Refrigerator

Solution Proposal by Toshiba
Toshiba Electronic Devices & Storage Corporation provides comprehensive device solutions to customers developing new products by applying its thorough understanding of the systems acquired through the analysis of basic product designs.
Refrigerator Overall block diagram

- AC
- Surge Absorption
- Heater
- DC-DC Circuit
- LDO
- Compressor MCU
- Current Sense Op-amp
- LDO
- Compressor
- Brushless
- Compressor
- M
- LDO
- Surge Absorption
- MOSFET
- Inner Fan
- Motor Damper
- MCD
- MCD
- MCD
- MCD
- MCD
- LED Light
- LED
- Control MCU for Display Panel
- LED Driver
- Sensor
- Door switch
- Auto Icemaker
- Key
- Speaker
- M
- Stepping
- Stepping
- Stepping
- MOSFET
- Stepping
- Stepping
- Stepping
- Stepping
- Stepping
Refrigerator  Details of DC-DC unit

**DC-DC power supply circuits**

Device selection points
- Small-signal MOSFET is optimal for DC-DC translation.
- LDO is suitable for stable power supply to MCU

Proposals from Toshiba
- **Setting of low power consumption with low on-resistance**
  U-MOS Series MOSFET (Trench Type)
- **Setting of low power consumption with low on-resistance**
  Small-signal MOSFET
- **Optimum power supply for environments with high power supply noise**
  Small surface mount LDO regulator

**MCU power supply circuit**
Refrigerator Details of Motor Driving unit

**Compressor drive circuit**

- **Compressor MCU**
- **Op-amp**
- **Shunt Resistor**
- **IPD**
- **Brushless**
- **MCD**

**Device selection points**
- Intelligent power devices (IPDs) are suitable for driving high-voltage motors such as compressors.
- MCDs are used for driving stepping and brushless DC motors.
- An operational amplifier is used to amplify signals such as current sensing.

**Proposals from Toshiba**
- **Setting of low power consumption with low on-resistance**
  - Small-signal MOSFET
- **Built-in high-voltage power MOSFET**
- **Operational amplifier with integrated phase compensation circuit**
  - General-purpose operational amplifier
- **Easy control of motors**
  - Motor driver
- **Easy software development using general-purpose CPU cores**
  - Microcontroller

**Damper drive circuit**

- **Central and Fan Control MCU**
- **MCD**
- **Stepping**

**Fan drive circuit**

- **Central and Fan Control MCU**
- **MCD**
- **Brushless**
- **P-ch MOSFET**
- **Brush**

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Device selection points
- A phototriac coupler is the good way to control the AC load.
- Small-signal MOSFET is optimal for driving LEDs.

Proposals from Toshiba
- **Switching with low on-resistance**
  Small-signal MOSFET
- **Operational amplifier with integrated phase compensation circuit**
  General-purpose operational amplifier
- **Efficient control of AC load**
  Triac output photo couplers
- **Easy software development using general-purpose CPU cores**
  Microcontroller
Recommended Devices
Device solutions to address customer needs

As described above, in the design of refrigerators, "Low power consumption of the set", "Robust operation" and "Miniaturization of circuit boards" are important factors. Toshiba's proposals are based on these three solution perspectives.
Device solutions to address customer needs

<table>
<thead>
<tr>
<th></th>
<th>High efficiency - Low-loss</th>
<th>Noise immunity</th>
<th>Small size Package Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U-MOSVI series MOSFET</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Small-signal MOSFET</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>High-voltage three-phase motor driver IC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>General-purpose operational amplifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Small surface mount LDO regulator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Triac output photo couplers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Motor driver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Microcontroller</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Suitable for power management switches and easy to handle and greatly contributes to miniaturization.

1. **Low on-resistance**

   By keeping the on-resistance between the source and drain low, heat generation and power consumption can be kept low.

2. **Low leakage current**

   Drain cut-off current $I_{DSS} = 10\mu A$ (max.) ($V_{DS} = -20$ V)

3. **Enhancement type**

   It is easy to handle because it is an enhancement type in which no collector current when no gate voltage is applied.

**TPCC8136 Characteristics Curves**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPCC8136</th>
<th>SSM6J501NU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>TSON</td>
<td>SOT-1220</td>
</tr>
<tr>
<td>$V_{DSS}$ [V]</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>$I_G$ [A]</td>
<td>-9.4</td>
<td>-8</td>
</tr>
<tr>
<td>$P_D$ [W]</td>
<td>1.9</td>
<td>1</td>
</tr>
<tr>
<td>$C_{iss}$ (Typ.) [pF]</td>
<td>2350</td>
<td>2500</td>
</tr>
<tr>
<td>$R_{on} (Max)$ [mΩ] @$V_{GS} = -4.5$ V</td>
<td>16</td>
<td>15.4</td>
</tr>
<tr>
<td>Polarity</td>
<td>P-ch</td>
<td>P-ch</td>
</tr>
</tbody>
</table>

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Small-signal MOSFET
SSM3K333R / SSM3K335R / SSM3J332R / SSM3J334R

Suitable for power management switches and greatly contributes to miniaturization.

1. Low voltage drive
   - $V_{GS} = 4.5$ V drive (SSM3K333R)
   - $V_{GS} = 1.8$ V drive (SSM6P39TU)
   - $V_{GS} = 1.2$ V drive (SSM3K35AFS)

2. Low on-resistance
   - By keeping the on-resistance between the source and drain low, heat generation and power consumption can be kept low.

3. Small package
   - Small package is suitable for high-density mounting.

<table>
<thead>
<tr>
<th>Part number</th>
<th>SSM3K333R</th>
<th>SSM3K335R</th>
<th>SSM3J332R</th>
<th>SSM3J334R</th>
<th>SSM6P39TU</th>
<th>SSM3K35AFU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SOT-23F</td>
<td>UF6</td>
<td>SSM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{DSS}$ (Min) [V]</td>
<td>30</td>
<td>30</td>
<td>-30</td>
<td>-30</td>
<td>-20</td>
<td>20</td>
</tr>
<tr>
<td>$I_D$ (Max) [A]</td>
<td>6</td>
<td>6</td>
<td>-6</td>
<td>-4</td>
<td>-1.5</td>
<td>0.25</td>
</tr>
<tr>
<td>$R_{DS(on)}$ (Max) [Ω]</td>
<td>0.042</td>
<td>0.056</td>
<td>0.05</td>
<td>0.105</td>
<td>0.213</td>
<td>1.1</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>P-ch</td>
<td>P-ch</td>
<td>P-ch × 2</td>
<td>N-ch</td>
<td></td>
</tr>
</tbody>
</table>

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A DC-brushless motor driver with a built-in MOSFET can be driven at a variable speed by control signals from the MCU.

1. **Built-in circuitry required to drive the motor**
   It contains a level-shifting high-side driver, low-side driver, and power MOSFET.

2. **High voltage power terminals and control terminals are separated**
   High-voltage/large-current terminals and the control terminals are separated on both sides of the package, thereby eliminating the complexity of wiring.

3. **Included protection functions**
   It has built-in over-current protection, thermal shutdown, shutdown (SD) and under-voltage protection functions.

**TPD4207F**  
Application Circuit Example

---

**TPD4207F**  
Part number: SSOP30

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD4207F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SSOP30</td>
</tr>
<tr>
<td>$V_{BB}$ (Max) [V]</td>
<td>600</td>
</tr>
<tr>
<td>$I_{OUTDC}$ (Max) [A]</td>
<td>5.0</td>
</tr>
<tr>
<td>$V_{CC}$ [V]</td>
<td>13.5 to 16.5</td>
</tr>
</tbody>
</table>

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CMOS single-operation amplifier with a built-in phase compensator, low-voltage drive, and low-current power supply.

1. **Low voltage operation is possible.**
   
   Compared with bipolar general-purpose operational amplifiers, low-voltage operation is possible: $V_{DD} = \pm 0.75$ to $\pm 3.5$ V or 1.5 to 7 V.

2. **Low-current power supply**
   
   $I_{DD}(\text{Typ.}) = 60[\mu\text{A}]$
   
   The low-current power supply characteristics of CMOS processes contribute to extend the battery life of small IoT devices. [Note 3]

3. **Built-in phase compensator circuit**
   
   Because the phase compensation circuit is built-in, there is no need for any external device.

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TC75S51FU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>USV</td>
</tr>
<tr>
<td>$V_{DD(\text{op})}$ [V]</td>
<td>$\pm 0.75$ to $\pm 3.5$ or 1.5 to 7.0</td>
</tr>
<tr>
<td>$I_{DD}$ (Max) [µA]</td>
<td>200</td>
</tr>
<tr>
<td>$f_t$ (Typ.) [MHz]</td>
<td>0.6</td>
</tr>
</tbody>
</table>

[Note 1] Various sensors: vibration detection sensors, shock sensors, acceleration sensors, pressure sensors, infrared sensors, and temperature sensors.

[Note 2] Based on our survey (as of May 2017).

[Note 3] Comparison with our bipolar process operational amplifier.

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Small surface mount LDO regulator
TCR3DF / TCR2EF series

Value provided

Variety of products that meet high performance requirements, from general-purpose products to ultra-small package type.

1. Low dropout voltage
   The newly developed new-generation process significantly improved the dropout characteristics.

2. High ripple rejection
   Our LDO regulator has a high ripple rejection characteristic, and eliminates switching noise efficiently.

3. Ceramic capacitors can be used.
   Improved drop-out characteristics have enabled the use of ceramic capacitors as external capacitors.

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TCR3DF Series</th>
<th>TCR2EF series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SMV</td>
<td>SMV</td>
</tr>
<tr>
<td>$V_N$ (Max) [V]</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>$I_{OUT}$ (Max) [A]</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>$V_{OUT}$ [V]</td>
<td>1.0 to 4.5</td>
<td>1.0 to 5.0</td>
</tr>
</tbody>
</table>

◆ Return to Block Diagram TOP
The photocoupler consists of a non zero cross type phototriac, optically coupled to an infrared light emitting diode.

1. **Non zero cross type**
   This is suitable for the case where the operation time is short and phase control is necessary.

2. **Switching characteristic**
   It has excellent points such as high speed, low noise and silence.

3. **Miniaturization of mounting area**
   The minimum size is 3.7×7.0×2.1 mm. (SO6)

**Line up**

<table>
<thead>
<tr>
<th>Feature</th>
<th>TLP267J</th>
<th>TLP560J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>TLP267J</td>
<td>TLP560J</td>
</tr>
<tr>
<td>Package</td>
<td>SO6</td>
<td>DIP6</td>
</tr>
<tr>
<td>V_{DRM} (Max) [V]</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>BV_{r} (Min) [Vrms]</td>
<td>3750</td>
<td>2500</td>
</tr>
<tr>
<td>T_{on} (°C)</td>
<td>-40 to 100</td>
<td>-40 to 100</td>
</tr>
<tr>
<td>Feature</td>
<td>Non-zero-voltage turn-on</td>
<td></td>
</tr>
</tbody>
</table>

**Internal connection diagram**

The photocoupler consists of a non zero cross type phototriac, optically coupled to an infrared light emitting diode.

**Value provided**

TLP267J

Internal connection diagram

**Notes:**
- When a VDE approved type is needed, please designate the Option (V4).
- UL-approved: UL1577, File No.E67349
- cUL-approved: CSA Component Acceptance Service No.5A File No.E67349
- VDE-approved: EN60747-5-5, EN60065 or EN60950-1 (Note)
- CQC-approved: GB4943.1, GB8898 Thailand Factory

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Support for low voltage motor driving (2.5V min.) with low power consumption.

1. **Low voltage operation**
   
   Motor driving voltage is 2.5V min. for low voltage applications such as battery operation devices.

2. **Low current consumption**
   
   Stand-by current is below 2uA (IC total) for power saving of devices.

3. **Abnormality detection functions**
   
   Over current detection (ISD), Over heat detection (TSD) & Low voltage detection (UVLO) are available for safe motor driving.

---

### Line up

<table>
<thead>
<tr>
<th>Part Number</th>
<th>TC78H621FNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ac}$ (Max)</td>
<td>18</td>
</tr>
<tr>
<td>$I_{OUT}$ (Max)</td>
<td>1.1</td>
</tr>
<tr>
<td>$R_{on,upper \ and \ lower}$</td>
<td>0.8</td>
</tr>
<tr>
<td>Control Interface</td>
<td>ENABE / PHASE inputs</td>
</tr>
<tr>
<td>Step</td>
<td>Two-phase excitation</td>
</tr>
<tr>
<td>Feature</td>
<td>Motor driving voltage: 2.5 V (Min)</td>
</tr>
<tr>
<td>Abnormality detection function</td>
<td>Over heat, Over current, Low voltage</td>
</tr>
<tr>
<td>Package</td>
<td>TSSOP16</td>
</tr>
</tbody>
</table>

---

TSOP16 Package (5.0mm×6.4mm×1.2mm)
Single phase brushless motor driver
TC78B002FNG/FTG

Simple fan motor drive with low noise & low vibration.

1. Suitable for small Fan motor
   Motor driving voltage is 2.5V min. for low voltage applications such as battery operation devices.

2. Low noise & low vibration
   Smooth waveform by soft switching drive realizes low noise and low vibration.

3. Small package
   Small QFN16 package with high heat dissipation.

WQFN16 Package (3mm×3mm×0.75mm)

<table>
<thead>
<tr>
<th>Line up</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VM (Max) [V]</td>
<td>18</td>
</tr>
<tr>
<td>I_{OUT} (Max) [A]</td>
<td>1.5</td>
</tr>
<tr>
<td>Drive type</td>
<td>Single phase full wave drive</td>
</tr>
</tbody>
</table>

Features & Others:
- PWM control
- Soft switching drive
- Quick start
- Hall bias circuit
- Error detection: Current limit, Thermal shutdown

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Return to Block Diagram TOP
**Microcontroller**

**TX03 series M370 group/TX04 series M470 group**

Value provided

**System cost reduction, noise reduction, higher efficiency and less development work.**

1. **Equipped with motor control co-processor**

   Toshiba’s original co-processor vector engine (VE) for motor control reduces CPU load and allows control of multiple motors and peripherals.

2. **Equipped with motor control logic circuit**

   Versatile three-phase PWM output with high efficiency and low noise control made possible by sense timing. The advanced encoder lightens CPU load of each PWM processing.

3. **Equipped with analog circuit for motor control**

   Multiple high speed, high accuracy AD converter are integrated, allowing conversion timing and PWM output to be linked. External functions such as high-performance op-amps are on-chip.

---

**TX™ Family**

**TX04**

- Series
- ~120MHz
- for High-Efficiency Signal Processing Applications

- M440 Group
- M460 Group
- M470 Group

**TX03**

- Series
- ~144MHz
- for a Broad Range of Applications

- M310 Group
- M330 Group
- M340 Group
- M360 Group
- M370 Group
- M380 Group
- M390 Group

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**Line up**

- TX03 series M370 group: Arm® Cortex®-M3, includes 1st gen VE
- TX04 series M470 group: Arm® Cortex®-M4, includes 2nd gen VE

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