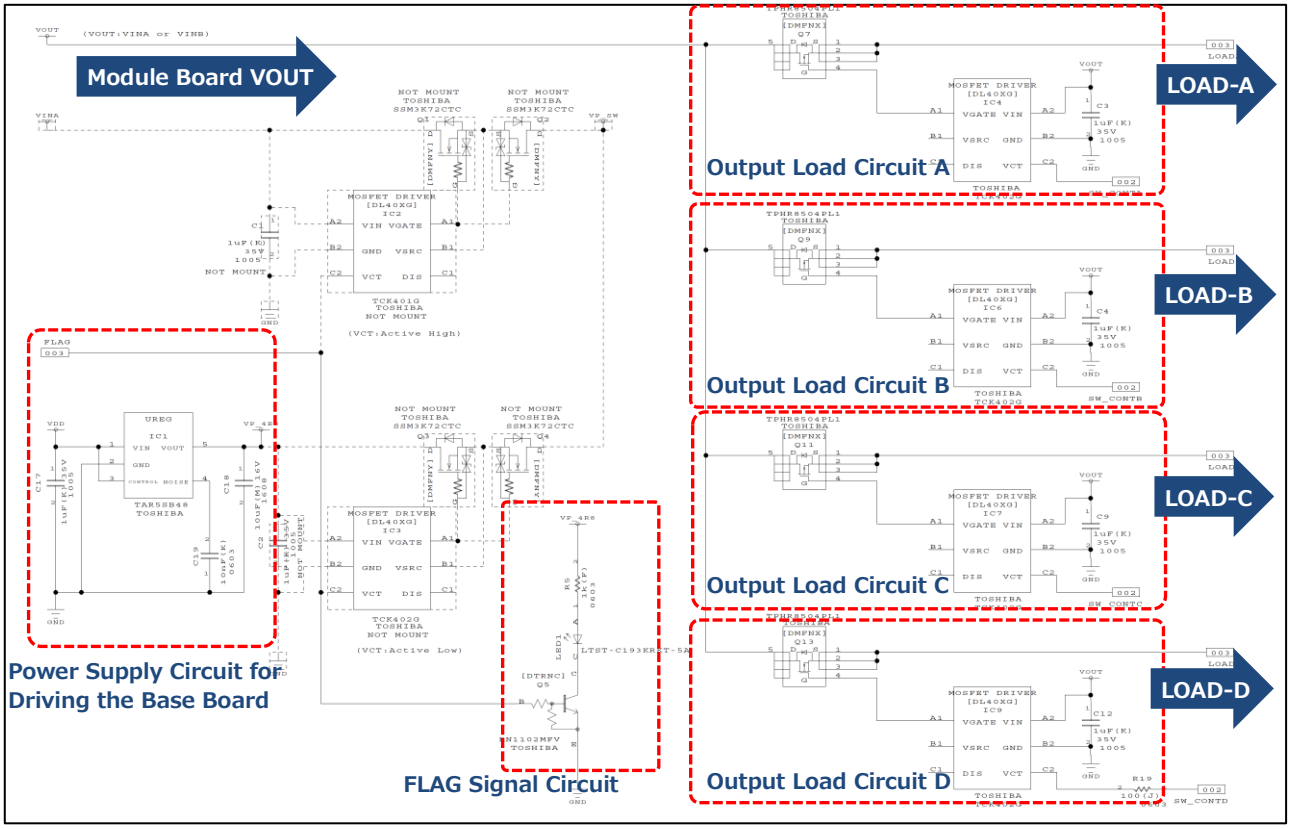


Fig. 4.2 Base Board Circuit (1)

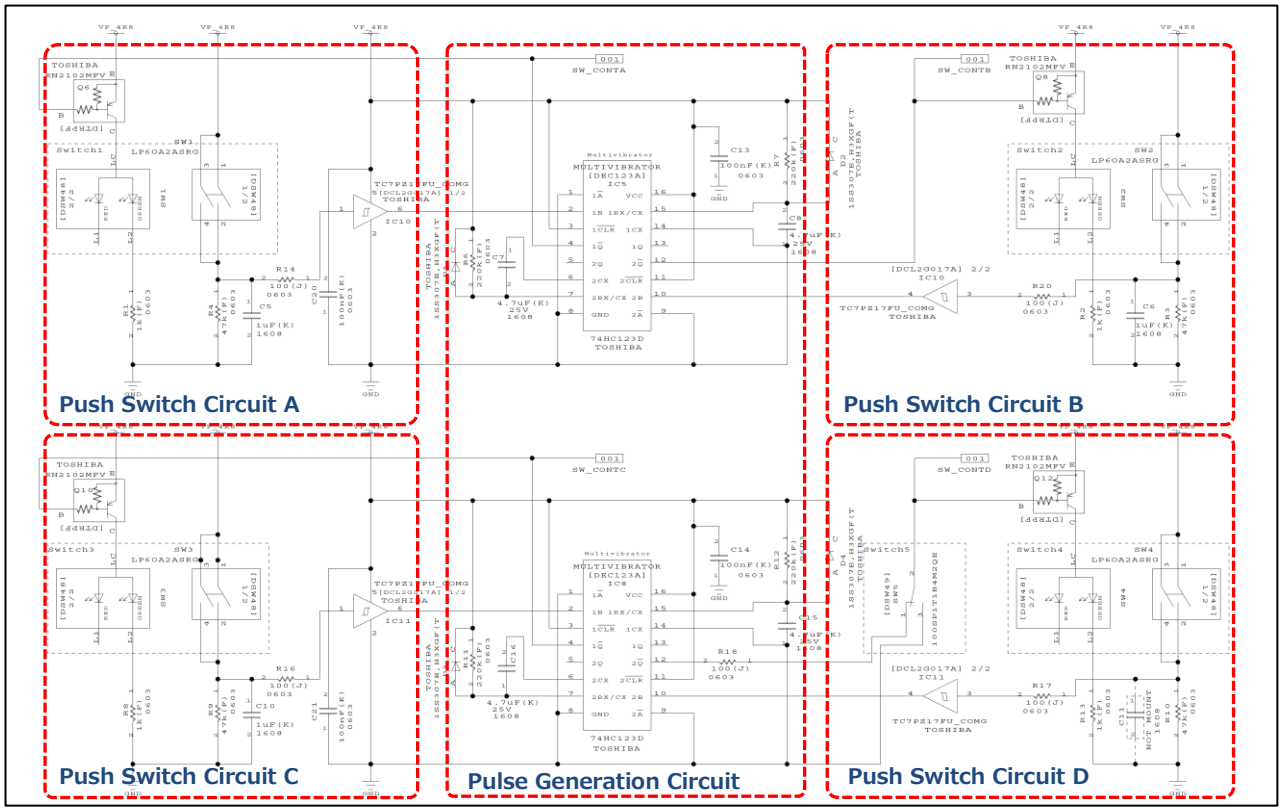


Fig. 4.3 Base Board Circuit (2)

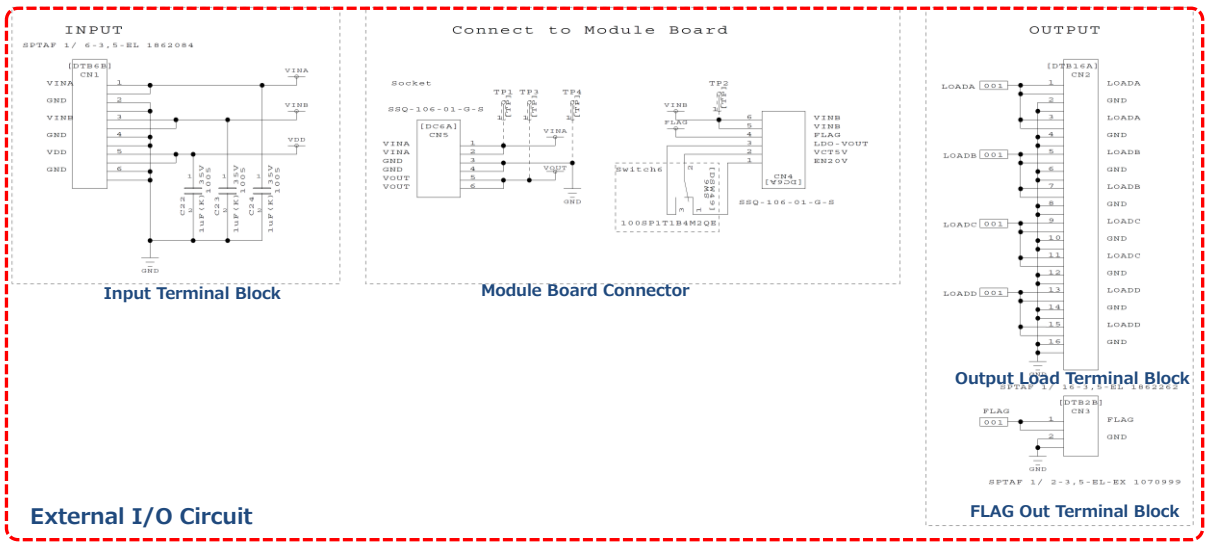


Fig. 4.4 Base Board Circuit (3)

The base board consists of the following circuits:

(1) Power supply circuit for driving the base board

It generates the power supply required to operate each circuit on the base board. The drive power supply VDD (5V to 12V) supplied to the input terminal block (CN1) is used to generate the internal power supply VP_4R8 (approximately 4.8V) via LDO TAR5SB48.

(2) FLAG signal-on circuit

The built-in resistor transistor (BRT) RN1102MFV lights the LED when FLAG output signal from the module board is High level (approximately 3.3V).

(3) Output load circuit (A to D)

High-side switches are configured with power MOSFET TPHR8504PL1 and MOSFET gate driver IC TCK402G. The power-out VOUT of the module board is used to power TCK402G.

(4) Push switch circuit (A to D)

Four push switches are used to generate the trigger signals for pulse signal generation circuit. Resistor, capacitor and schmitt trigger input buffer TC7PZ17FU are used for removing fluctuations. While the pulse signal generated by the pulse generator is at High level, the LED in the key switch is lit and driven by the built-in resistor transistor RN2102MFV.

(5) Pulse generation circuit

Monostable multi-vibrator 74HC123D uses the trigger signals from four push switches to generate a single-shot pulse of approximately 1 second for that system.

(6) External I/O circuit

Following connectors are used during the evaluation of the eFuse application circuit module board. The input terminal block (CN1) takes VINA input, and VDD input. The output load terminal block (CN2) allows to connect four loads (LOAD-A, LOAD-B, LOAD-C, LOAD-D). The terminal block (CN3) outputs FLAG signal. And connectors (CN4, CN5) are used for connecting the module board to the base board.

4.2.2. Output Load Energization Method

Four pulse energization switches that output current to the load for approximately 1 second after pressing the switch and one DC energization/pulse energization switch are mounted on the base board.

There are four output loads (LOAD-A, LOAD-B, LOAD-C, LOAD-D) on the base board. When the corresponding pulse energization switch is pressed, one-shot pulse of the following duration is generated by the monostable multi-vibrator 74HC123D, and the high-side switch of the output load circuit is turned on and current flows to the output load while this pulse is at the High level.

$$t_{wout} = 1 \times Cx \times Rx = 1 \times 4.7\mu F \times 220k\Omega \text{ (approximately 1.03sec)}$$

As for LOAD-D output, if DC energization/pulse energization switch is switched to DC energization, DC energization takes precedence over pulse energization, and current is continuously output. Therefore, be careful not to overheat or burn the load when DC energization is enabled.

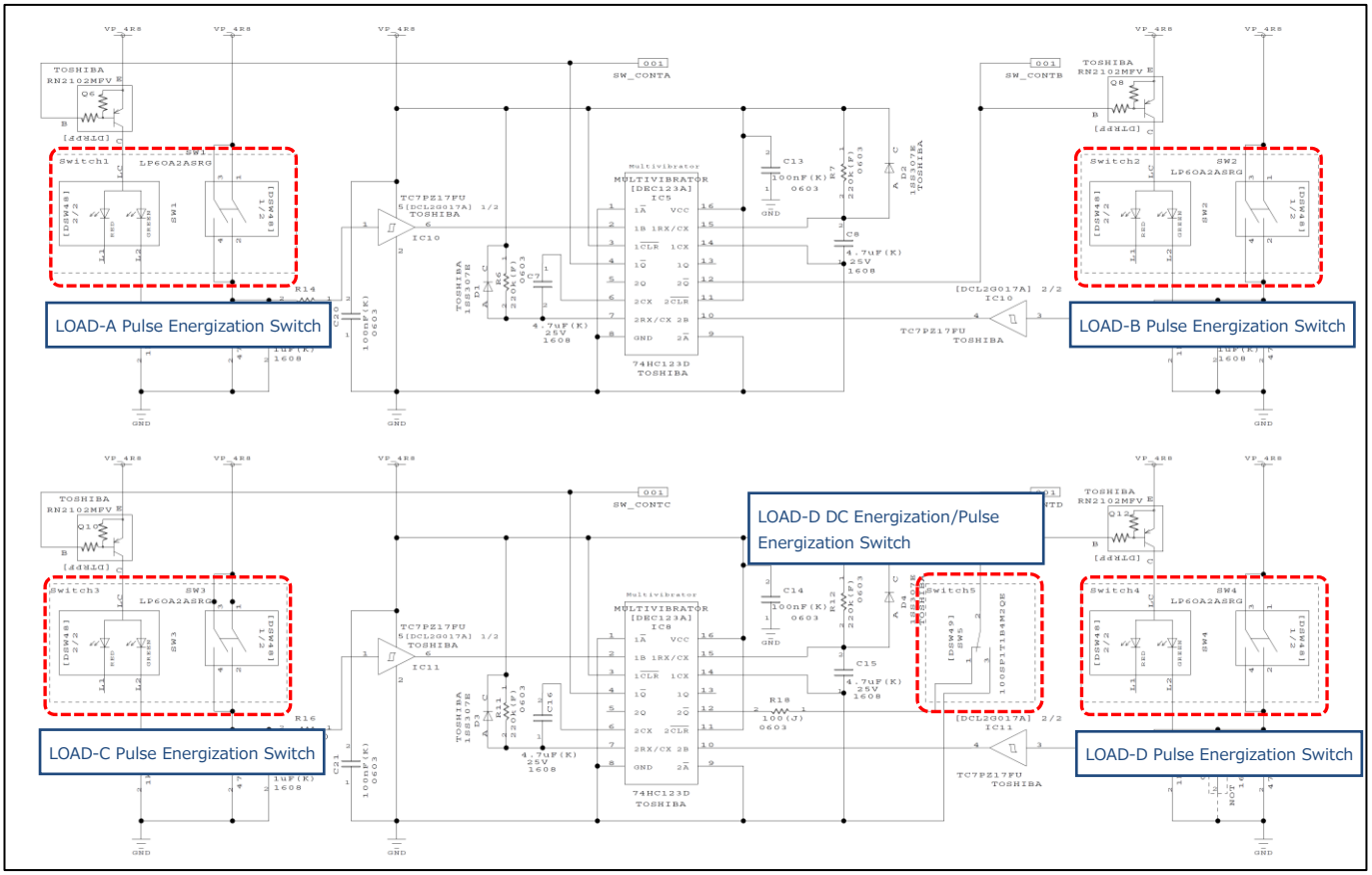


Fig. 4.5 Switches Related to Output Load Energization on Base Board Circuit

5. PCB Designs

5.1. Module Board

Fig. 5.1 shows an example of the component layout of the module board (eFuse Application Circuit (with Thermal Shutdown)).

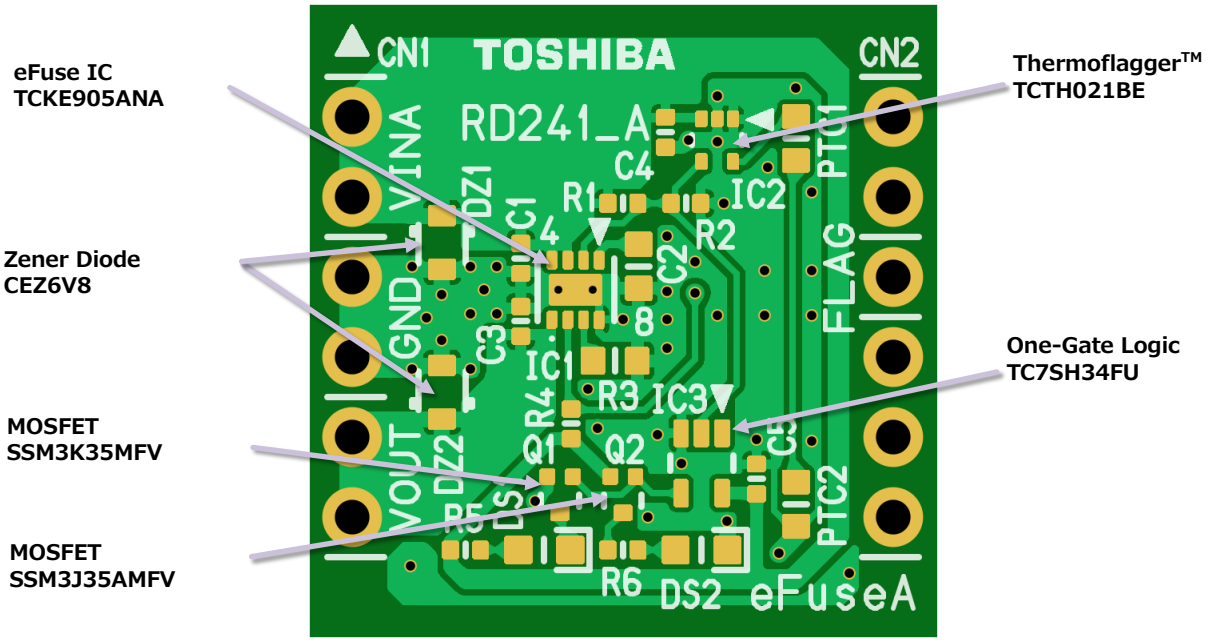


Fig. 5.1 Module Board Component Layout

5.2. Base Board

Fig. 5.2 shows an example of the component layout of the base board.

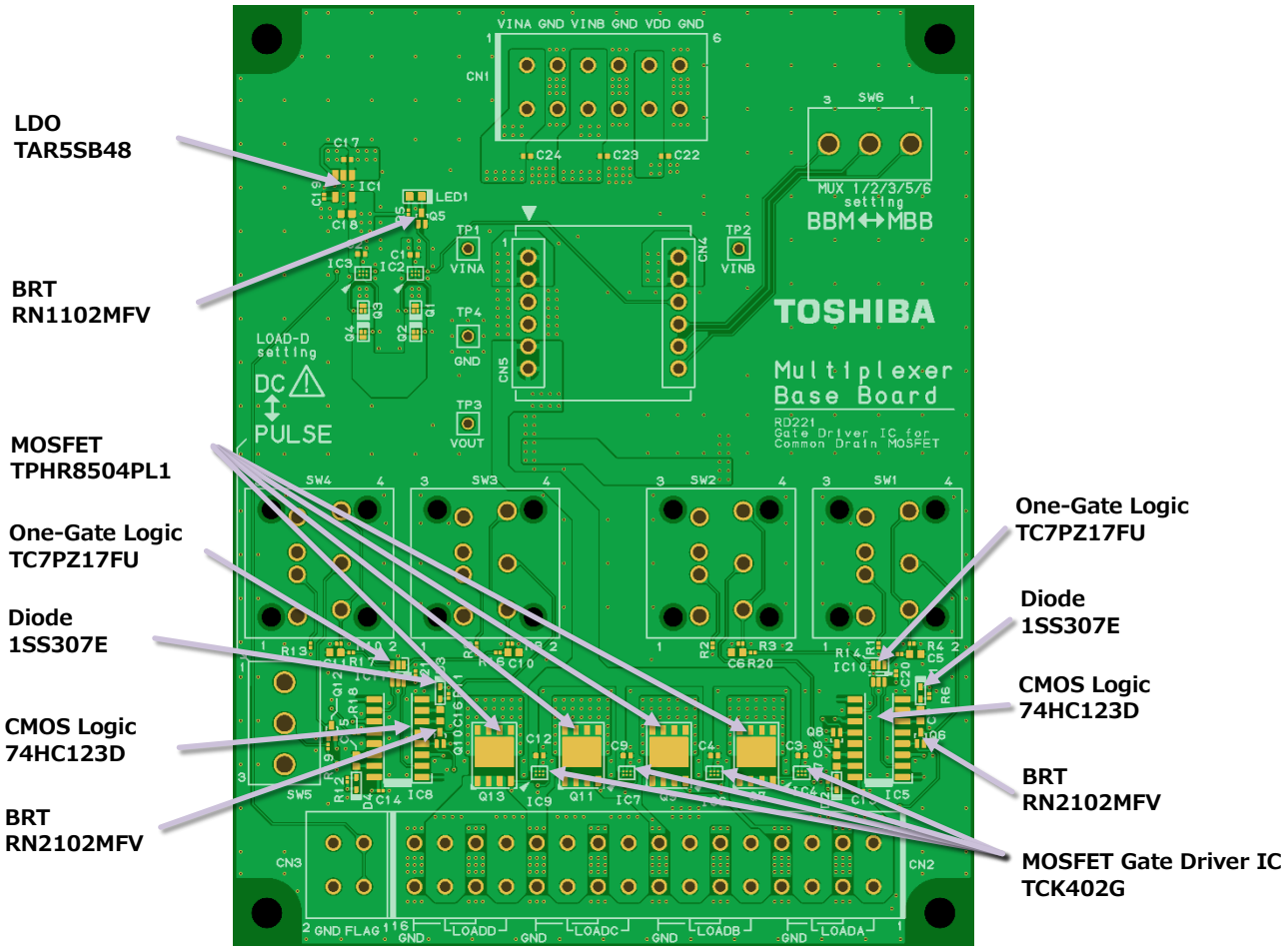


Fig. 5.2 Base Board Component Layout

5.3. Design Considerations

Points to consider during PCB pattern design:

- Pattern Design Considering Current

  Since the base board and the module board have circuits in which large currents flow, a sufficient pattern width must be ensured in designing the pattern to prevent problems due to temperature rise or voltage drop caused by the pattern when the maximum current with added margin is applied.

- Ground peripheral pattern design

  In order to suppress the voltage drop when current flows, it is necessary to consider good GND wiring, such as providing a ground plane or minimizing the pattern length.

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