Washing Machine

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.
Block Diagram
Criteria for device selection
- 650 V MOSFET is suitable for switching on primary side of AC-DC converter.
- Transistor output photocoupler is for output voltage feedback.
- Stable system can be realized by using LDO that is resistant to noise generated by the motor drive unit.

Proposals from Toshiba
- Optimal for high efficiency power supply switching
  DTMOS IV series power MOSFET
- Photocoupler with excellent environmental resistance
  Transistor output photocoupler
- Resistant to power supply noise
  Small surface mount LDO regulator

※ Click the number in the circuit diagram to jump to the detailed description page.
Washing Machine  Detail of PFC circuit

PFC circuit
Full switching

Criteria for device selection
- MOSFET is suitable for full switching solutions.
- IGBT is suitable for partial switching solutions.
- Transistor output photocoupler is for signal isolation.
- Microcomputer can be used for PFC control.

Proposals from Toshiba
- **Optimal for high efficiency power supply switching**
  DTMOS IV series power MOSFET
- **Photocoupler with excellent environmental resistance**
  Transistor output photocoupler
- **Controlling a system including the main motor at low power consumption and high performance**
  MCU

※ Click the number in the circuit diagram to jump to the detailed description page.
Washing Machine  Detail of motor drive unit

Main motor drive unit

MCD (controller) + gate driver + IPM

MCD (controller) + gate driver + MOSFET

Water pump drive unit

MCD (controller) + high voltage IPD

 Criteria for device selection
- IPD is suitable for water pump motor drive.
- High speed MOSFET is suitable for driving the motor.
- Transistor output photocoupler is for signal isolation.
- Brushless motor driver can easily drive a three-phase brushless motor under inverter control.

Proposals from Toshiba
- Optimal for high efficiency power supply switching
  DTMOS IV series power MOSFET
- Photocoupler with excellent environmental resistance
  Transistor output photocoupler
- Motor drive circuit with high voltage can be realized
  High voltage IPD
- Easy to drive the motor
  Motor driver
- Controlling a system including the main motor at low power consumption and high performance
  MCU

※ Click the number in the circuit diagram to jump to the detailed description page.
Washing Machine  Detail of communication unit / sensor input unit

Communication unit

Criteria for device selection
- Low $R_{\text{d,y}}$ characteristic of ESD protection diode (TVS) is significant indicator of ESD protection performance.
- Stable system can be realized by using an operational amplifier that is resistant to noise generated by the motor drive unit.

Proposals from Toshiba
- **Absorb static electricity (ESD)** from external terminals and prevent circuit malfunction
- **Accurately capturing changes of consumption current**, etc.
  Ultra low noise operational amplifier
- **Controlling a system including the main motor** at low power consumption and high performance

Sensor input unit

※ Click the number in the circuit diagram to jump to the detailed description page.
Washing Machine  Detail of operation unit

Criteria for device selection
- Typically an LED type display uses over 4 digits 7 segment LEDs.
- White LEDs for LCD back light uses LED drivers capable of large output current.
- An MCU controls a main motor digitally which changes the torque complexity and drastically.

Proposals from Toshiba
- Only one external register sets LED drive current. It can reduce BOM cost.
  7 segment LED driver
- 1ch type LED driver is suitable for a small LCD back light.
  Step up type LED driver
- Controlling a system including the main motor at low power consumption and high performance
  MCU

Operation unit (example of Key/LED)

Operation unit (example of LCD)

※ Click the number in the circuit diagram to jump to the detailed description page.
Recommended Devices
Device solutions to address customer needs

As described above, in order to design Washing Machine, “Quieter and more efficient motors”, “Lower power consumption of the set” and “Miniaturization of circuit boards” are important factors. Toshiba’s proposals are based on these three solution perspectives.

- Quieter and more efficient motors
  - High voltage three-phase motor driving

- Lower power consumption of the set
  - High efficiency
  - Low loss

- Miniaturization of circuit boards
  - Compatible with compact packages
## Device solutions to address customer needs

<table>
<thead>
<tr>
<th></th>
<th>Device</th>
<th>High voltage three-phase motor driving</th>
<th>High efficiency</th>
<th>Low loss</th>
<th>Compatible with compact packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DTMOS IV series power MOSFET</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Transistor output photocoupler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Small surface mount LDO regulator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Intelligent power devices (IPDs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Motor driver</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>TVS diode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ultra low noise operational amplifier</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7 segment LED driver</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>LED driver for LCD backlight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Motor control MCU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. **High voltage three-phase motor driving**
2. **High efficiency**
3. **Low loss**
4. **Compatible with compact packages**
The performance index RonA is reduced by 30 % (compared with conventional products) to improve power efficiency, which greatly contributes to miniaturization.

1. 30 % reduction of RonA

The newly developed single epitaxial process has reduced the RonA by 30 %. (Comparison of DTMOSIII products : Our Comparison)

2. Reduction of on-resistance rise at high temperature

Single epitaxial process reduces the on-resistance rise at high temperatures.

3. Optimization of gate switching speed

The gate switching speed has been optimized by reducing Coss (12 % : compared with conventional products) and by reducing on-resistance (super junction structural DTMOS).

### Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TK31N60W</th>
<th>TK28A65W</th>
<th>TK20A60W5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>TO-247</td>
<td>TO-220SIS</td>
<td>TO-220SIS</td>
</tr>
<tr>
<td>V_{DS} [V]</td>
<td>600</td>
<td>650</td>
<td>600</td>
</tr>
<tr>
<td>I_D [A]</td>
<td>30.8</td>
<td>27.6</td>
<td>20</td>
</tr>
<tr>
<td>R_{DS(ON)} [Ω] @V_{GS} = 10 V</td>
<td>Typ. 0.073</td>
<td>0.094</td>
<td>0.15</td>
</tr>
<tr>
<td>Polarity</td>
<td>N-ch</td>
<td>N-ch</td>
<td>N-ch</td>
</tr>
</tbody>
</table>
Transistor output photocoupler
TLP383 / TLP293 / TLP785 / TLP385

Value provided

Reduction in required circuit board area and improving reliability enabling maintenance-free operation.

1 High conversion efficiency ($I_F = 0.5$ mA)

The TLP383/TLP293 is a high-isolation photocoupler that optically couples a phototransistor and high-output infrared LED. Compared to conventional electromagnetic relays and insulating transformers, it provides low-input current and higher conversion efficiency.

Industrial equipment
General-purpose inverter
Servo amplifier
Robot
Machine Tool
High-output power supply
Security equipment
Semiconductor tester
PLC (Programmable Logic Controller)

High level of insulation and noise blocking

2 High temperature operation guarantee

The TLP383/TLP293 is designed to operate under severe conditions of ambient temperature environment, such as inverters, robots, machinery, and high-output power supplies.

<table>
<thead>
<tr>
<th>Part number</th>
<th>TLP383</th>
<th>TLP293</th>
<th>TLP785</th>
<th>TLP385</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SO6L (4pin)</td>
<td>SO4</td>
<td>DIP4</td>
<td>SO6L (4pin)</td>
</tr>
<tr>
<td>$BV_{CC}$ (Min) [Vrms]</td>
<td>5000</td>
<td>3750</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>$T_{op}$ [°C]</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
<td>-55 to 110</td>
<td>-55 to 110</td>
</tr>
</tbody>
</table>

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**Small surface mount LDO regulator**
**TCR3DF / TCR2EF series**

**Value provided**

Wide range of products that meet high performance requirements are provided from general purpose products to ultra compact packages.

1. **Low dropout voltage**

   Even if the input voltage is reduced to a certain level, such as when the power supply quality is unstable, output can be stable and heat loss is also reduced. These contribute to higher power supply quality.

2. **High ripple rejection**

   Ripple rejection ratio R.R, which indicates fluctuation of power supply voltage is high and ripples can be rejected efficiently.

3. **Can be used with ceramic capacitors**

   Improved dropout 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>$V_{IN}$ (Max) [V]</td>
<td>5.5</td>
<td>4.4</td>
</tr>
<tr>
<td>$I_{OUT}$ (Max) [mA]</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Output voltage range [V]</td>
<td>1.0 to 4.5</td>
<td>1.0 to 5.0</td>
</tr>
</tbody>
</table>

[Return to Block Diagram TOP]
This product has a built-in output power MOSFET and can directly drive a brushless DC motor with an output power of 60 W or less.

**1 Various built-in circuits required to drive the motor**

A level shifting high side driver, low side driver and power MOSFET for output are built-in. The brushless DC motor can be driven directly by a control signal from the PWM controller IC.

**2 Various built-in circuits required to drive the motor**

This IPD can be applied to AC 200 V input system even in areas where commercial power supply quality is unstable and voltages are increased to 450 V.

**3 Small package**

The compact package SSOP30 enables to realize smaller and thinner control board. This contributes to improvement of degree of freedom in design and the reduction of motor case size.

### Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TPD4204F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SOP30</td>
</tr>
<tr>
<td>( V_{BB} ) [V]</td>
<td>600</td>
</tr>
<tr>
<td>( I_{OUT} ) [A]</td>
<td>2.5</td>
</tr>
<tr>
<td>( V_{CC} ) [V]</td>
<td>13.5 to 16.5</td>
</tr>
</tbody>
</table>

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Toshiba's proprietary technology makes it unnecessary to adjust the lead angle and realizes high efficiency over a wide motor speed range.

1 High efficiency motor control over a wide motor speed range is realized

Toshiba’s proprietary lead angle control technology provides high efficiency motor control regardless of motor speed, load torque and power supply voltage.

2 Low noise, low vibration motor control

Sine wave drive with smooth current waveforms contributes to lower motor noise and vibration compared to conventional rectangular wave drive.

3 Low loss, low heat generation

The built-in MOSFET has a low output on-resistance of 0.23 Ω (Typ.). Loss and heat generated by the IC during motor operation can be reduced.

---

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TC78B016FTG</th>
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</thead>
<tbody>
<tr>
<td>Power supply voltage (operating range) [V]</td>
<td>6 to 30</td>
</tr>
<tr>
<td>Output current (operating range) [A]</td>
<td>3</td>
</tr>
<tr>
<td>Drive system</td>
<td>Sine wave drive system</td>
</tr>
</tbody>
</table>
| Other / Features  | Lead angle control: Optimum voltage/current phase control  
Sensor input: Hall element/Hall IC compatible  
Speed control input: PWM signal input/analog voltage input  
Abnormality detection function: Overheat detection, Overcurrent detection, Motor lock detection  
Output on-resistance (vertical sum): 0.23 Ω (Typ.) |

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WQFN36 package (5 × 5 × 0.8 mm)

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**Value provided**

This absorbs static electricity (ESD) from external terminals, prevents circuit malfunction, and protects devices.

1. **Improved ESD pulse absorption**

   Both low operating resistance and low capacitance are realized and ensures high signal protection performance and signal quality.

2. **Reduce ESD energy by low clamp voltage**

   Steadily protect the connected circuits / devices using proprietary technology.

3. **Optimal for high-density mounting**

   A variety of small size packages are available.

---

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>DF2B7ASL</th>
<th>DF2S6P1CT</th>
<th>DF2B5M4SL</th>
<th>DF2B6M4SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SL2</td>
<td>CST2</td>
<td>SL2</td>
<td>SL2</td>
</tr>
<tr>
<td>$V_{ESD}$ [kV]</td>
<td>±30</td>
<td>±30</td>
<td>±20</td>
<td>±20</td>
</tr>
<tr>
<td>$V_{RMN}$ (Max) [V]</td>
<td>5.5</td>
<td>5.5</td>
<td>3.6</td>
<td>5.5</td>
</tr>
<tr>
<td>$C_t$ (Typ.) [pF]</td>
<td>8.5</td>
<td>90</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>$R_{DYN}$ (Typ.) [Ω]</td>
<td>0.2</td>
<td>0.23</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**NOTE**: This product is an ESD protection diode and cannot be used for purposes other than ESD protection (including but not limited to voltage regulation diode applications).
Ultra low noise operational amplifier
TC75S67TU

Value provided

Very small signals detected by various sensors can be amplified with very low noise.

1. **Ultra-low noise**
   \[ V_{IN} \text{ (Typ.)} = 6.0 \text{ [nV/} \sqrt{\text{Hz}}] \]
   \[ @f = 1 \text{ kHz} \]

   Very small signals detected by various sensors[Note 1] can be amplified with low noise using CMOS Op-amp by optimizing the processing. We achieved one of the industry’s lowest[Note 2] input equivalent noise voltage.

2. **Low current consumption**
   \[ I_{DD} \text{ (Typ.)} = 430 \text{ [} \mu\text{A}] \]

   The low current consumption characteristics of CMOS processing contributes to the extension of battery life of the compact IoT devices[Note 3].

3. **Low supply voltage operation**
   \[ V_{DD} = 2.2 \text{ to } 5.5 \text{ V} \]

---

[Note 1] Sensor types: vibration detection sensor, shock sensor, accelerometer, pressure sensor, infrared sensor, and temperature sensor
[Note 2] Based on Toshiba data (as of May 2017)
[Note 3] Compared with Toshiba’s Op-amp using bipolar processing

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Ultra low noise characteristic
(Company Comparison)

---

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TC75S67TU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>UFV</td>
</tr>
<tr>
<td>( V_{DD} ) (Max) [V]</td>
<td>±2.75</td>
</tr>
<tr>
<td>( V_{DD} ) (Min) [V]</td>
<td>±1.1</td>
</tr>
<tr>
<td>( I_{DD} ) (Max) [\mu A]</td>
<td>700</td>
</tr>
<tr>
<td>( V_{IN} ) (Typ.) [nV/\sqrt{Hz}] @f = 1 kHz</td>
<td>6</td>
</tr>
</tbody>
</table>

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◆Return to Block Diagram TOP
7-segment LED driver
TB62785NG / FTG

Value provided

LED driver which can light a 4-digit, 7-segment LED using one device

1 Suitable for 7-segment LED displays
This driver can serially control a 4-digit 7-segment LED. Matrix drive is performed by scanning the digits at 480 Hz. The 3-wire control can also be cascaded, reducing the number of harnesses.

2 Current control possible with one external resistor
The LED current can be set with an external resistor. No other components are needed.

3 Lead insertion type package
We have a line-up of free-standing lead insertion packages (SDIP24) and small packages (QFN24) that can be used for the main board.

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TB62785NG</th>
<th>TB62785FTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SDIP24</td>
<td>VQFN24</td>
</tr>
<tr>
<td>Outputs</td>
<td>4 columns × 7 outputs</td>
<td></td>
</tr>
<tr>
<td>Operating voltage</td>
<td>4 to 5.5 V</td>
<td></td>
</tr>
<tr>
<td>Internal power supply</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Max. LED power supply</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Max. output current</td>
<td>50 mA</td>
<td></td>
</tr>
<tr>
<td>Cascade connection</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>PWM control</td>
<td>○ 16-step light control possible (total)</td>
<td></td>
</tr>
</tbody>
</table>

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**Step up type LED drivers for a white LED**

1ch drive TB62763FMG, 4ch drive TB62771FTG

---

**Value provided**

Driving series connection Hi-current type white LEDs. There are 1ch and 4ch drive type drivers.

**1 Suitable driving a white LED for an LCD back light**

Line up are 1ch and 4ch type drivers. 1ch type is suitable for mobile LCD and 4ch one is for small LCD PC.

**2 Capable driving series connection white LEDs**

1ch type maximum driving number of series connection LED is 6, 4ch one is 9/ch. Built-in step up type power supply adjusts LED driving voltage according to the LED $V_f$.

**3 PWM dimming function**

Minimum high level time period is 330 ns about 4ch PWM control based on constant current power supply. 1ch type is possible to dim by few kHz PWM.

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>TB62763FMG</th>
<th>TB62771FTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SON8</td>
<td>WQFN24</td>
</tr>
<tr>
<td>Driving ch number</td>
<td>1 ch</td>
<td>4 ch</td>
</tr>
<tr>
<td>Maximum LED driving number</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Operation voltage</td>
<td>2.8 to 5.5 V</td>
<td>4.75 to 40 V</td>
</tr>
<tr>
<td>LED driving current</td>
<td>$\sim$80 mA</td>
<td>$\sim$150 mA</td>
</tr>
<tr>
<td>Built-in constant current power supply</td>
<td>N/A</td>
<td>Available</td>
</tr>
<tr>
<td>Built-in FET for stepping up power supply</td>
<td>Available</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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Built-in Toshiba original vector engine (VE) hardware contributes high accuracy and low power consumption motor control

1. Built-in ARM® Cortex®-M3 CPU core
   TMPM37AFSQG implements Cortex®-M3 core with 80 MHz maximum operation frequency. Various development tool and their partners allow users many options.

2. Suitable as a motor control MCU
   Built-in Toshiba original vector engine (VE) hardware contributes high accuracy and low power consumption motor control

3. System cost down and development efficiency improvement
   TMPM37AFSQG executes sensing data monitoring and processing efficiently by combining built-in analog function such as ADC and comparator, and CPU system. The original NANO FLASH™ is possible to rewrite at high-speed. It reduces user software development time period.

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TMPM37AFSQG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum operation frequency</td>
<td>80 MHz</td>
</tr>
<tr>
<td>Instruction ROM</td>
<td>64 KB</td>
</tr>
<tr>
<td>RAM</td>
<td>4 KB</td>
</tr>
<tr>
<td>3 phase PWM output</td>
<td>1 ch</td>
</tr>
<tr>
<td>UART / SIO</td>
<td>1</td>
</tr>
<tr>
<td>I2C</td>
<td>1</td>
</tr>
<tr>
<td>ADC</td>
<td>5 ch (12 bit)</td>
</tr>
</tbody>
</table>

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