Technologies to Reduce Power Consumption of Wireless Communication ICs and Audio Power Amplifiers for Automotive Use

Accompanying the spread of eco-friendly automobiles including electric vehicles, demand has been increasing for reduction of the power consumption of automotive semiconductor devices. In the wireless communication field, attention has been focused on Bluetooth® Low Energy (Bluetooth® LE) integrated circuits (ICs) that make it possible to connect a smartphone not only to car entertainment equipment but also to various in-vehicle electronic systems in order to provide diagnostic information, including remaining battery charge and tire air pressure, with low power consumption. In the field of power amplifiers for in-vehicle audio equipment, both the reduction of power consumption and the suppression of heat generation for space-saving purposes are increasingly required.

Toshiba Electronic Devices & Storage Corporation has released Bluetooth® LE ICs that achieve low power consumption through the application of a low-current receiver architecture and a newly developed low-current radio-frequency (RF) circuit. We have also released a high-efficiency linear power amplifier that achieves both low power consumption and heat generation suppression comparable to those of a digital power amplifier, despite its smaller number of parts similar to the number in a conventional linear power amplifier, through the application of our proprietary technologies. These products are expected to facilitate reduction of the size of in-vehicle electronic systems while meeting the requirements of eco-friendly automobiles.

1. Introduction

In the automotive market, in addition to the basic functions of driving, turning and stopping, the car is also expected to be friendly to the environment, ensure safety, and provide additional comfort through the use of networked information. Under these circumstances, automotive semiconductors play an increasingly important role where low power consumption is a key requirement.

In recent years, use cases involving wireless communications among automotive equipment such as linking data between automobiles and smartphones are increasing (**Figure 1**). Toshiba Electronic Devices & Storage Corporation has over 20 years of development experience in automotive wireless ICs, primarily using Bluetooth®. In addition to the Bluetooth® LE ICs that connect car entertainment devices and smartphones, there are products for other applications such as remote keyless entry (RKE) and ETC (electronic toll collection system). Here we will discuss the

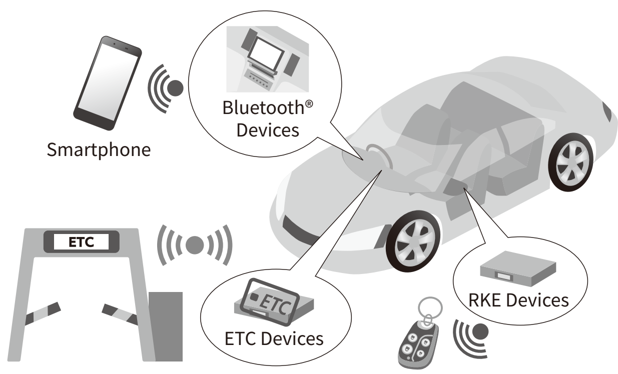


Figure 1: Application of wireless communication technologies for automotive use

Wireless communication applications for automotive use include Bluetooth® devices, RKE devices and ETC devices.

Bluetooth® LE ICs, which feature lower power consumption.

In the field of car audio power amplifiers that drive car speakers, various new applications in addition to conventional audio playback are emerging (**Figure 2**). Low power consumption is required here as well. We will also describe a high-efficiency linear audio power amplifier technology that we developed independently.

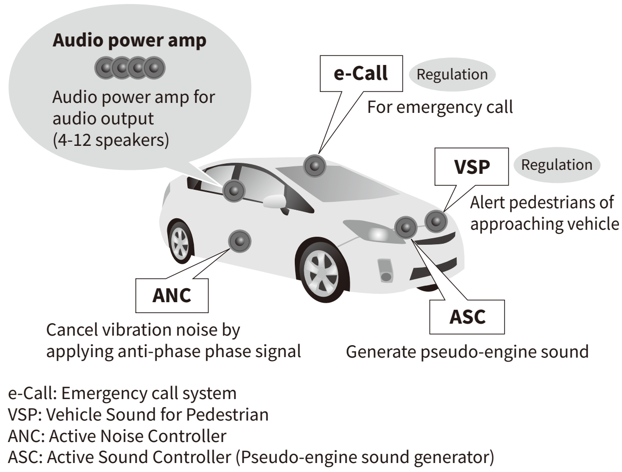


Figure 2: Growing demand for application of audio technologies for automotive use

With the advances in automobiles, demand for audio output for equipment other than car audio and navigation is increasing.

2. Lower power consumption wireless IC (Bluetooth® LE compatible IC) for automotive use

Conventional Bluetooth® technology is used for car entertainment applications such as (legally regulated) hands-free calling using smartphones and audio streamed playback. In the future, the functionally advanced Bluetooth® LE standard will become popular with the widespread adoption of Bluetooth® Ver. 5.0.

New applications of smartphone connectivity are appearing, such as key handling for car sharing, transfer of vehicle data during parking, etc. For these applications, low-power Bluetooth® LE is suitable because these functions are often used while the engine is stopped, and conventional voice and audio will be eventually replaced with Bluetooth® LE.

Table 1 shows the features of our company's automotive Bluetooth® LE compatible ICs, comparing older and newer models. The TC35679IFTG, which started mass production in 2017, operates over a wide temperature range of - 40 to 105°C for automotive use, compliant with the Bluetooth® Ver. 4.2 standard. It has a receiver architecture suitable for low-current operation and incorporates a newly developed high-efficiency power supply system with low switching noise as well as low-current RF circuits that includes a power amplifier. As a results, a low-power operation of 3.3 mA was achieved for the entire chip both during receiving and transmitting (Figure 3) (1).

Table 1: Features of Bluetooth® LE ICs for automotive use

Part No.	TC35679IFTG	TC35681IFTG
Mass-production date	2017	2019
Bluetooth® specification	Ver.4.2	Ver.5.0
Operating temperature range	– 40 – 105˚C	– 40 – 125˚C
Number of external components	7 units	11 units
Peak current	3.3 mA@±0 dBm	11 mA@+8 dBm
Transmit power	±0 dBm	+8 dBm
Effective data rate	700 k bits/sec	1 M bits/sec
Communication distance	130.0 m	603.4 m

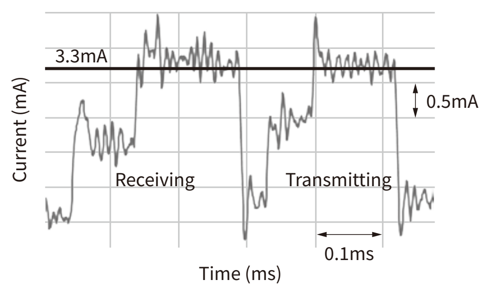
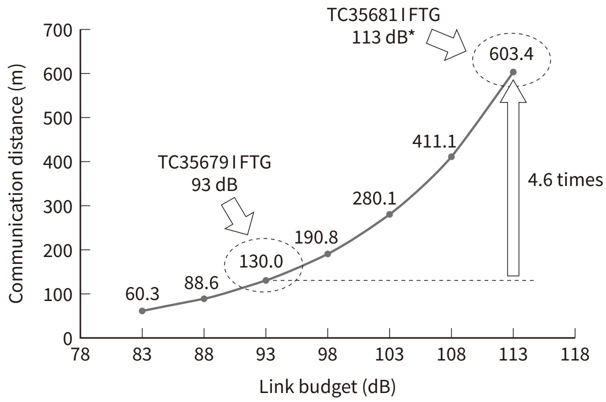


Figure 3: Example of current waveform of the TC35679IFTG at time of connection

The TC35679IFTG, compliant with Bluetooth® ver4.2, has current dissipation during transmission/reception of only 3.3mA.

By developing a new RF circuit, a low-power operation of 3.3mA was realized both during receiving and transmitting (**Figure 3**) (1).
In addition, the TC 35681IFTG also conforms to the Ver. 5.0 standard. Mass production is scheduled to begin in 2019, with a wide operating temperature range of -40 to 125°C, with the same low current consumption as the TC35679IFTG.
Thus, the TC35681IFTG and TC35679IFTG have very small peak currents during receiving and transmitting, and are suitable for RKE and similar applications.
Figure 4 shows the communication distance and link budget (*1) between the TC35681IFTG and TC35679IFTG. The link budget of the TC 35681IFTG was dramatically improved to 113dB, compared to 93dB of the TC 35679IFTG, and the range has increased 4.6 times. This means that power amplifiers can be improved by applying the following two technologies (2):

(1) Improving the ability to suppress spurious noise that increases with increasing transmit power
(2) Improving efficiency by adjusting the on/off timing of the two switching transistors in the output stage



* Calculated based on measured values

Figure 4: Trends in communication distance vs. link budget

The TC35681IFTG increased its link budget substantially to 113dB, and its communication distance increased 4.6 times compared with the TC35679IFTG.

When long distance communications become possible, the use cases will expand to include, for example, searching for an open

3. High-efficiency Linear Audio Power Amplifier IC

New applications using audio output, which are emerging with the evolution of the vehicles, will be promoted through global regulation, enabling usages such as e-call (an emergency calling system), Vehicle Sound for Pedestrian (VSP) to alert pedestrians of approaching vehicles, a dynamic vehicle noise controller ANC (Active Noise Controller), a pseudo-engine sound generator ASC (Electrical Sound Controller) that electrically reproduces the engine sound, and the like. Operation with low power consumption is required for these audio power amplifiers installed in these devices so as not to degrade the total fuel consumption of the vehicle. In addition, with the improvement of the functions and performance of each in-vehicle device, adoption of multi-tasked high-speed processors will be increased. The fact that the equipment's internal temperature becomes higher than that of conventional systems is also a problem, and in order to suppress heat generation it becomes necessary to reduce the power consumption here as well.

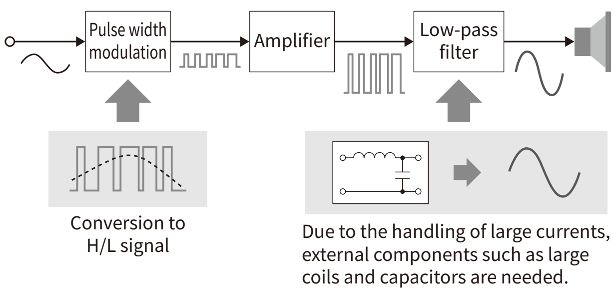


Figure 5: Configuration of digital power amplifier

Digital amplifiers convert analog input signals to H/L signals by pulse width modulation, amplify them, and demodulate them back to analog audio signals using low-pass filters.

Generally, audio power amplifiers are roughly divided into analog ones that linearly amplify an input signal and digital amplifiers that convert an audio input signal into an H/L (high/low) signal to perform switching amplification. When low power consumption is required, the latter is often used from the viewpoint of amplifier efficiency. However, in the latter system, the signal after the switching amplification must be passed through a low-pass filter and converted back to analog. As a result, large capacitors and coils are necessary. For this reason, system cost rises and the space required for these extra peripheral components becomes an issue (**Figure 5**).

(*1) The difference between transmit power (unit: dBm) and receiver sensitivity (unit: dBm). The larger this value, the longer the communication distance.

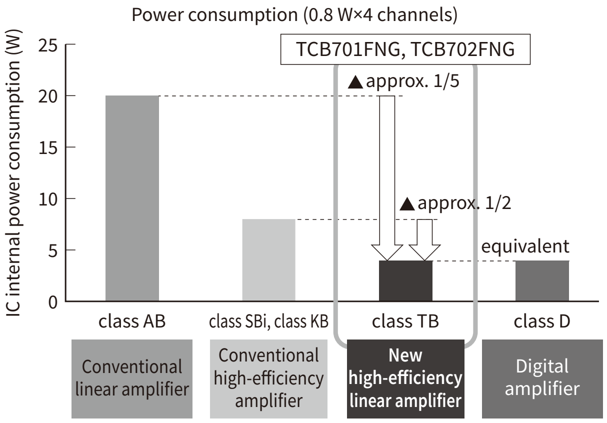
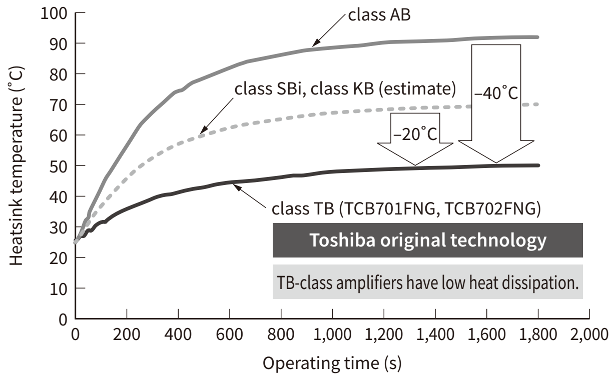


Figure 6: Comparison of power consumption of different types of power amplifiers

The newly developed class TB audio power amplifier realizes a power consumption level similar to class D, using peripheral circuitry equivalent to that for class AB.



* Test conditions Supply voltage: 13.2 V Input frequency: 1 kHz
Load resistance: 4 Ω Output power: 0.4 W × 4 channels
Ambient temperature: 25˚C
Thermal resistance of heatsink:
6.5˚C/W (size: 85 × 85 × 2 mm, Aluminium plate)

Figure 7: Temperature rise curves of heat sinks for different types of power amplifiers

By measuring the heatsink temperature under the same output conditions, the class TB displayed a rise about 20-40˚C less than for other classes.

To solve this, a new high-efficiency linear power amplifier technology was developed. Peripheral parts are equivalent to those for conventional linear amplifiers, and it is possible to achieve low power consumption equivalent to a digital amplifier under actual use conditions (output power for continuous sinusoidal drive conversion of 4W or less). For audio power amplifiers, the different modes of operation are defined as "classes" (digital amplifiers are "Class D"), and we developed a new high-efficiency linear power amplifier that we have named class TB (Tied BTL (Bridge Tied Load)).

The high-efficiency power linear amplifier technology already exists. Our previous generation is called class KB (Knit BTL), whereas another company's system goes by the name of class SBi (Single Ended BTL improved). For either system, the power consumption achieved is not quite as low as for Class D.

A specific example of power consumption is shown in **Figure 6**. Here, the IC's internal power consumption for each class is shown with the output power set to a continuous sinusoidal drive of 0.8W. In other words, the difference between these power consumption values is the difference in heat dissipation. The TCB701FNG and TCB702FNG, which are class TB power amplifiers, can reduce the internal power consumption loss down to about 1/5 of that of conventional linear amplifiers (class AB), and to about 1/2 compared to class SBi and class KB units. It can be seen that the efficiency is almost the same as for Class D and achieved without additional peripheral components.

The design principle of our class TB amplifier is based on that of an in-vehicle audio power amplifier. Automotive audio speakers generally consist of a total of four (for left/right and front/rear units). In a conventional system, the signal applied to one speaker swings between the power supply rail and ground (GND), and the power amplifiers for the speakers operate independently in 4 channels. However, in a class TB configuration, the connections of the power amplifiers are switched, such that one channel, two channels, or four channels of power amplifiers are vertically stacked between the power supply rail and GND. As a result, this reduces the current flowing per speaker channel to 1 → 1/2 → 1/4, thus achieving power reduction.

An example of an actually measured temperature rise characteristic is shown in **Figure 7**. These data show that, with a heatsink of identical size attached to class AB, class SBi, class KB, and class TB respectively at a constant output power of 0.4W delivered to the 4 channels, the temperature of the heatsink increases over time. The saturation temperature of the class TB power amplifier can be reduced by about 40°C compared with the class AB and by about 20°C compared to the class SBi and the class KB.

4. Conclusion

Semiconductors for low power consumption and long-distance communication using Bluetooth® LE technology and high-efficiency linear audio power amplifier ICs will serve the needs of the upcoming eco-car market.
As the use cases for automotive semiconductors expand, their rate of adoption in automobiles will increase. Going forward, we will accurately analyze the market demand, focus on timely development, and deliver high-quality, high-reliability automotive semiconductor devices to the market.

References

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