Electric Toothbrush

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
Electric Toothbrush   Detail of circuit (1)

Motor control unit (1)

Motor control unit (2)

LED driver

Criteria for device selection
- Since a current is required for driving the motor, a MOSFET with low $R_{ON}$ is required for realizing low loss.
- The use of low consumption products can increase the overall efficiency of the system.
- The circuit board area can be reduced by adopting small package products.

Proposals from Toshiba
- Realize a set with low power consumption by low on-resistance Small-signal MOSFET
- Schottky barrier diode (SBD), which realizes low $V_F$ and low $I_R$
  Schottky barrier diode (SBD)
- Wide line-up of bipolar transistor
  Bipolar transistor

※ Click the number in the circuit diagram to jump to the detailed description page
Wireless power supply receiving unit

Rectifying circuit

SBD

Wireless Receiver IC

Power supply circuit

LDO Regulator

MCU

Bluetooth SoC

Criteria for device selection

- The rectified current of the wireless power supply requires SBDs with a low $V_F$.
- The use of low consumption products can increase the overall efficiency of the system.
- The circuit board area can be reduced by adopting small package products.

Proposals from Toshiba

- Rectifier diode suitable for high density mounting
  Schottky barrier diode (SBD)
- LDO regulator with low dropout characteristics
  Small surface mount LDO regulator

※ Click the number in the circuit diagram to jump to the detailed description page
Electric Toothbrush  Detail of circuit (3)

Criteria for device selection

- A low offset operational amplifier is required for high precision current sensing.
- The use of low consumption products can increase the overall efficiency of the system.
- The substrate area can be reduced by adopting small package products.

Proposals from Toshiba

- Low noise operational amplifier with low $V_{IO}$
  Ultra-low noise operational amplifier
- Small-signal MOSFET with low $R_{ON}$
  Small-signal MOSFET

※ Click the number in the circuit diagram to jump to the detailed description page
Recommended
Devices
As described above, in the design of Electric Toothbrush, “Low power consumption of the set”, “Improved reliability of the set” and “Miniaturization of circuit boards” are important factors. Toshiba’s proposals are based on these three solution perspectives.

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

- **Improved reliability of the set**
  - Reduction of power consumption

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

<table>
<thead>
<tr>
<th></th>
<th>High efficiency</th>
<th>Low loss</th>
<th>Reduction of power consumption</th>
<th>Compatible with compact packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small-signal MOSFET</td>
<td>● ●</td>
<td>● ●</td>
<td>● ●</td>
</tr>
<tr>
<td>2</td>
<td>Schottky barrier diode (SBD)</td>
<td>●</td>
<td>●</td>
<td>● ●</td>
</tr>
<tr>
<td>3</td>
<td>Bipolar transistor</td>
<td>●</td>
<td>●</td>
<td>● ●</td>
</tr>
<tr>
<td>4</td>
<td>Small surface mount LDO regulator</td>
<td>●</td>
<td>●</td>
<td>● ●</td>
</tr>
<tr>
<td>5</td>
<td>Ultra-low noise operational amplifier</td>
<td>●</td>
<td>●</td>
<td>● ●</td>
</tr>
</tbody>
</table>
Small-signal MOSFET
SSM3J338R / SSM3K324R / SSM3K35AMFV

Value provided

Suitable for power management switches and greatly contributes to reduction of power consumption and miniaturization of the set.

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

2. Small gate input charge
   Switching characteristics is improved by suppressing required performance for driving MOSFET and reducing gate input charge.

3. Optimal for high-density mounting
   Variety of packages are available.

Lineup of low on-resistance product and trade-off characteristics between on-resistance and capacitance

<table>
<thead>
<tr>
<th>Part number</th>
<th>SSM3J338R</th>
<th>SSM3K324R</th>
<th>SSM3K35AMFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>SOT-23F</td>
<td>VESM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.9 x 2.4 mm)</td>
<td>(1.2 x 1.2 mm)</td>
<td></td>
</tr>
<tr>
<td>V_{DSS} [V]</td>
<td>-12</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>I_{D} [A]</td>
<td>-6</td>
<td>4</td>
<td>0.25</td>
</tr>
<tr>
<td>R_{DSON} [mΩ] @V_{GS} = 4.5 V</td>
<td>Typ. 15.9</td>
<td>45</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Max 20.2</td>
<td>56</td>
<td>1100</td>
</tr>
</tbody>
</table>

© 2019 Toshiba Electronic Devices & Storage Corporation

Return to Block Diagram TOP
Schottky barrier diode (SBD)  
CUHS20F30 / CUHS20F40

Value provided

High voltage and low leakage are realized, and protects the circuit from counter electromotive force caused by motor drive.

1 Compact package with high power dissipation

Products are suitable for various power dissipation level.
Low thermal resistance ($R_{th(j-a)} = 105 \, ^\circ C/W$)

2 Line-up of various products

Products line-up offers products with reverse voltage $V_R$ up to 30 V, 40 V and 60 V.

**Line up**

<table>
<thead>
<tr>
<th>Part number</th>
<th>CUHS20F30</th>
<th>CUHS20F40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>US2H (2.5 x 1.4 mm)</td>
<td></td>
</tr>
<tr>
<td>$V_R$ [V]</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>$I_0$ [A]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$V_I$ (Typ.) [V] $@I_I = 1$ A</td>
<td>0.35</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Easy to thermal design by low transient thermal resistance

© 2019 Toshiba Electronic Devices & Storage Corporation
Through our extensive product lineup, we provide products that meet the needs of our customers.

1. Many package lineups
   A large number of packages, such as flat lead and leadless, are available, allowing you to choose products that suit your board.

2. The collector-emitter saturation voltage is low.
   The saturation voltage between the collector and emitter is low and the power consumption is low.

3. Have high ESD tolerance
   In applications where static electricity is likely to occur, such as in vacuum cleaners, bipolar transistors with higher ESD-resistance than MOSFET are helpful.

### Bipolar transistor

2SC2712 / 2SA1162, HN1B01FU, TBC847 / TBC857

**Value provided**

### Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>NPN</th>
<th>PNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2SC2712</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2SA1162</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBC847</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBC857</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HN1B01FU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(NPN+PNP)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Package</th>
<th>S-Mini</th>
<th>SOT23</th>
<th>US6</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{ceo} (Max) [V]</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>I_{c} [mA]</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

© 2019 Toshiba Electronic Devices & Storage Corporation
Small surface mount LDO regulator
TCR5AM series, TCR3UG series, TCR3D series

Value provided

Not influenced by fluctuation of battery voltage and stable power supply is realized.

1. High ripple rejection

Our LDO regulator has high ripple rejection characteristic. Stable power supply is realized by removing switching noise generated in the circuit.

2. Low loss (low dropout)

The heat generated by the circuit can be minimized since our LDO regulator minimizes the losses generated by the circuit.

3. Optimal for high-density mounting

A variety of small size packages are available.

Low dropout voltage

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TCR5AM series</th>
<th>TCR3UG series</th>
<th>TCR3D series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>DFN5B (1.2 x 1.2 mm)</td>
<td>WCSP4F (0.645 x 0.645 mm)</td>
<td>WCSP4E DFN4B SMV</td>
</tr>
<tr>
<td>I_{OUT} [A]</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>V_{DO} [mV]</td>
<td>@I_{OUT} = 500 mA</td>
<td>@I_{OUT} = 300 mA</td>
<td>@I_{OUT} = 300 mA</td>
</tr>
<tr>
<td>I_s [μA]</td>
<td>40</td>
<td>0.34</td>
<td>65</td>
</tr>
</tbody>
</table>

◆ Return to Block Diagram TOP
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_{NI} (Typ.) = 6.0 [nV/√Hz] @f = 1 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 Small package

This is a flat lead type compact package, which contributes to the miniaturization and lower height of the printed circuit board. Packaging size: 2.0 x 2.1 x 0.7 mm

3 Low current consumption
I_{DD} (Typ.) = 430 [μA]

The adoption of the CMOS process achieves lower current-consumption characteristics than our bipolar process operational amplifier.

Ultra-low noise characteristic

V_{NI} = f

Conventional products: TC75S63TU

New product: TC75S67TU

[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

Line up

<table>
<thead>
<tr>
<th>Part number</th>
<th>TC75S67TU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package</td>
<td>UFV (2.0 x 2.1 mm)</td>
</tr>
<tr>
<td>V_{DD,SS} (Max) [V]</td>
<td>±2.75</td>
</tr>
<tr>
<td>V_{DD,SS} (Min) [V]</td>
<td>±1.1</td>
</tr>
<tr>
<td>I_{DD} (Max) [μA]</td>
<td>700</td>
</tr>
<tr>
<td>V_{NI} (Typ.) [nV/√Hz] @f = 1 kHz</td>
<td>6</td>
</tr>
</tbody>
</table>
If you are interested in these products and have questions or comments about any of them, please do not hesitate to contact us below:

Contact address: https://toshiba.semicon-storage.com/ap-en/contact.html
This terms of use is made between Toshiba Electronic Devices and Storage Corporation ("We") and customers who use documents and data that are consulted to design electronics applications on which our semiconductor devices are mounted ("this Reference Design"). Customers shall comply with this terms of use. Please note that it is assumed that customers agree to any and all this terms of use if customers download this Reference Design. We may, at its sole and exclusive discretion, change, alter, modify, add, and/or remove any part of this terms of use at any time without any prior notice. We may terminate this terms of use at any time and for any reason. Upon termination of this terms of use, customers shall destroy this Reference Design. In the event of any breach thereof by customers, customers shall destroy this Reference Design, and furnish us a written confirmation to prove such destruction.

1. Restrictions on usage
1. This Reference Design is provided solely as reference data for designing electronics applications. Customers shall not use this Reference Design for any other purpose, including without limitation, verification of reliability.
2. This Reference Design is for customer's own use and not for sale, lease or other transfer.
3. Customers shall not use this Reference Design for evaluation in high or low temperature, high humidity, or high electromagnetic environments.
4. This Reference Design shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.

2. Limitations
1. We reserve the right to make changes to this Reference Design without notice.
2. This Reference Design should be treated as a reference only. We are not responsible for any incorrect or incomplete data and information.
3. Semiconductor devices can malfunction or fail. When designing electronics applications by referring to this Reference Design, customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of semiconductor devices could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Customers must also refer to and comply with the latest versions of all relevant our information, including without limitation, specifications, data sheets and application notes for semiconductor devices, as well as the precautions and conditions set forth in the "Semiconductor Reliability Handbook".
4. When designing electronics applications by referring to this Reference Design, customers must evaluate the whole system adequately. Customers are solely responsible for all aspects of their own product design or applications. WE ASSUME NO LIABILITY FOR CUSTOMERS’ PRODUCT DESIGN OR APPLICATIONS.
5. No responsibility is assumed by us for any infringement of patents or any other intellectual property rights of third parties that may result from the use of this Reference Design. No license to any intellectual property right is granted by this terms of use, whether express or implied, by estoppel or otherwise.
6. THIS REFERENCE DESIGN IS PROVIDED “AS IS”. WE (a) ASSUME NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (b) DISCLAIM ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO THIS REFERENCE DESIGN, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

3. Export Control
Customers shall not use or otherwise make available this Reference Design for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). This Reference Design may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of this Reference Design are strictly prohibited except in compliance with all applicable export laws and regulations.

4. Governing Laws
This terms of use shall be governed and construed by laws of Japan.
RESTRICTIONS ON PRODUCT USE

- Toshiba Electronic Devices & Storage Corporation, and its subsidiaries and affiliates (collectively “TOShiba”), reserve the right to make changes to the information in this document, and related hardware, software and systems (collectively “Product”) without notice.

- This document and any information herein may not be reproduced without prior written permission from TOShiba. Even with TOShiba’s written permission, reproduction is permissible only if reproduction is without alteration/omission.

- Though TOShiba works continually to improve Product’s quality and reliability, Product can malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which Minimize risk and avoid situations in which a malfunction or failure of Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Before customers use the Product, create designs including the Product, or incorporate the Product into their own applications, customers must also refer to and comply with (a) the latest versions of all relevant TOShiba information, including without limitation, this document, the specifications, the data sheets and application notes for Product and the precautions and conditions set forth in the “TOSHIBA Semiconductor Reliability Handbook” and (b) the instructions for the application with which the Product will be used with or for. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this Product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. TOShiba assumes no liability for damages or losses occurring as a result of noncompliance with applicable laws and regulations.

- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOShiba for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.

- ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

- GaAs (Gallium Arsenide) is used in Product. GaAs is harmful to humans if consumed or absorbed, whether in the form of dust or vapor. Handle with care and do not break, cut, crush, grind, dissolve chemically or otherwise expose GaAs in Product.

- Do not disassemble, analyze, reverse-engineer, alter, modify, translate or copy Product, whether in whole or in part.

- Product shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.

- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOSHIBA for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.

- ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

- GaAs (Gallium Arsenide) is used in Product. GaAs is harmful to humans if consumed or absorbed, whether in the form of dust or vapor. Handle with care and do not break, cut, crush, grind, dissolve chemically or otherwise expose GaAs in Product.

- Do not use or otherwise make available Product or related software or technology for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). Product and related software and technology may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of Product or related software or technology are strictly prohibited except in compliance with all applicable export laws and regulations.

- Please contact your TOShiba sales representative for details as to environmental matters such as the RoHS compatibility of Product. Please use Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. TOShiba assumes no liability for damages or losses occurring as a result of noncompliance with applicable laws and regulations.