Power Multiplexer Circuit

Design Guide

RD221-DGUIDE-01
# Table of Contents

1. **INTRODUCTION** .................................................................4

2. **SPECIFICATIONS AND BLOCK DIAGRAM** ..........................5

2.1. Specifications ........................................................................5

2.2. Block Diagram ....................................................................... 6

3. **CIRCUIT DESIGN** .................................................................7

3.1. Module Board ....................................................................... 7

3.1.1. BBM Operation ...............................................................7

3.1.2. MBB Operation ............................................................... 8

3.1.3. Circuit for MOSFET Gate Driver IC ................................. 11

3.1.4. BBM/MBB Switching Operation ...................................... 13

3.1.5. Circuit of eFuse IC Version Board ................................. 14

3.2. Base Board ....................................................................... 15

3.2.1. Circuit of the Base Board .............................................. 15

3.2.2. Output Load Energization Method ................................. 17

4. **PCB DESIGN** ................................................................... 18

4.1. Component Layout Example ............................................... 18

4.2. Design Precautions ............................................................. 21

5. **COMPONENT OVERVIEW** ............................................. 22

5.1. MOSFET Gate Driver IC .................................................... 22

5.2. MOSFET ........................................................................... 23

5.3. eFuse IC ........................................................................... 24

5.4. Comparator IC (TC75S70L6X) ............................................. 26
5.5. LDO Regulator ........................................................................................................... 26

5.6. L-MOS, Standardized CMOS Logic IC ......................................................................... 26

5.7. Zener Diode ................................................................................................................. 27

5.8. Diode .......................................................................................................................... 27

5.9. Transistor with Built-in Resistor .................................................................................. 27
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)](image)

![Fig. 1.2 MBB (Make-Before-Break)](image)
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

<table>
<thead>
<tr>
<th>Board Name</th>
<th>Board Type</th>
<th>Input Voltage VINA/VINB</th>
<th>Maximum Output Current *</th>
<th>BBM Operation Support</th>
<th>MBB Operation Support</th>
<th>Switching Element</th>
<th>For Output MOSFET</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUX1</td>
<td>Standard 1</td>
<td>20 V 5 V</td>
<td>3 A</td>
<td>Yes</td>
<td>Yes</td>
<td>Gate Driver IC</td>
<td>TCK421G, TCK425G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TPHR6503PL1</td>
</tr>
<tr>
<td>MUX2</td>
<td>Standard 2</td>
<td>12 V 5 V</td>
<td>3 A</td>
<td>Yes</td>
<td>Yes</td>
<td>Gate Driver IC</td>
<td>TCK423G, TCK425G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TPN1R603PL</td>
</tr>
<tr>
<td>MUX3</td>
<td>High Power 1</td>
<td>20 V 9 V</td>
<td>5 A</td>
<td>Yes</td>
<td>Yes</td>
<td>Gate Driver IC</td>
<td>TCK421G, TCK424G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TPN1R603PL</td>
</tr>
<tr>
<td>MUX4</td>
<td>eFuse IC</td>
<td>12 V 5 V</td>
<td>3 A</td>
<td>Yes</td>
<td>-</td>
<td>eFuse IC</td>
<td>TCKE812NA, TCK712BNL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SSM6K513NU</td>
</tr>
<tr>
<td>MUX5</td>
<td>High Power 2</td>
<td>24 V 12 V</td>
<td>5 A</td>
<td>Yes</td>
<td>Yes</td>
<td>Gate Driver IC</td>
<td>TCK420G, TCK422G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TPHR8504PL1</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Input</th>
<th>VINA input (VINA 5 to 24 V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VINB input (VINB 5 to 12 V)</td>
</tr>
<tr>
<td></td>
<td>Drive power supply (VDD 5 to 12 V)</td>
</tr>
<tr>
<td>Output</td>
<td>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)</td>
</tr>
<tr>
<td></td>
<td>FLAG output (H-level (approx. 3.3 V) is output when VINA is input)</td>
</tr>
</tbody>
</table>
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 MUX1)**

**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 MUX1 is operated in the BBM mode.

VINB is continuously energized with 5 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 5 V to 20 V, there is a start-up-time $t_{\text{ON}}$ 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 5 V, there is a start-up time $t_{\text{ON}}$ of about 3 ms when MOSFET driver IC TCK425G 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. 3.3 V) while VINA is applied.

Details of each operation in the waveform are as follows.

① 5 V is applied to VINB, and VINB voltage (approx. 5 V) is output.
② When 20 V is applied to VINA, FLAG output becomes High (approx. 3.3 V). VINA driver (TCK421G) starts operating at this timing.
③ 0 V is output because of VINB driver (TCK425G) is off.
④ VINA voltage (about 20 V) is generated after $t_{\text{ON}}$ of VINA driver (TCK421G).
⑤ When the voltage at VINA becomes 0 V, FLAG output becomes Low (0 V). VINB driver (TCK425G) starts operating at this timing.
⑥ 0 V is output because VINA driver (TCK421G) is off.
⑦ VINB voltage (approximately 5 V) is output after $t_{\text{ON}}$ of VINB driver (TCK425G).
3.1.2. MBB Operation

The MBB operation outline of this circuit is described below. The MBB operation circuit shown in Fig. 3.2 assumes that VINA voltage > VINB voltage and VINB is continuously energized.

① Apply voltage to VINB (VINA voltage is off). Common drain connected MOSFET Q1 and Q2 are turned on by MOSFET driver IC TCK42xG, and VINB voltage is output to VOUT.

② When VINA 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 VINB voltage is output to VOUT.

③ Even when voltage is applied from VINA, reverse current does not flow to VINB because of the body diode of Q1.

The above operation allows seamless voltage-output switching from VINB to VINA by MBB operation.

In addition, the following operations enable seamless voltage-output switching to VINB from VINA by MBB operation.

① VINA is turned off (0 V) while VINA is being supplied.

② The voltage dropped by the forward voltage of the body diode of Q1 from VINB voltage is output to VOUT.

③ Q3 turns off. Thus Q1 is turned ON. VINB 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)**

<table>
<thead>
<tr>
<th>Time (state)</th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
<th>t4</th>
<th>t5</th>
<th>t6</th>
</tr>
</thead>
<tbody>
<tr>
<td>VINA In</td>
<td>0 V</td>
<td>0 V</td>
<td>ON</td>
<td>ON</td>
<td>0 V</td>
<td>0 V</td>
</tr>
<tr>
<td>VINB In</td>
<td>0 V</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>FLAG Out*</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Q1 Gate</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Q2 Gate</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Q3 Gate Shut-off</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>VOUT</td>
<td>0 V</td>
<td>VINB end</td>
<td>**</td>
<td>VINA end</td>
<td>***</td>
<td>**</td>
</tr>
</tbody>
</table>

* 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**

---

Q1 body diode forward voltage dropped from VINB
Fig. 3.4 shows the waveforms during actual MBB operation (of MUX1 as an example).

![Fig. 3.4 MBB Operation Waveform (2 ms/div)](image)

VINA = 20 V, VINB = 5 V, RL = 300 Ω, CL = None

This section describes the operation of seamlessly switching the voltage without dropping to 0 V when VINB is continuously energized as 5 V and 20 V pulses of 10 ms are applied to VINA.

1. 5 V is applied to VINB, and VINB voltage (about 5 V) is sent to the output.
2. When 20 V is applied to VINA, the FLAG output becomes High (approx. 3.3 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 MOSFET TPHR6503PL1 corresponding to Q1 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 TPH6503PL1 corresponding to Q1 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. TPH6503PL1 corresponding to Q1 is turned on. VINB voltage (approx. 5 V) is output.
3.1.3. Circuit for MOSFET Gate Driver IC

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

Fig. 3.5 Module Board (MUX1) 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 MUX1 supports 20 V (VINA) and 5 V (VINB) inputs. A zener diode CUHZ30V with a zener voltage of 30 V is used on VINA side and a zener diode CUHZ6V8 with a zener voltage of 6.8 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 3.3 V output LDO TCR1HF33B (developed product) 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), two MOSFETs TPHR6503PL1 in common drain configuration are 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 (5 V, max. 3 A), two MOSFETs TPHR6503PL1 in common drain configuration are used. And to control gate signals of these MOSFETs a 5 V bus compatible MOSFET gate driver IC TCK425G 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 (5 V, max. 3 A) is output from VOUT as shown below.

- If the power is input only to either VINA (20 V) or VINB (5 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) using MOSFET gate driver IC can switch between BBM operation or MBB operation.

![Fig. 3.6 BBM/MBB Switching on the Module-Board (MUX1)](image)

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. 3.3 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 TCK425G 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 TCK425G is constantly turned on if the voltage is input to VINB, and MBB operation is realized by operating the gate cut-off MOSFET.
3.1.5. Circuit of eFuse IC Version Board

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

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 TCKE712BNL.
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.

![Circuit Diagram](image)

**Fig. 3.11 Switches for Output Load Energization on Base Board Circuit**
4. PCB Design

4.1. Component Layout Example

Fig. 4.1, Fig. 4.2, and Fig. 4.3 show the component layout of module board and base board.

Fig. 4.1 Module Board Main Component Layout (Front Side – Example MUX1)
Fig. 4.2 Module Board Main Component Layout (Back Side – Example MUX1)
Fig. 4.3 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: $V_{IN \text{ max}} = 40 \text{ V}$
- Wide input voltage operation: $V_{IN} = 2.7 \text{ to } 28 \text{ V}$
- Gate-Source protection circuit
- Over Voltage Lock Out: $V_{IN_{OVLO}} = 6.31 \text{ V, } 10.83 \text{ V, } 14.29 \text{ V, } 23.26 \text{ V and } 27.73 \text{ V typ}$
- Under Voltage Lock Out: $V_{IN_{UVLO}} = 2.0 \text{ V typ}$
- Built in Charge pump circuit: Gate source voltage $V_{GS} = 5.6 \text{ V and } 10 \text{ V typ}$
- Low standby current : $I_{Q(OFF)} = 0.9 \mu\text{A max at } V_{IN} = 12 \text{ V (Except TCK424G, TCK425G)}$

External View, Pin Assignment

![External View, Pin Assignment](image)

List of Products Number, OVLO and VGS

<table>
<thead>
<tr>
<th>Part Number</th>
<th>OVLO Threshold, Falling Typ. (V)</th>
<th>External MOSFET Gate Source Voltage (Control ON) Typ. (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCK420G</td>
<td>27.73</td>
<td>10</td>
</tr>
<tr>
<td>TCK421G</td>
<td>23.26</td>
<td>10</td>
</tr>
<tr>
<td>TCK422G</td>
<td>14.29</td>
<td>10</td>
</tr>
<tr>
<td>TCK423G</td>
<td>14.29</td>
<td>5.6</td>
</tr>
<tr>
<td>TCK424G</td>
<td>10.83</td>
<td>5.6</td>
</tr>
<tr>
<td>TCK425G</td>
<td>6.31</td>
<td>5.6</td>
</tr>
</tbody>
</table>
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: \( V_{\text{IN\ max}} = 40 \text{ V} \)
- Wide input voltage range: \( V_{\text{IN}} = 2.7 \text{ to 28 V} \)
- 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.

<table>
<thead>
<tr>
<th>Location</th>
<th>Part Number</th>
<th>Package</th>
<th>( V_{\text{DSS}} )</th>
<th>( V_{\text{GSS}} )</th>
<th>( R_{\text{DS(ON)}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Board</td>
<td>TPHR6503PL1</td>
<td>SOP Advance (N)</td>
<td>30 V</td>
<td>+/-20 V</td>
<td>0.65 m( \Omega ) @10 V</td>
</tr>
<tr>
<td>For output</td>
<td>TPN1R603PL</td>
<td>TSON Advance</td>
<td>30 V</td>
<td>+/-20 V</td>
<td>1.6 m( \Omega ) @10 V</td>
</tr>
<tr>
<td>For output</td>
<td>SSM6K513NU</td>
<td>UDFN6B</td>
<td>30 V</td>
<td>+/-20 V</td>
<td>8.9 m( \Omega ) @10 V</td>
</tr>
<tr>
<td>For output</td>
<td>TPHR8504PL1</td>
<td>SOP Advance (N)</td>
<td>40 V</td>
<td>+/-20 V</td>
<td>0.85 m( \Omega ) @10 V</td>
</tr>
<tr>
<td>For control</td>
<td>SSM3K72CTC</td>
<td>CST3C</td>
<td>30 V</td>
<td>+/-20 V</td>
<td>4.7 ( \Omega ) @4.5 V</td>
</tr>
<tr>
<td>For control</td>
<td>SSM3K15ACTC</td>
<td>CST3C</td>
<td>30 V</td>
<td>+/-20 V</td>
<td>6.0 ( \Omega ) @2.5 V</td>
</tr>
<tr>
<td>Base Board</td>
<td>TPHR8504PL1</td>
<td>SOP Advance (N)</td>
<td>40 V</td>
<td>+/-20 V</td>
<td>0.85 m( \Omega ) @10 V</td>
</tr>
</tbody>
</table>
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: $V_{\text{IN max}} = 18.0 \text{ V}$
- High output current: $I_{\text{OUT (DC)}} = 5.0 \text{ A}$
- Low ON resistance : $R_{\text{ON}} = 28 \text{ m}\Omega \text{ (typ.)}$
- Adjustable overcurrent limit : up to 5.0 A
- Fixed over voltage clamp
  - 5 V power rail TCKE805 : $V_{\text{OVC}} = 6.04 \text{ V (typ.)}$
  - 12 V power rail TCKE812 : $V_{\text{OVC}} = 15.1 \text{ V (typ.)}$
  - 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
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: $V_{IN \text{ max}} = 13.2 \text{ V}$
- Low ON resistance: $R_{ON} = 53 \text{ m}\Omega \text{ (typ.)}$
- 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

![External View, Pin Assignment](image)
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: $I_{DD} = 18$ µA (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.

<table>
<thead>
<tr>
<th>Board</th>
<th>Part Number</th>
<th>Package</th>
<th>$V_{IN}$ Max</th>
<th>$V_{OUT}$</th>
<th>$I_{OUT}$ Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Board</td>
<td>TCR1HF33B*</td>
<td>SMV</td>
<td>40 V</td>
<td>3.3 V</td>
<td>150 mA</td>
</tr>
<tr>
<td></td>
<td>TCR1HF50B*</td>
<td>SMV</td>
<td>40 V</td>
<td>5.0 V</td>
<td>150 mA</td>
</tr>
<tr>
<td>Base Board</td>
<td>TAR5SB48</td>
<td>SMV</td>
<td>15 V</td>
<td>4.8 V</td>
<td>200 mA</td>
</tr>
</tbody>
</table>

*Under development

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.

<table>
<thead>
<tr>
<th>Board</th>
<th>Part Number</th>
<th>Package</th>
<th>Function</th>
<th>$V_{CC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Board</td>
<td>TC7WZ04FK</td>
<td>SM8</td>
<td>Triple Inverter</td>
<td>1.65 to 5.5 V</td>
</tr>
<tr>
<td></td>
<td>TC7PZ14FU</td>
<td>US6</td>
<td>Dual Schmitt Inverter</td>
<td>1.65 to 5.5 V</td>
</tr>
<tr>
<td>Base Board</td>
<td>TC7PZ17FU</td>
<td>US6</td>
<td>Dual Schmitt Buffer</td>
<td>1.65 to 5.5 V</td>
</tr>
<tr>
<td></td>
<td>74HC123D</td>
<td>SOIC16</td>
<td>Dual Monostable Multi-vibrator</td>
<td>2.0 to 6.0 V</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>$V_Z$ (V) Typ.</th>
<th>VESD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUHZ6V8</td>
<td>US2H</td>
<td>6.8 V @$I_Z$ = 10 mA</td>
<td>±30 kV</td>
</tr>
<tr>
<td>CUHZ12V</td>
<td>US2H</td>
<td>12 V @$I_Z$ = 10 mA</td>
<td>±30 kV</td>
</tr>
<tr>
<td>CUHZ16V</td>
<td>US2H</td>
<td>16 V @$I_Z$ = 10 mA</td>
<td>±30 kV</td>
</tr>
<tr>
<td>CUHZ30V</td>
<td>US2H</td>
<td>30 V @$I_Z$ = 10 mA</td>
<td>±30 kV</td>
</tr>
</tbody>
</table>

5.8. Diode

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

<table>
<thead>
<tr>
<th>Board</th>
<th>Part Number</th>
<th>Package</th>
<th>$V_R$</th>
<th>$I_O$</th>
<th>$V_F$ Max</th>
<th>$I_R$ Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Board</td>
<td>DSF01S30SL</td>
<td>SL2</td>
<td>30 V</td>
<td>100 mA</td>
<td>0.3 V @$I_F$ = 10 mA</td>
<td>50 μA @$V_R$ = 30 V</td>
</tr>
<tr>
<td>Base Board</td>
<td>1SS307E</td>
<td>ESC</td>
<td>80 V</td>
<td>100 mA</td>
<td>1.3 V @$I_F$ = 100 mA</td>
<td>10 nA @$V_R$ = 80 V</td>
</tr>
</tbody>
</table>

5.9. Transistor with Built-in Resistor

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

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Polarity</th>
<th>$V_{CBO}$</th>
<th>$I_C$</th>
<th>R1/R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RN1114MFV</td>
<td>VESM</td>
<td>NPN</td>
<td>50 V</td>
<td>100 mA</td>
<td>1 kΩ/10 kΩ</td>
</tr>
<tr>
<td>RN2102MFV</td>
<td>VESM</td>
<td>PNP</td>
<td>-50 V</td>
<td>-100 mA</td>
<td>10 kΩ/10 kΩ</td>
</tr>
</tbody>
</table>
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