

**Power Multiplexer Circuit  
(With Additional Circuit Using  
Common-Drain MOSFET)**

**Design Guide**

**RD221B-DGUIDE-01**

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**TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION**

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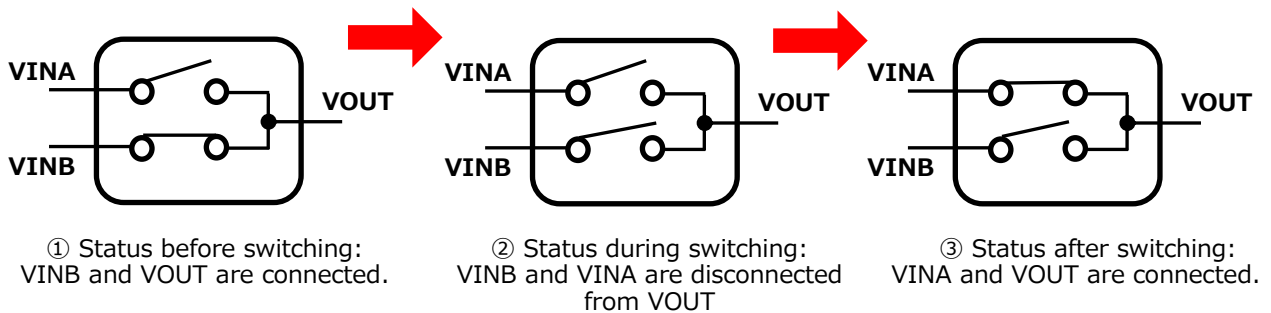
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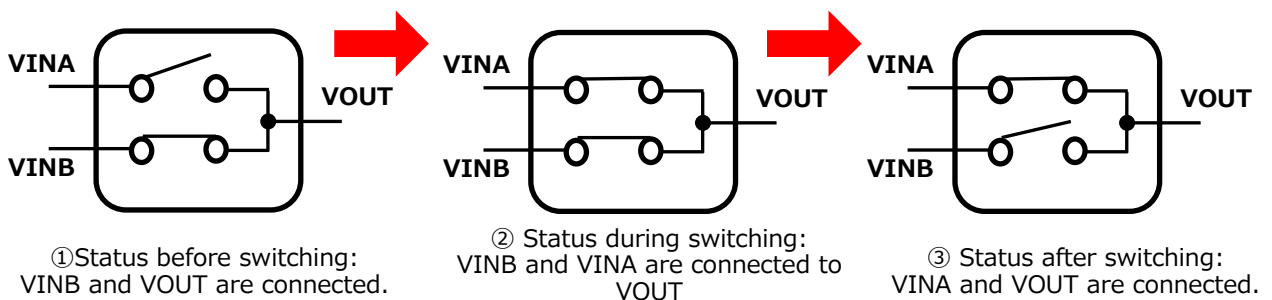
### 1. Introduction

This Design Guide provides an overview of the power multiplexer circuit design, PCB design, and product usage.

Demand for power multiplexer circuits used for switching and supply power from multiple sources such as USB terminal, a non-contact power supply terminal, and a built-in battery such as a lithium-ion battery is increasing in consumer applications such as mobile devices like smartphones, PCs, tablets, and wearable devices as well as game devices and charging devices for various types of batteries. In addition, high-current battery recharging, such as USB Power Delivery and quick recharging, requires a low-loss MOSFET to provide power. In addition, it is necessary to prevent reverse current flow to the input side when switching the power supply source and seamlessly switch the output voltage (ideal diode characteristic). This requires a BBM (Break-Before-Make) or MBB (Make-Before-Break) operation to achieve these characteristics.



**Fig. 1.1 BBM (Break-Before-Make)**



**Fig. 1.2 MBB (Make-Before-Break)**

## 2. Specifications and Block Diagram

### 2.1. Specifications

Table 2.1 and Table 2.2 list the main specifications of this circuit.

**Table 2.1 Module Board Specifications**

Board Name	Board Type	Input Voltage VINA/VINB	Maximum Output Current *	BBM Operation Support	MBB Operation Support	Switching Element		For Output MOSFET
MUX1	Standard 1	20 V 5 V	3 A	Yes	Yes	Gate Driver IC	TCK421G TCK425G	TPHR6503PL1
MUX2	Standard 2	12 V 5 V	3 A	Yes	Yes	Gate Driver IC	TCK423G TCK425G	TPN1R603PL
MUX3	High Power 1	20 V 9 V	5 A	Yes	Yes	Gate Driver IC	TCK421G TCK424G	TPN1R603PL
MUX4	eFuse IC	12 V 5 V	3 A	Yes	-	eFuse IC	TCKE812NA TCKE712BNL	SSM6K513NU -
MUX5	High Power 2	24 V 12 V	5 A	Yes	Yes	Gate Driver IC	TCK420G TCK422G	TPHR8504PL1
MUX6	Compact Type	20 V 9 V	3 A	Yes	Yes	Gate Driver IC	TCK421G TCK424G	SSM10N961L

\* The product can carry a current exceeding the specified value. However, the board should be used within the range not exceeding the specified value due to heat dissipation design.

**Table 2.2 Base Board Specifications**

Input	VINA input (VINA 5 to 24 V) VINB input (VINB 5 to 12 V) Drive power supply (VDD 5 to 12 V)
Output	Output load A to D (LOAD-A~LOAD-D, each Load can have both resistive load and capacitive load, Max current 3 A or 5 A depending on module board) FLAG output (H-level (approx. 3.3 / 5 V) is output when VINA is input)

### 2.2. Block Diagram

Fig. 2.1 and Fig. 2.2 show the block diagrams of this circuit.

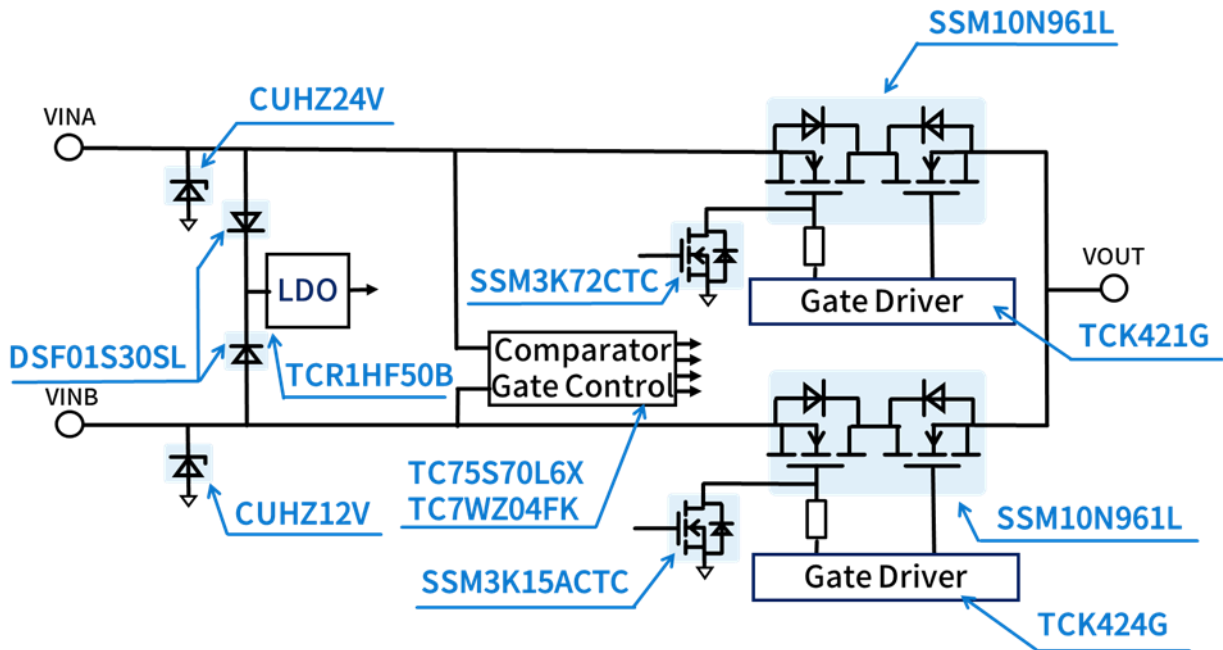


Fig. 2.1 Block Diagram (Module Board – Example MUX6)

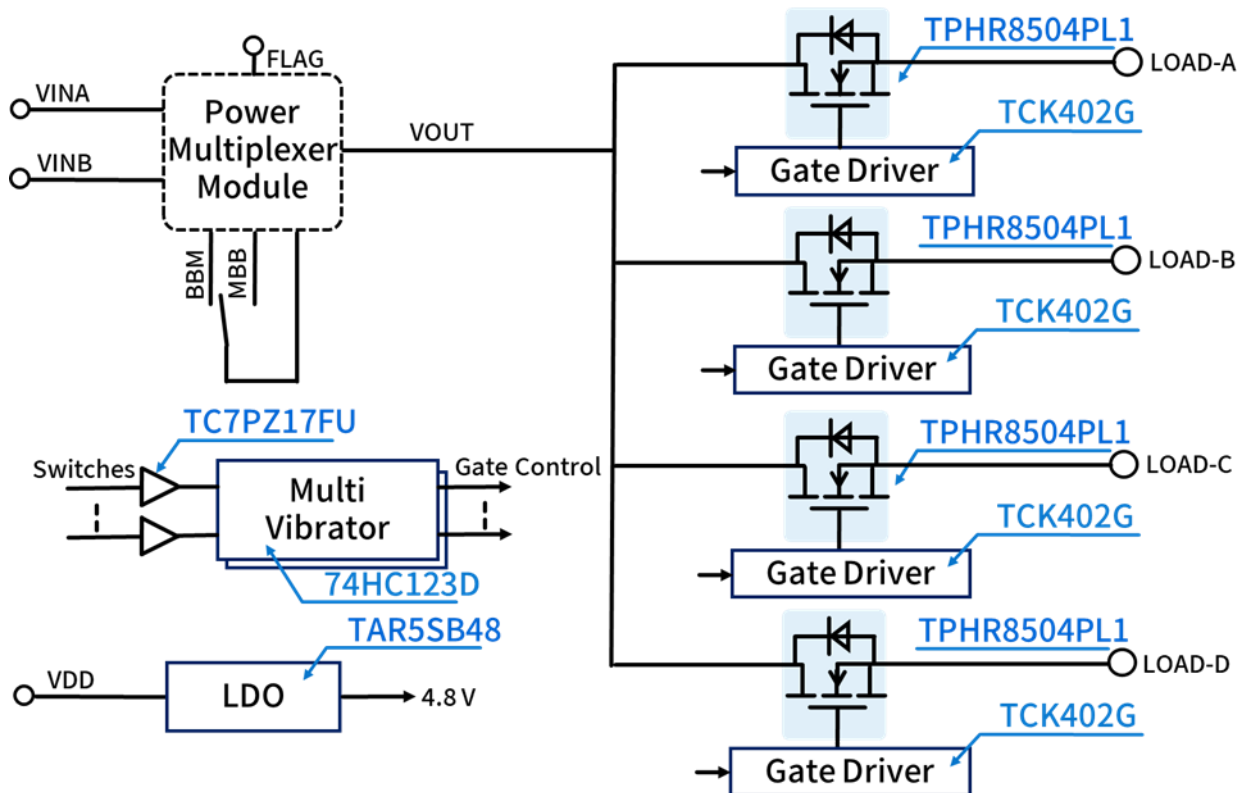


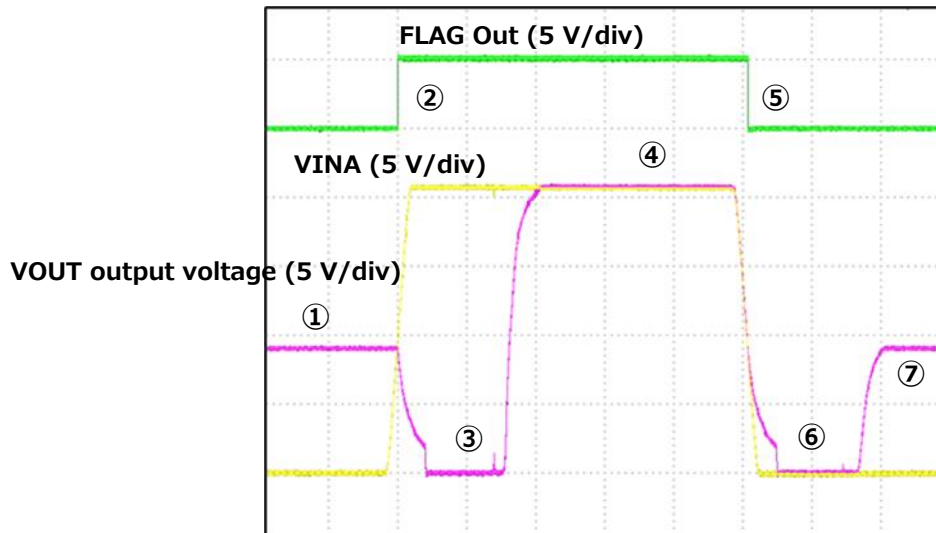
Fig. 2.2 Block Diagram (Base Board)

### 3. Circuit Design

#### 3.1. Module Board

##### 3.1.1. BBM Operation

Fig. 3.1 shows the waveform when the module board MUX6 is operated in the BBM mode.



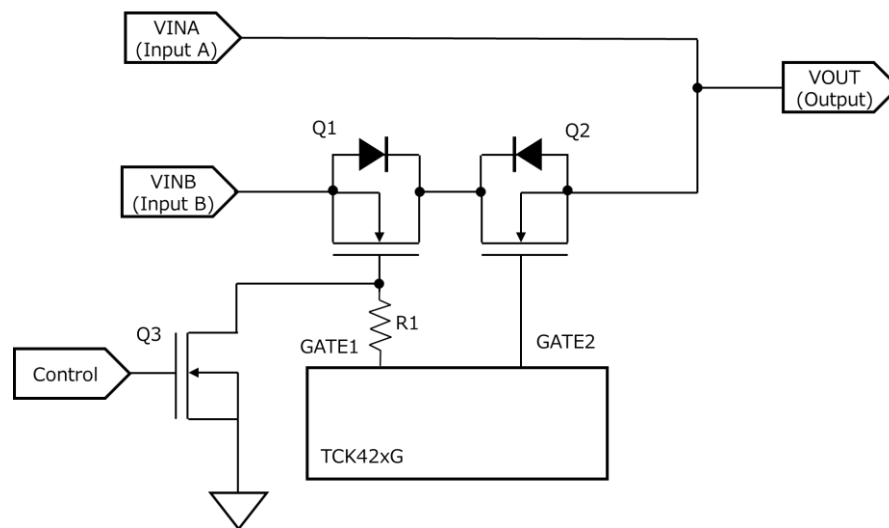
**Fig. 3.1 Waveform during BBM Operation (2 ms/div)**  
**VINA = 20 V, VINB = 9 V, RL = 300  $\Omega$ , CL = None**

VINB is continuously energized with 9 V, and 20 V voltage pulses of 10 ms are applied to VINA. When 20 V is applied to VINA and the output voltage switches from 9 V to 20 V, there is a start-up time  $t_{ON}$  of approximately 3 ms when MOSFET driver IC TCK421G that controls VINA voltage is turned on, and the output voltage during this time is 0 V. Also, when VINA pin becomes 0 V and the output voltage switches from 20 V to 9 V, there is a start-up time  $t_{ON}$  of about 3 ms when MOSFET driver IC TCK424G that controls VINB voltage is turned on in the same way, and the output voltage during this time becomes 0 V. FLAG output is High (approx. 5 V) while VINA is applied.

Details of each operation in the waveform are as follows.

- ① 9 V is applied to VINB, and VINB voltage (approx. 9 V) is output.
- ② When 20 V is applied to VINA, FLAG output becomes High (approx. 5 V). VINA driver (TCK421G) starts operating at this timing.
- ③ 0 V is output because of VINB driver (TCK424G) is off.
- ④ VINA voltage (about 20 V) is generated after  $t_{ON}$  of VINA driver (TCK421G).
- ⑤ When the voltage at VINA becomes 0 V, FLAG output becomes Low (0 V). VINB driver (TCK424G) starts operating at this timing.
- ⑥ 0 V is output because VINA driver (TCK421G) is off.
- ⑦ VINB voltage (approximately 9 V) is output after  $t_{ON}$  of VINB driver (TCK424G).

### 3.1.2. MBB Operation



**Fig. 3.2 MBB Operation Circuit**

The MBB operation outline of this circuit is described below. The MBB operation circuit shown in Fig. 3.2 assumes that  $V_{INA} > V_{INB}$  and  $V_{INB}$  is continuously energized.

- ① Apply voltage to  $V_{INB}$  ( $V_{INA}$  voltage is off). Common drain connected MOSFET Q1 and Q2 are turned on by MOSFET driver IC TCK42xG, and  $V_{INB}$  voltage is output to VOUT .
- ② When  $V_{INA}$  is detected, the Gate Shut-off MOSFET Q3 is turned on. This causes the voltage at the gate of MOSFET Q1 to become 0 V and Q1 is turned off. Therefore the voltage dropped by the forward voltage of the body diode of Q1 from  $V_{INB}$  voltage is output to VOUT.
- ③ Even when voltage is applied from  $V_{INA}$ , reverse current does not flow to  $V_{INB}$  because of the body diode of Q1.

The above operation allows seamless voltage-output switching from  $V_{INB}$  to  $V_{INA}$  by MBB operation.

In addition, the following operations enable seamless voltage-output switching to  $V_{INB}$  from  $V_{INA}$  by MBB operation.

- ①  $V_{INA}$  is turned off (0 V) while  $V_{INA}$  is being supplied.
- ② The voltage dropped by the forward voltage of the body diode of Q1 from  $V_{INB}$  voltage is output to VOUT.
- ③ Q3 turns off. Thus Q1 is turned ON.  $V_{INB}$  voltage is output to VOUT.



Table 3.1 shows the timing transition table of MBB operation, and Fig. 3.3 shows the timing chart of MBB operation. The operation assumes that VINA voltage > VINB voltage.

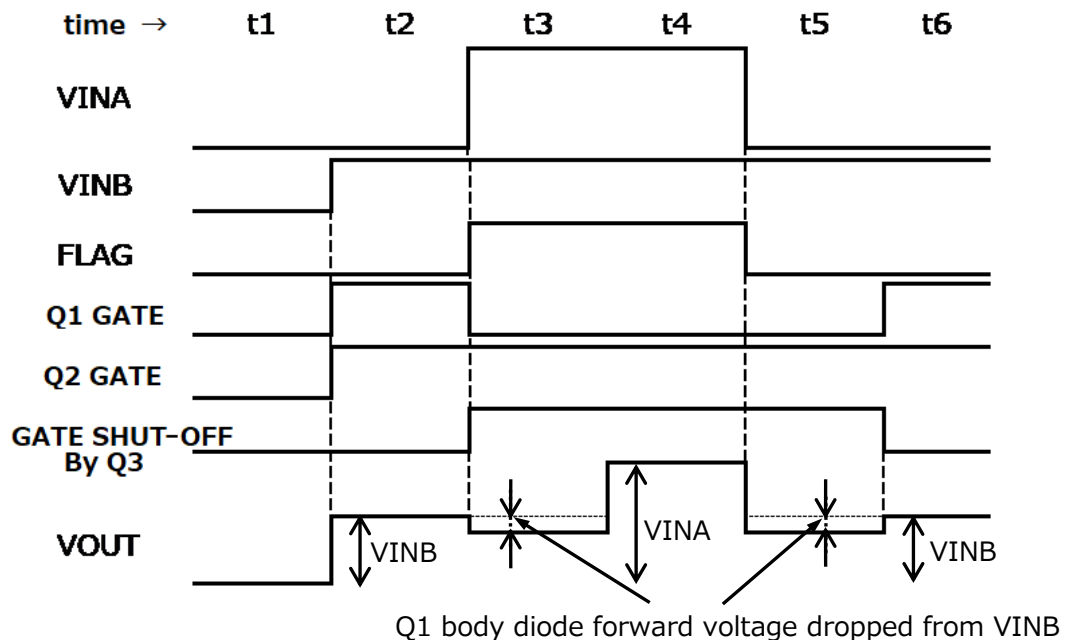
**Table 3.1 Timing Transitions of MBB Operation (Input VINA Voltage > VINB Voltage)**

Time (state)	t1	t2	t3	t4	t5	t6
VINA In	0 V	0 V	ON	ON	0 V	0 V
VINB In	0 V	ON	ON	ON	ON	ON
FLAG Out*	L	L	H	H	L	L
Q1 Gate	OFF	ON	OFF	OFF	OFF	ON
Q2 Gate	OFF	ON	ON	ON	ON	ON
Q3 Gate Shut-off	OFF	OFF	ON	ON	ON	OFF
VOUT	0 V	VINB end	**	VINA end ***	**	VINB end

\* H output (approx. 3.3 V) when there is VINA input, and L output (0 V) when there is no VINA input.

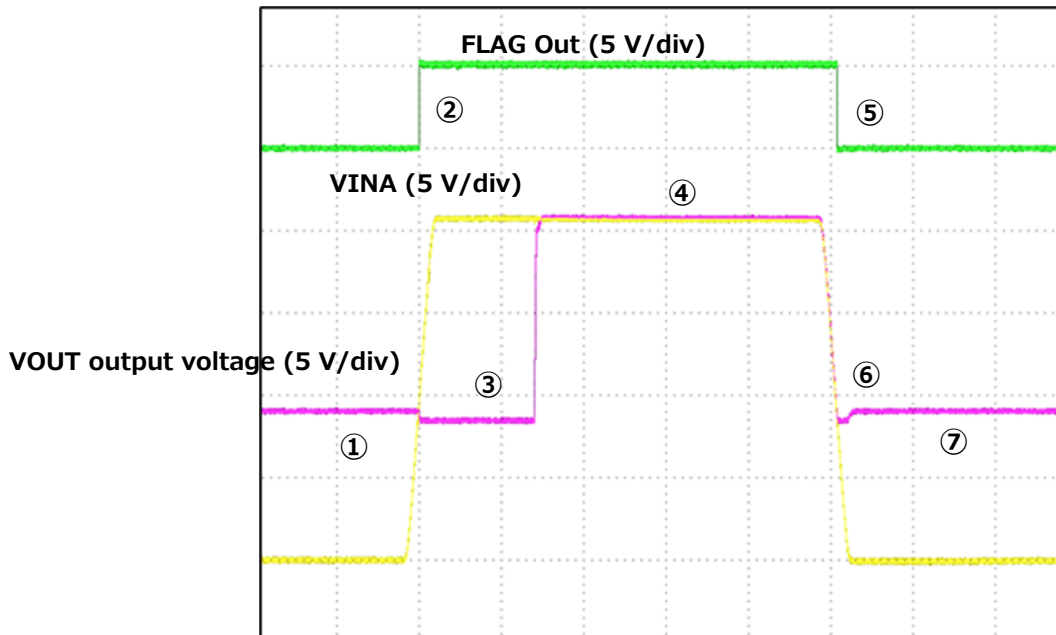
\*\* The voltage dropped by the forward voltage of the body diode of Q1 from VINB voltage is output to VOUT.

\*\*\* VINA voltage is reached after  $t_{ON}$  of TCK42xG (about 3 ms). It holds the voltage of the previous timing until then.



**Fig. 3.3 MBB Operation Timing Chart**

Fig. 3.4 shows the waveforms during actual MBB operation (of MUX6 as an example).



**Fig. 3.4 MBB Operation Waveform (2 ms/div)**  
**VINA = 20 V, VINB = 9 V, RL = 300  $\Omega$ , CL = None**

This section describes the operation of seamlessly switching the voltage without dropping to 0 V when VINB is continuously energized as 9 V and 20 V pulses of 10 ms are applied to VINA.

- ① 9 V is applied to VINB, and VINB voltage (about 9 V) is sent to the output.
- ② When 20 V is applied to VINA, the FLAG output becomes High (approx. 5 V). And VINA driver (TCK421G) starts operating at this timing.
- ③ In VINB driver circuit, the gate shut-off MOSFET SSM3K15ACTC corresponding to Q3 in Fig. 3.2 is turned on, and the MOSFET corresponding to Q1 in SSM10N961L is turned off. During the start-up time  $t_{ON}$  after TCK421G is turned on in ② (about 3 ms), the voltage dropped by the forward voltage of the body diode of Q1 from VINB voltage is output to VOUT.
- ④ VINA voltage (about 20 V) is output after  $t_{ON}$  period of TCK421G from the time it turned on in step ③.
- ⑤ When the applied voltage of VINA becomes 0 V, FLAG output becomes Low (0 V).
- ⑥ Since VINA voltage became 0 V, the Gate Shut-off MOSFET corresponding to Q3 in Fig. 3.2 is turned off, and the MOSFET corresponding to Q1 in SSM10N961L starts turn-on operation. During this time, voltage dropped by the forward voltage of the body diode of Q1 from VINB voltage is output to VOUT.
- ⑦ The MOSFET corresponding to Q1 is turned on and VINB voltage (approx. 9 V) is output.

### 3.1.3. Circuit for MOSFET Gate Driver IC

MUX6 circuit is shown below as an example circuit for the module board (MUX1, MUX2, MUX3, MUX5, MUX6) using MOSFET gate driver ICs.

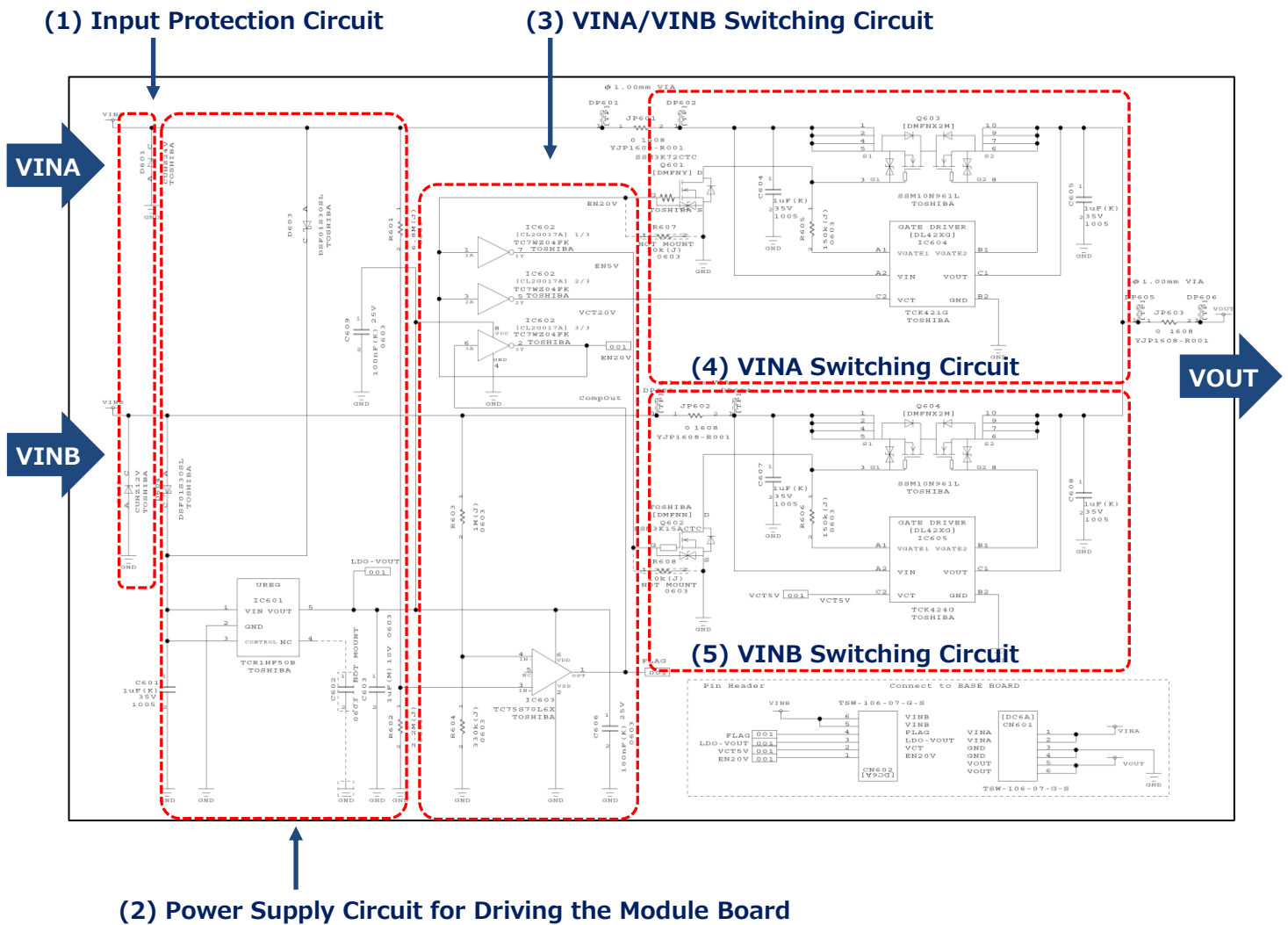


Fig. 3.5 Module Board (MUX6) Circuit

The module board consists of the following circuits:

(1) Input protection circuit

There are two power inputs for the power multiplexer: VINA and VINB, and MUX6 supports 20 V (VINA) and 9 V (VINB) inputs. A zener diode [CHUZ24V](#) with a zener voltage of 24 V is used on VINA side and a zener diode [CHUZ12V](#) with a zener voltage of 12 V is used on VINB side to protect the circuit from overvoltage surges, etc. from the input.

(2) Power supply circuit for driving the module board

A 5 V output LDO [TCR1HF50B](#) is used as the power supply for ICs used in VINA/VINB switching circuit described below. VINA and VINB are connected to the power inputs of the LDOs via Schottky barrier diode [DSF01S30SL](#). If either power supply VINA or VINB is applied, the power supply for driving the module board is supplied.

(3) VINA/VINB switching circuit

A comparator [TC75S70L6X](#) is used to detect the voltages of VINA and VINB and to output the H-level (approx. 3.3 V) to FLAG output when the voltage is input to VINA, and a CMOS logic IC [TC7WZ04FK](#) is used to generate a switching control signal between VINA and VINB from the output of the comparator.

(4) VINA switching circuit

To switch to the output of VINA power supply (20 V, max. 3 A), a common-drain MOSFET [SSM10N961L](#) is used. And to control the gate signals of these MOSFETs a 20 V bus compatible MOSFET gate driver IC [TCK421G](#) is used. [SSM3K72CTC](#) is used as a gate shut-off MOSFET for the input-side MOSFET of the common-drain configuration.

(5) VINB switching circuit

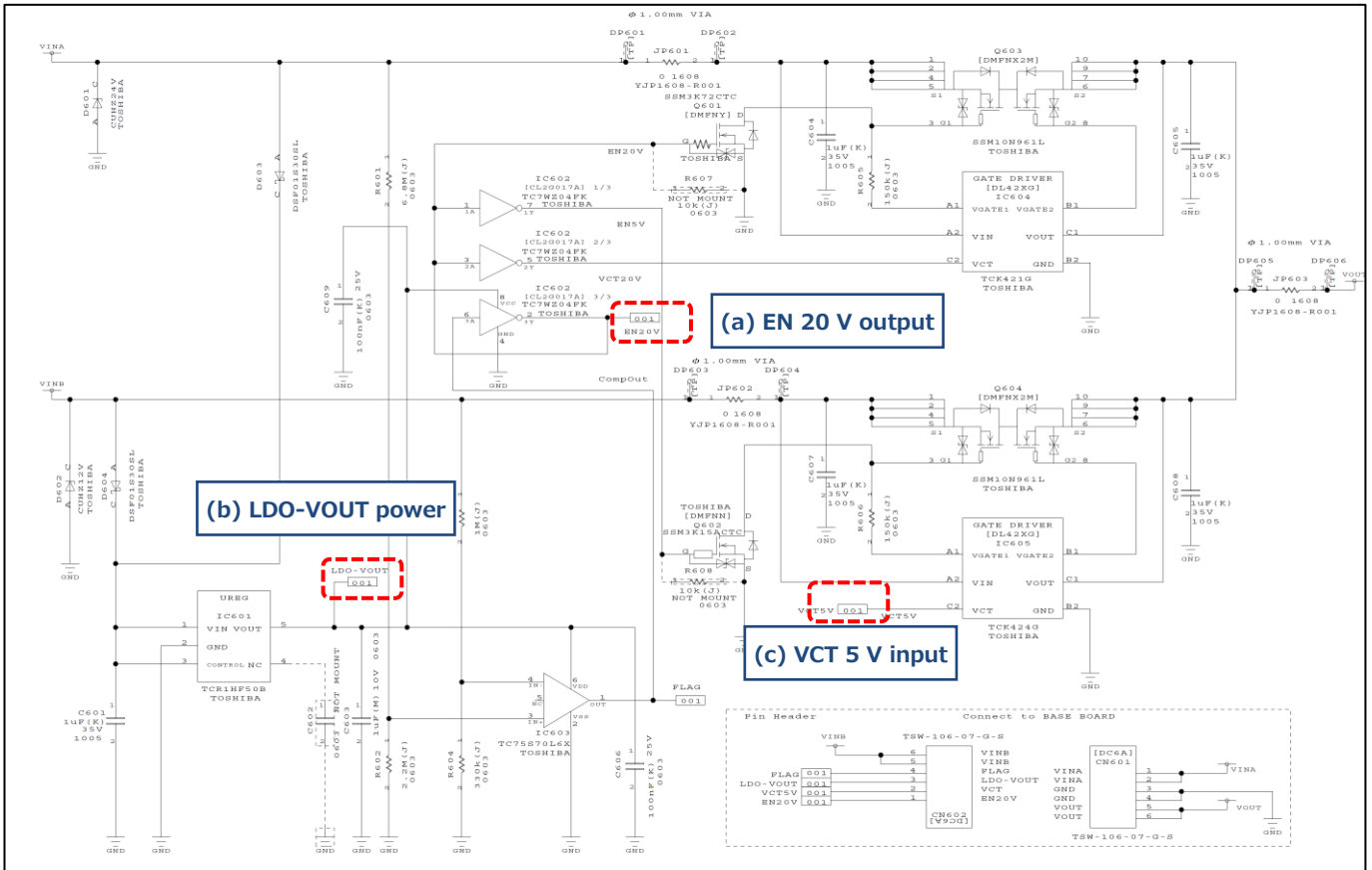
To control the output of VINB power supply (9 V, max. 3 A), a common-drain MOSFET [SSM10N961L](#) is used. And to control gate signals of these MOSFETs a 9 V bus compatible MOSFET gate driver IC [TCK424G](#) is used. [SSM3K15ACTC](#) is used as a gate shut-off MOSFET for the input-side MOSFET of the common-drain configuration.

The power supplied from VINA (20 V, max. 3 A) and VINB (9 V, max. 3 A) is output from VOUT as shown below.

- If the power is input only to either VINA (20 V) or VINB (9 V) connector, the input power is output to VOUT.
- If power is input to both VINA and VINB, the power of VINA (20 V) is output to VOUT.

**3.1.4. BBM/MBB Switching Operation**

Module board (MUX1, MUX2, MUX3, MUX5, MUX6) using MOSFET gate driver IC can switch between BBM operation or MBB operation.



**Fig. 3.6 BBM/MBB Switching on the Module-Board (MUX6)**

BBM/MBB operation switching is achieved switching the signals of the module board connector with a toggle switch on the base board. The input voltages of VINA and VINB are compared using a comparator and if the voltage is input to VINA, High level (approx. 5 V) is output to the FLAG, and if the voltage is not input to VINA, Low level (0 V) is output to the FLAG.

(a) EN20V output (Inverted output of FLAG signal, High level output when no voltage is input to VINA)

(b) LDO-VOUT output (High level output if voltage is input to either of VINA, VINB)

(c) VCT5V input (control pin of VINB side MOSFET gate driver IC, gate on with H level input)

In BBM mode, (a) EN20V output is connected to (c) VCT5V input. Thus, MOSFET gate driver IC TCK424G on VINB side is gated off when voltage is input to VINA and gated on when voltage is not input to VINA to achieve BBM operation.

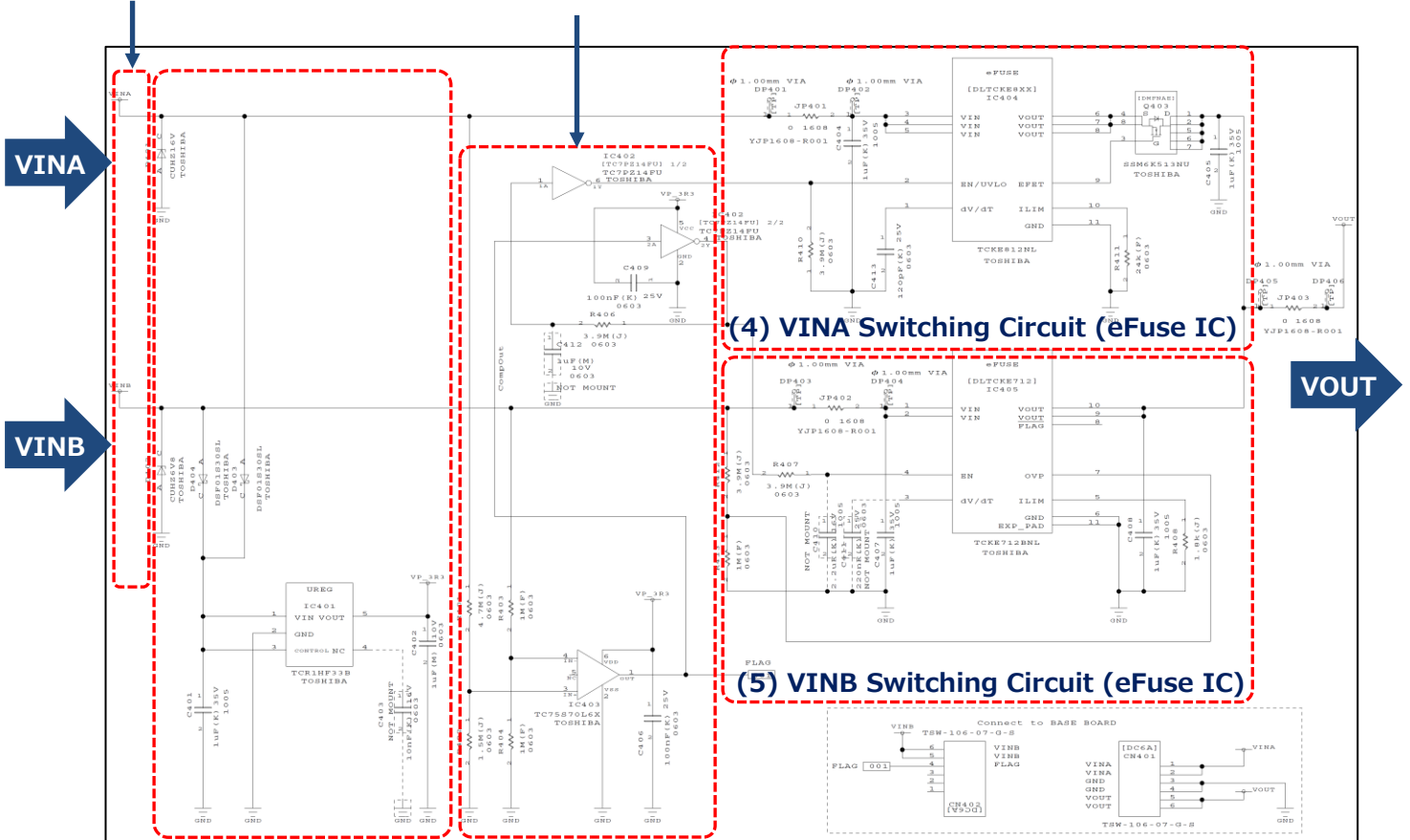
In MBB mode, (b) LDO-VOUT output is connected to (c) VCT5V input. As a result, VINB side MOSFET gate driver IC TCK424G is constantly turned on if the voltage is input to VINB, and MBB operation is realized by operating the gate cut-off MOSFET.

### Circuit of eFuse IC Version Board

Circuit of the Module Board (MUX4) using eFuse IC is shown below.

**(1) Input Protection Circuit**

**(3) VINA/VINB Switching Circuit**



**(2) Power Supply Circuit for Driving the Module Board**

**Fig. 3.7 Module Board (MUX4) Circuit**

MUX4 module board uses eFuse IC instead of MOSFET gate driver ICs for the switching of inputs. A semiconductor fuse, eFuse IC is equipped with a variety of protective functions such as a high-speed current interrupt function and a short-circuit protection function when overcurrent is detected. Unlike circuits with MOSFET gate driver ICs, they do not drive external common-drain or common-source-connected MOSFET, so they only support BBM operation, but power multiplexer circuits can be realized with a simple configuration.

VINA (12 V) switch uses eFuse IC [TCKE812NL](#), MOSFET [SSM6K513NU](#) externally to prevent current backflow, and VINB (5 V) switch uses eFuse IC [TCKE712NL](#).

### 3.2. Base Board

#### 3.2.1. Circuit of the Base Board

Each circuit on the base board is shown below.

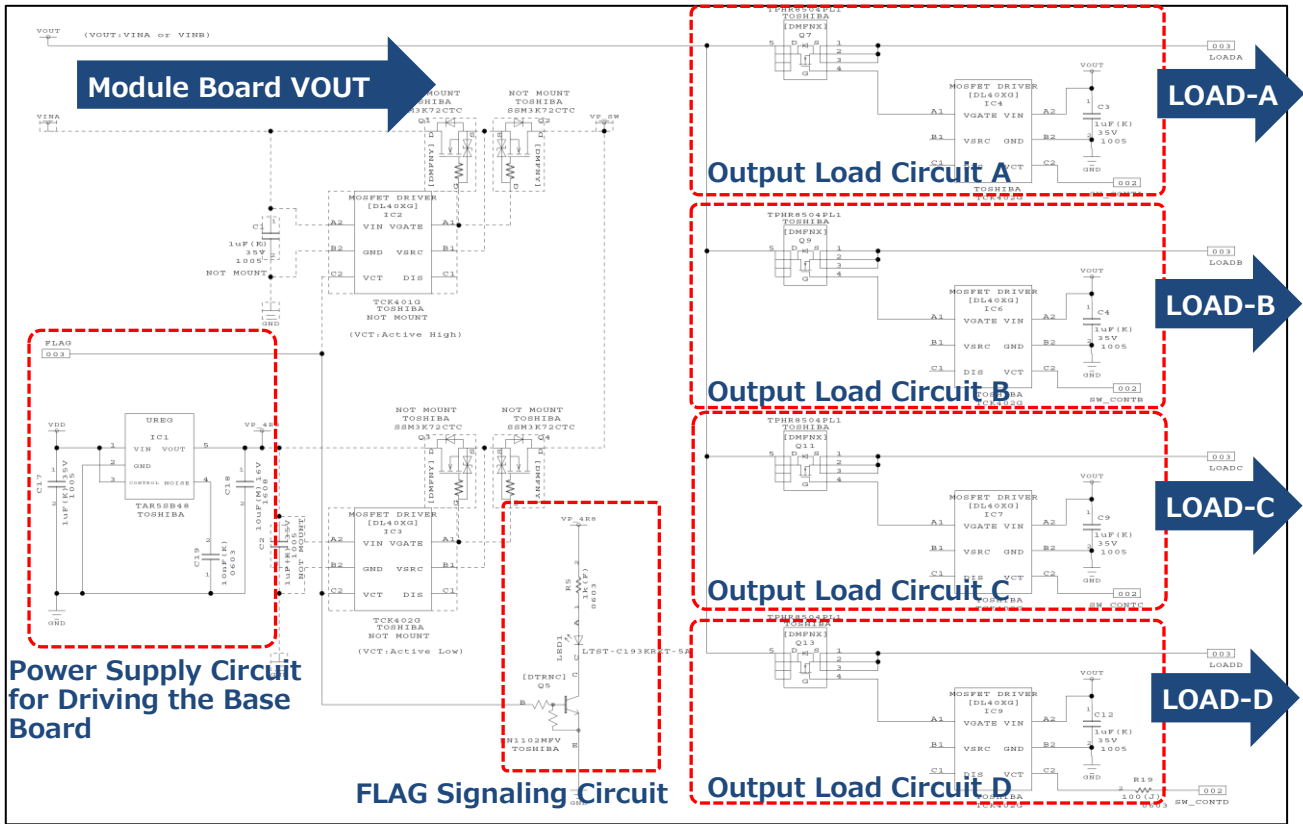


Fig. 3.8 Base Board Circuit (1)

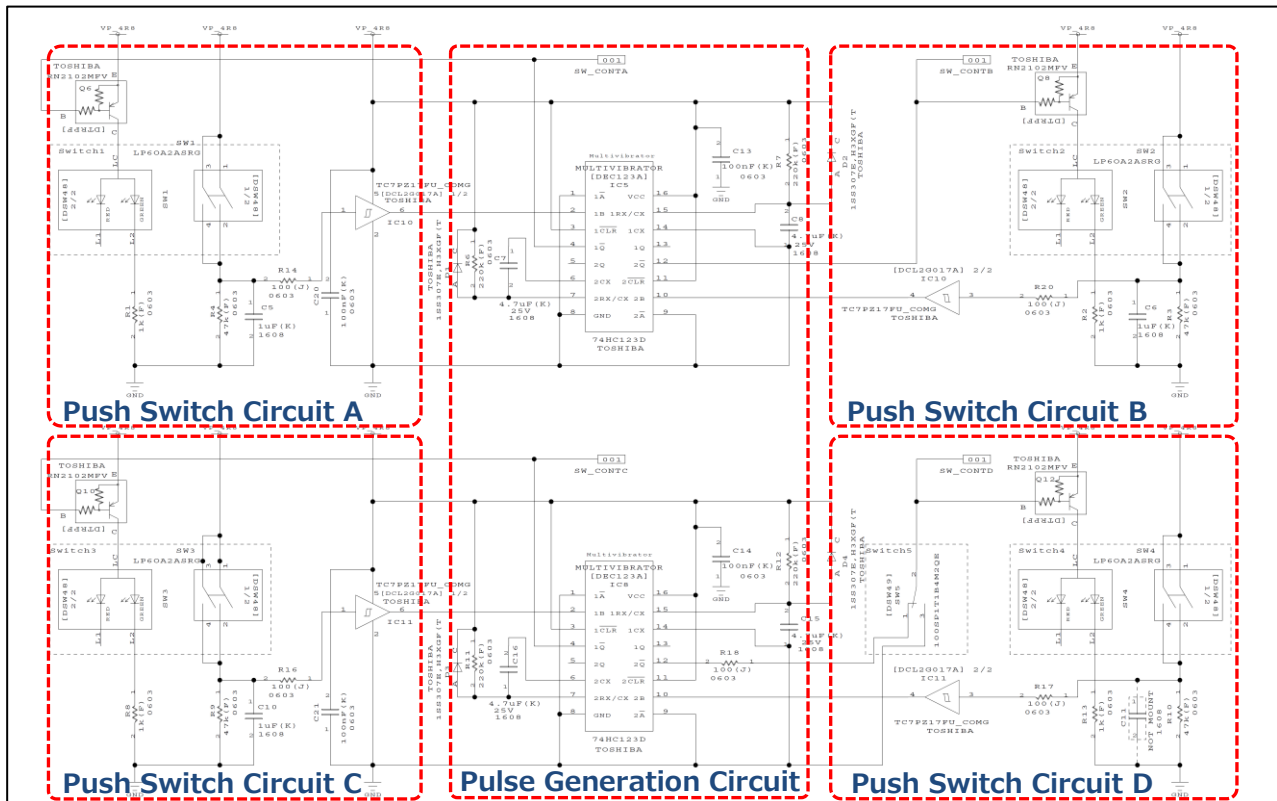
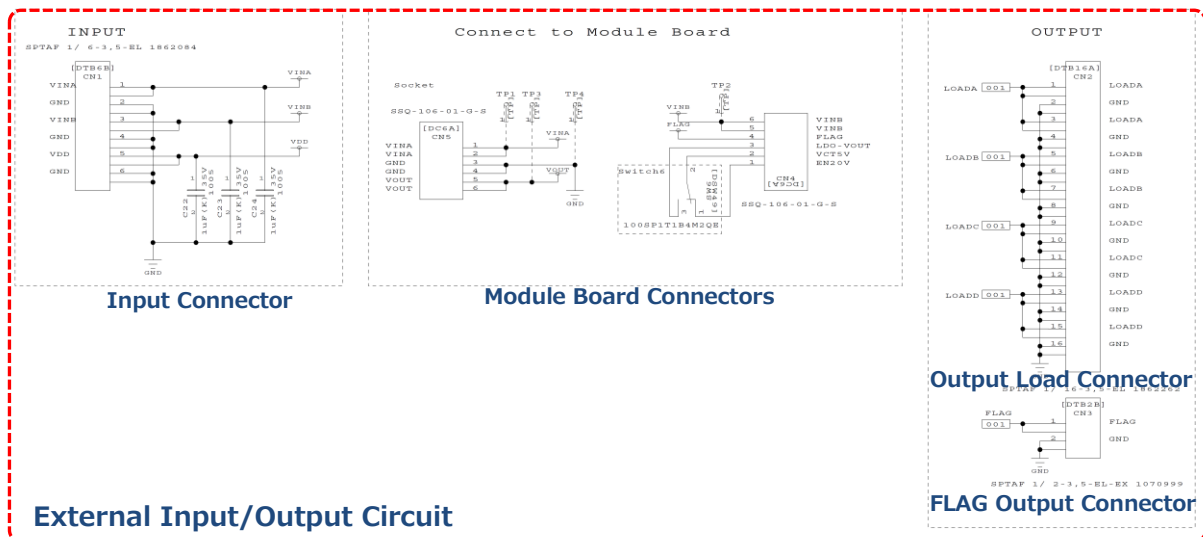


Fig. 3.9 Base Board Circuit (2)



**Fig. 3.10 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 required to operate each circuit on the base board. The drive power supply VDD (5 to 12 V) supplied to the input connector (CN1). It also generates the internal power supply VP\_4R8 (approx. 4.8 V) by LDO [TAR5SB48](#).

(2) FLAG signalling circuit

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

(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 H level, the LED in the key switch is lit and driven by the transistor [RN2102MFV](#) with built-in resistor.

(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 input/output circuit

Following connectors are used during the evaluation of power multiplexer module board. The input connector (CN1) takes VINA input, VINB input, and VDD input. The output load connector (CN2) output four loads (LOAD-A, LOAD-B, LOAD-C, LOAD-D). The connector (CN3) output FLAG signal. And connectors (CN4, CN5) are used for connecting the module board to base board.



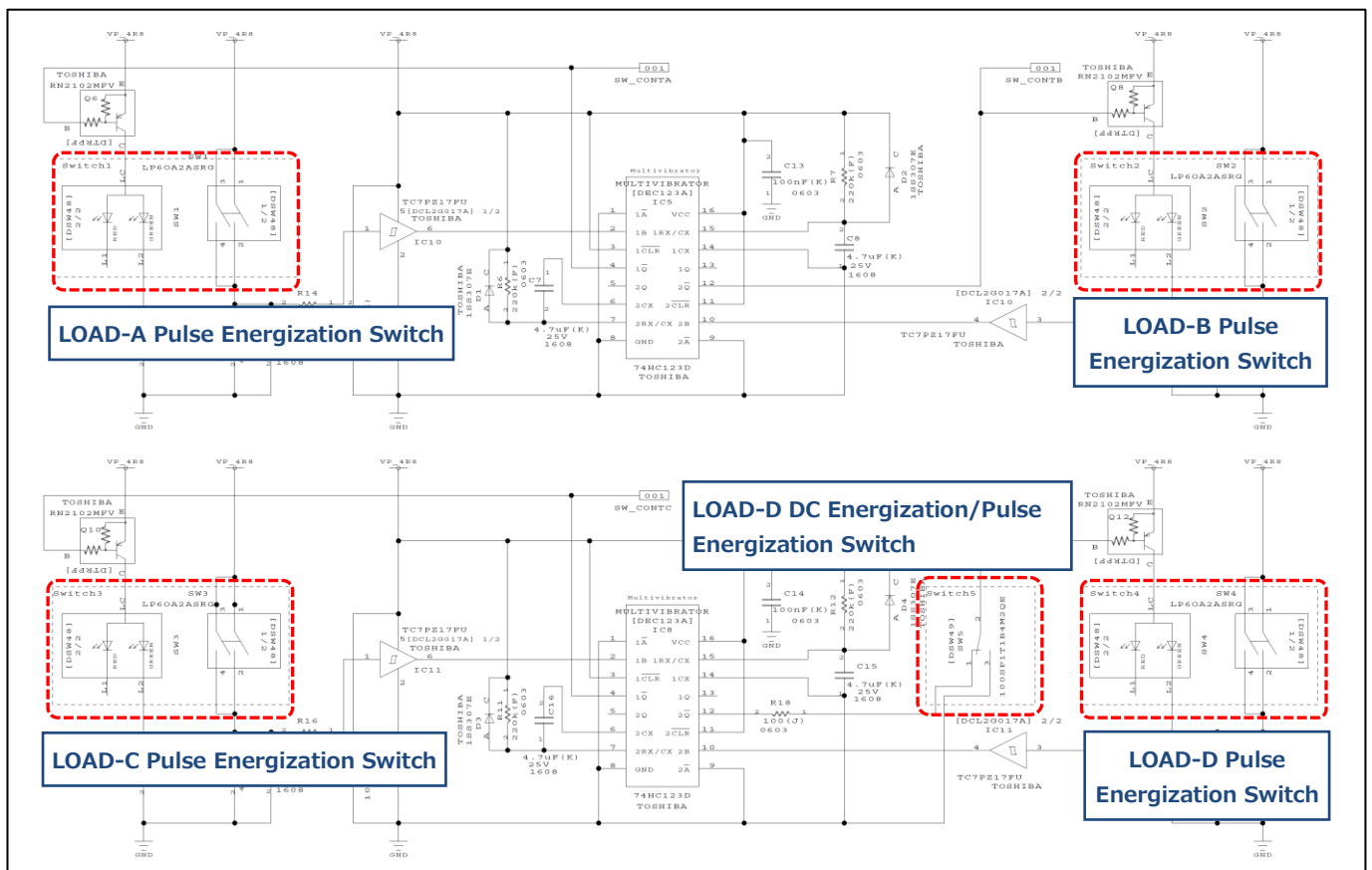
### 3.2.2. Output Load Energization Method

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.

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

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. 3.11 Switches for Output Load Energization on Base Board Circuit**

## 4. PCB Design

### 4.1. Component Layout Example

Fig. 4.1 and Fig. 4.2 show the component layout of module board and base board.

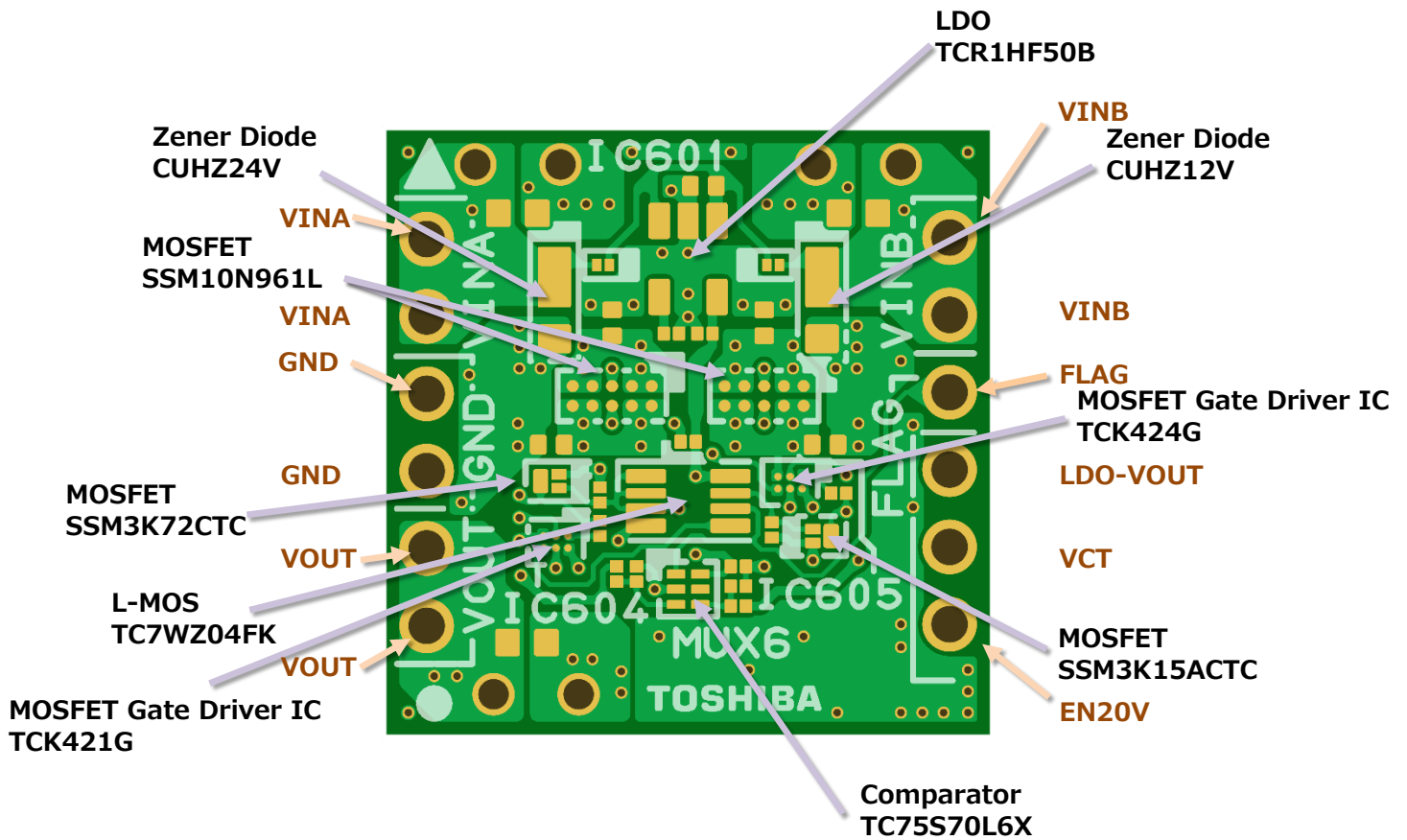


Fig. 4.1 Module Board Main Component Layout (Front Side – Example MUX6)

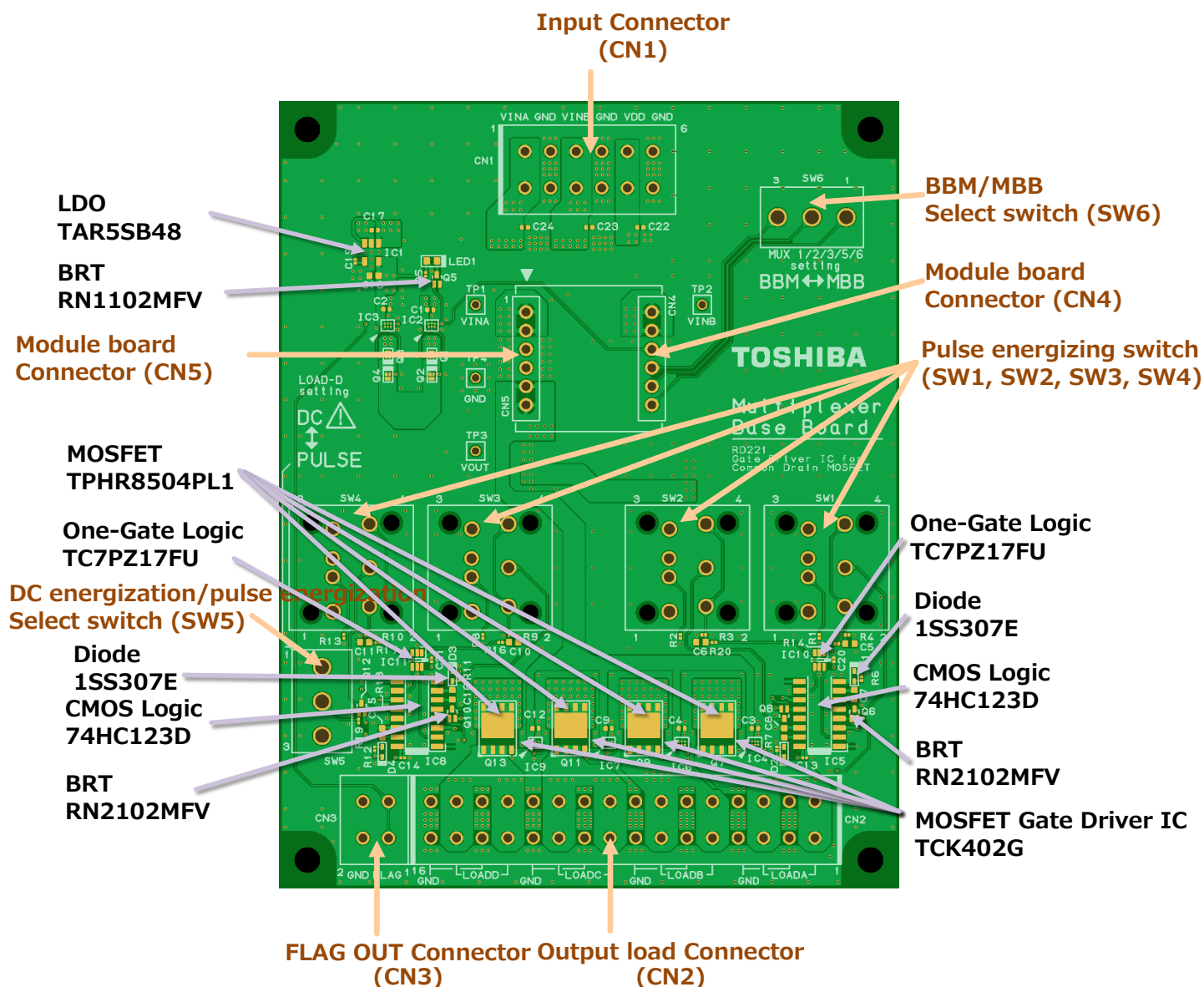


Fig. 4.2 Base Board Main Component Layout

### 4.2. Design Precautions

Consider the following when designing the PCB pattern.

- 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 the GND wiring, such as providing a ground plane or the shortest distance.

### 5. Component Overview

The components used in this circuit are described here.

#### 5.1. MOSFET Gate Driver IC

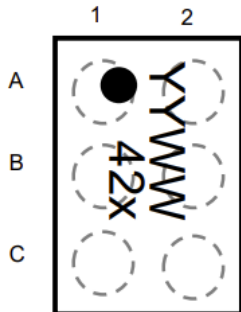
##### TCK42xG

In this design, these are used to drive the load switch MOSFET of VINA, VINB on the module board. Please [click here](#) for more information.

##### Features

- Gate driver for N-channel Common Drain MOSFET
- Gate driver for N-channel Single High side MOSFET
- High maximum input voltage:  $V_{IN\ max} = 40\ V$
- Wide input voltage operation:  $V_{IN} = 2.7\ to\ 28\ V$
- Gate-Source protection circuit
- Over Voltage Lock Out :  $V_{IN\_OVLO} = 6.31\ V, 10.83\ V, 14.29\ V, 23.26\ V\ and\ 27.73\ V\ typ$
- Under Voltage Lock Out :  $V_{IN\_UVLO} = 2.0\ V\ typ$
- Built in Charge pump circuit: Gate source voltage  $V_{GS} = 5.6\ V\ and\ 10\ V\ typ$
- Low standby current :  $I_{Q(OFF)} = 0.9\ \mu A\ max\ at\ V_{IN} = 12\ V\ (Except\ TCK424G, TCK425G)$

##### External View, Pin Assignment



A1: VGATE1  
 B1: VGATE2  
 C1: VOUT  
 A2: VIN  
 B2: GND  
 C2: VCT

YYWW: Lot No.

42x: Device name code  
 420: TCK420G  
 421: TCK421G  
 422: TCK422G  
 423: TCK423G  
 424: TCK424G  
 425: TCK425G

##### List of Products Number, OVLO and VGS

Part Number	OVLO Threshold, Falling Typ. (V)	External MOSFET Gate Source Voltage (Control ON) Typ. (V)
<a href="#">TCK420G</a>	27.73	10
<a href="#">TCK421G</a>	23.26	10
<a href="#">TCK422G</a>	14.29	10
<a href="#">TCK423G</a>	14.29	5.6
<a href="#">TCK424G</a>	10.83	5.6
<a href="#">TCK425G</a>	6.31	5.6

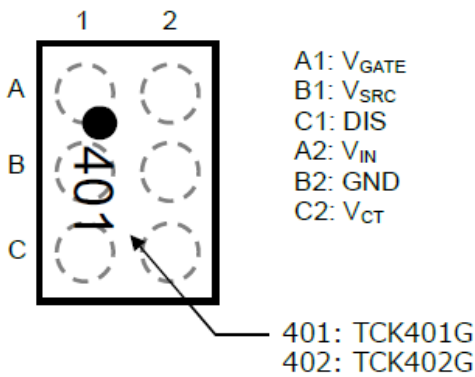
### TCK402G

In this design, it is used to drive the load switch application MOSFET on the base board. [Click here](#) for more information.

#### Features

- High maximum input voltage:  $V_{IN\ max} = 40\ V$
- Wide input voltage range:  $V_{IN} = 2.7\ to\ 28\ V$
- Auto output discharge
- Charge pump circuit
- Inrush current reducing circuit.
- Over voltage lock out (Over 28 V)
- Under voltage lock out (Under 2.7 V)

#### External View, Pin Assignment



### 5.2. MOSFET

The following MOSFETs are used in this design. Click the part number for more details.

Location		Part Number	Package	$V_{DSS}$	$V_{GSS}$	$R_{DS(ON)}$ Max
Module Board	For output	<a href="#">TPHR6503PL1</a>	SOP Advance (N)	30 V	+/-20 V	0.65 mΩ @10 V
	For output	<a href="#">TPN1R603PL</a>	TSON Advance	30 V	+/-20 V	1.6 mΩ @10 V
	For output	<a href="#">SSM6K513NU</a>	UDFN6B	30 V	+/-20 V	8.9 mΩ @10 V
	For output	<a href="#">TPHR8504PL1</a>	SOP Advance (N)	40 V	+/-20 V	0.85 mΩ @10 V
	For control	<a href="#">SSM3K72CTC</a>	CST3C	30 V	+/-20 V	4.7 Ω @4.5 V
	For control	<a href="#">SSM3K15ACTC</a>	CST3C	30 V	+/-20 V	6.0 Ω @2.5 V
Base Board	For output	<a href="#">TPHR8504PL1</a>	SOP Advance (N)	40 V	+/-20 V	0.85 mΩ @10 V

### 5.2.1. Common-Drain MOSFET

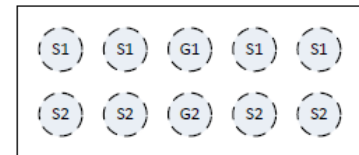
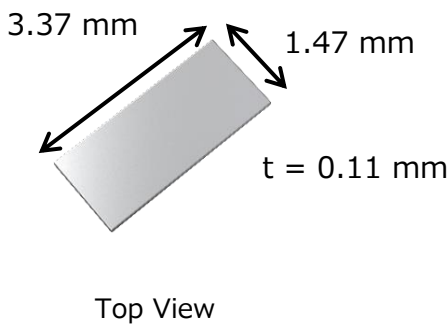
#### SSM10N961L

It is used as a load switch for VINA and VINB of module board in this design. Please [click here](#) for more information.

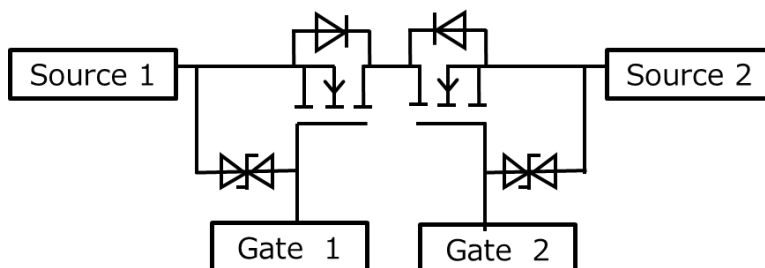
#### Features

- Common drain connection structure that supports bidirectional conduction
- Compact, thin package (TCSPAG-341501)
- Low on-resistance
- High source-to-source voltage rating:  $V_{SSS}$ : 30 V
- $V_{GS}$ :  $\pm 20$  V
- $I_S$ : 14 A
- $R_{SS(ON)}$ : 9.9 m $\Omega$  (Typ.) @  $V_{GS} = 10$  V
- $R_{SS(ON)}$ : 13.6 m $\Omega$  (Typ.) @  $V_{GS} = 4.5$  V

#### External View, Pin Assignment



#### Internal Circuit Diagram



### 5.3. eFuse IC

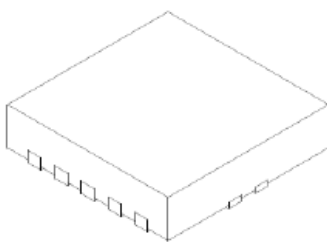
#### TCKE812NA

In this design, it is used as a VINA load switch on the module board. Please [click here](#) for more information.

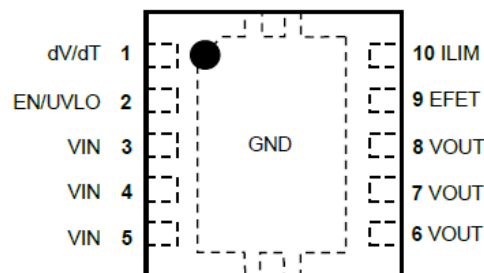
#### Features

- High input voltage:  $V_{IN\ max} = 18.0\ V$
- High output current:  $I_{OUT\ (DC)} = 5.0\ A$
- Low ON resistance :  $R_{ON} = 28\ m\Omega$  (typ.)
- Adjustable overcurrent limit : up to 5.0 A
- Fixed over voltage clamp
  - 5 V power rail TCKE805 :  $V_{OVC} = 6.04\ V$  (typ.)
  - 12 V power rail TCKE812 :  $V_{OVC} = 15.1\ V$  (typ.)
  - TCKE800 : No over voltage clamp
- Programmable slew rate control by external capacitance for inrush current reduction
- Programmable under voltage lockout by external resistor
- Reverse current blocking support by built in MOSFET driver
- Thermal shutdown
- Auto-discharge
- Small package: WSON10B (3.0 mm x 3.0 mm, t: 0.7 mm (typ.))
- IEC62368-1 Certified

#### External View, Pin Assignment



WSON10B





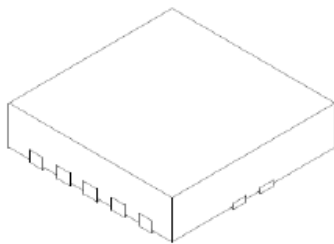
### TCKE712BNL

In this design, it is used as a VINB load switch on the module board. Please [click here](#) for more information.

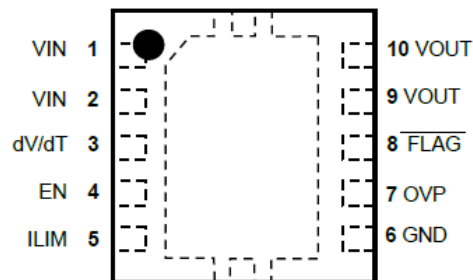
#### Features

- High input voltage:  $V_{IN\ max} = 13.2\ V$
- Low ON resistance :  $R_{ON} = 53\ m\Omega$  (typ.)
- Adjustable over current protection
- Adjustable over voltage protection
- Programmable Slew rate control by External Capacitance for Inrush current reduction
- FLAG indicates
- Reverse current blocking (SW OFF state)
- Thermal Shutdown
- Small package: WSON10 (3.0 mm x 3.0 mm, t: 0.7 mm (typ))

#### External View, Pin Assignment



WSON10



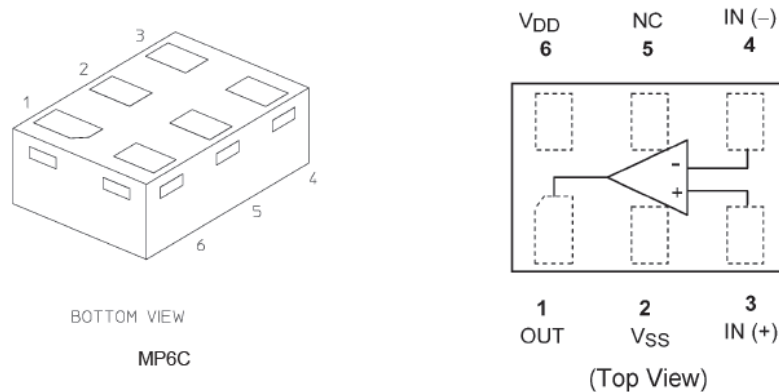
### 5.4. Comparator IC (TC75S70L6X)

In this design, it is used for controlling the module board. Please [click here](#) for more information.

#### Features

- Single circuit, Input/Output full swing comparator
- Low operating voltage:  $V_{DD} = 1.3$  to  $5.5$  V
- Low supply current:  $I_{DD} = 18 \mu\text{A}$  (typ.) (@ $V_{DD} = 1.5$  V)
- Ultra Small package: MP6C (1.0 mm × 1.45 mm, t = 0.55 mmMAX)
- Low input bias current: 1 pA (typ.)
- Push-pull output circuit
- Single power supply operation

#### External View, Pin Assignment



### 5.5. LDO Regulator

In this design, these are used for controlling the module board and base board. Click the part number for details.

Board	Part Number	Package	$V_{IN}$ Max	$V_{OUT}$	$I_{OUT}$ Max
Module Board	<a href="#">TCR1HF33B</a>	SMV	40 V	3.3 V	150 mA
	<a href="#">TCR1HF50B</a>	SMV	40 V	5.0 V	150 mA
Base Board	<a href="#">TAR5SB48</a>	SMV	15 V	4.8 V	200 mA

### 5.6. L-MOS, Standardized CMOS Logic IC

In this design, these are used for controlling the module board and base board. Click the part number for details.

Board	Part Number	Package	Function	$V_{CC}$
Module Board	<a href="#">TC7WZ04FK</a>	SM8	Triple Inverter	1.65 to 5.5 V
	<a href="#">TC7PZ14FU</a>	US6	Dual Schmitt Inverter	1.65 to 5.5 V
Base Board	<a href="#">TC7PZ17FU</a>	US6	Dual Schmitt Buffer	1.65 to 5.5 V
	<a href="#">74HC123D</a>	SOIC16	Dual Monostable Multi-vibrator	2.0 to 6.0 V

### 5.7. Zener Diode

In this design, these are used for overvoltage protection of the input voltage of the module board. Click the part number for details.

Part Number	Package	$V_Z$ (V) Typ.	VESD
<a href="#">CUHZ6V8</a>	US2H	6.8 V @ $I_Z = 10$ mA	±30 kV
<a href="#">CUHZ12V</a>	US2H	12 V @ $I_Z = 10$ mA	±30 kV
<a href="#">CUHZ16V</a>	US2H	16 V @ $I_Z = 10$ mA	±30 kV
<a href="#">CUHZ30V</a>	US2H	30 V @ $I_Z = 10$ mA	±30 kV

### 5.8. Diode

In this design, these are used for controlling the module board and base board. Click the part number for details.

Board	Part Number	Package	$V_R$	$I_O$	$V_F$ Max	$I_R$ Max
Module Board	<a href="#">DSF01S30SL</a>	SL2	30 V	100 mA	0.3 V @ $I_F = 10$ mA	50 $\mu$ A @ $V_R = 30$ V
Base Board	<a href="#">1SS307E</a>	ESC	80 V	100 mA	1.3 V @ $I_F = 100$ mA	10 nA @ $V_R = 80$ V

### 5.9. Transistor with Built-in Resistor

In this design, these are used for controlling the base board. Click the part number for details.

Part Number	Package	Polarity	$V_{CBO}$	$I_C$	R1/R2
<a href="#">RN1114MFV</a>	VESM	NPN	50 V	100 mA	1 k $\Omega$ /10 k $\Omega$
<a href="#">RN2102MFV</a>	VESM	PNP	-50 V	-100 mA	10 k $\Omega$ /10 k $\Omega$

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