TOSHIBA

Leading Innovation

Toshiba Wireless Power Solution

Mar. 2018

Mixed Signal LSI Marketing and Engineering Group

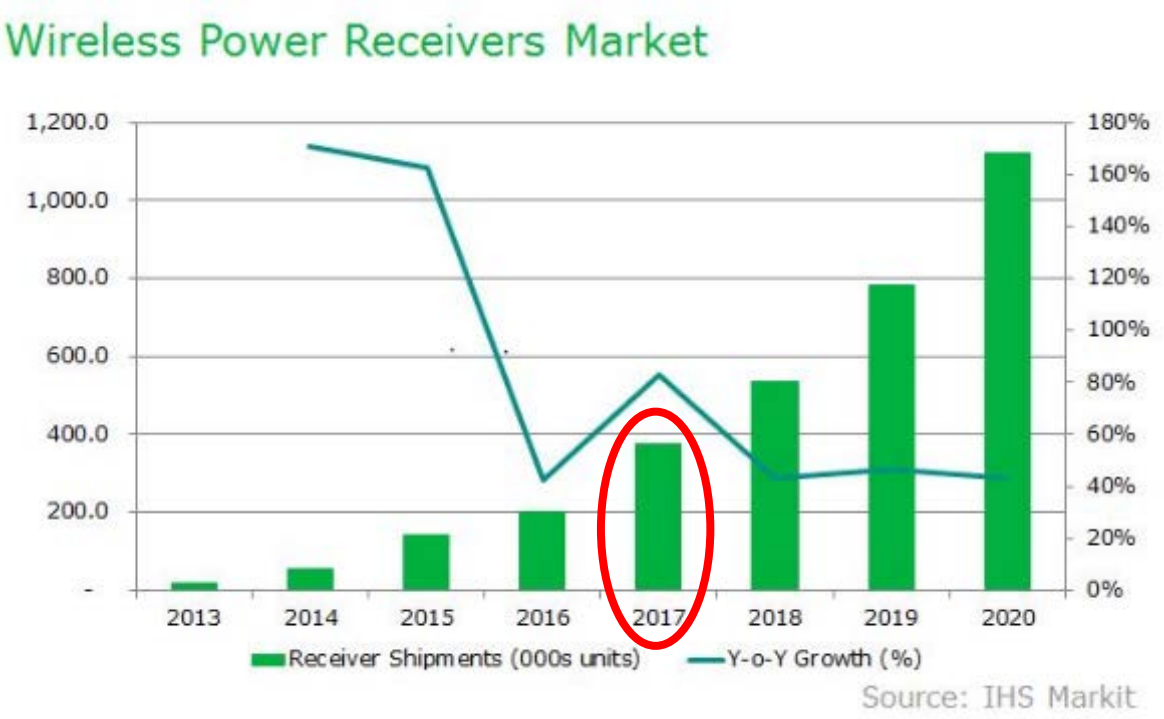
Toshiba Electronic Device & Storage Corporation

Confidential

Wireless Power Market

2017:

- **325 million wireless power products**
  - 300 million mobile phones
- **75 million wireless phone chargers**

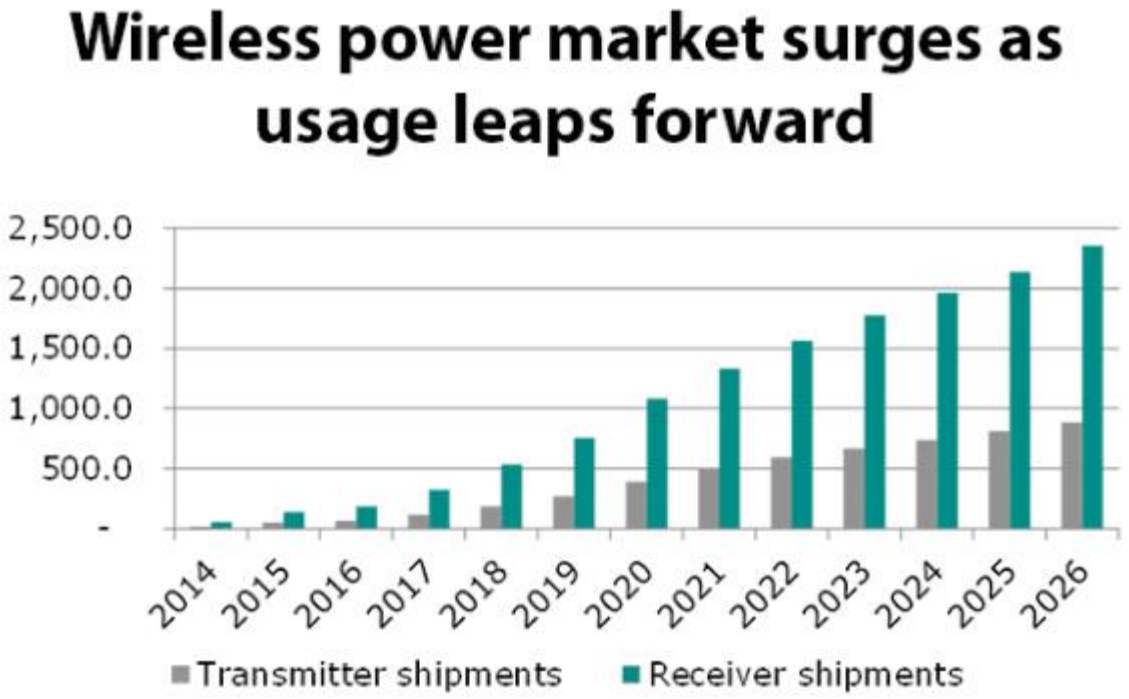


Source IHS: https://www.wirelesspowerconsortium.com/blog/273/wireless-power-market-surges-as-usage-leaps-forward

Source IHS: https://technology.ihs.com/584460/wireless-power-up-40-percent-in-2016

A growing wireless power market

- Phones:
  - 1000 million in 2020
  - 2000 million in 2025
- Chargers:
  - 500 million in 2021



Source IHS: https://www.wirelesspowerconsortium.com/blog/273/wireless-power-market-surges-as-usage-leaps-forward

Wireless power products in WW

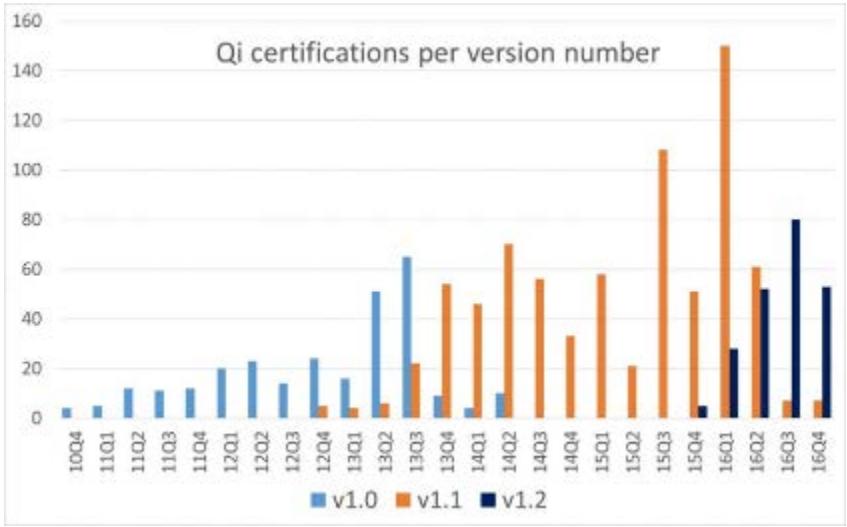
Qi is the most popular standard in WPT

- **Qi is defined by WPC(Wireless Power Consortium)**
- **Toshiba is a regular member of WPC. Apple joined in WPC in 2017Feb.**

The number of Qi registered (certified) different brands

2014 :56 brands registered
2015 :86 brands registered
2016 :156 brands registered

Toshiba products are
Compliant to Qi spec.



https://www.wirelesspowerconsortium.com/blog/268/152-brands-registered-a-qi-product-in-2016

It’s time to increase wireless technology demand

The market changes after iPhone adopts wireless power

•Picture from Apple website

- After iPhone8/X with the wireless power, the smartphone makers that was watching the markets started considering wireless power.
- The accessary makers also are accelerating to develop a charger pad that supports iPhone fast charge
- The number of smartphone makers studying wireless power are increasing

TOSHIBA Wireless Power IC Outline

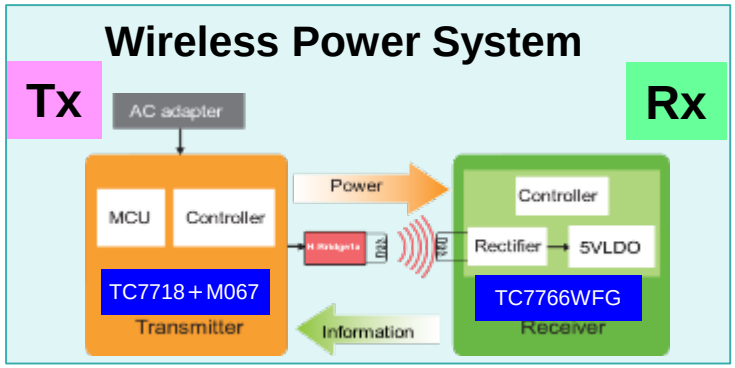
■ WPC Qi compliance (Qi Ver1.2)

WPC：Wireless Power Consortium

■ Advanced analog process 0.13um Process

TOSHIBA Own Process

Toshiba process that is Low-Ron and Low input capacitor enable to realize the high performance



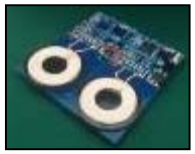
■ Transmitter ;Tx　Tx

TC7718FTG＋M067(15W)

1 coil / 2 coil

TB6865AFG series: 1W~5W

1 Device / 2 Device charge



2 Device Charging

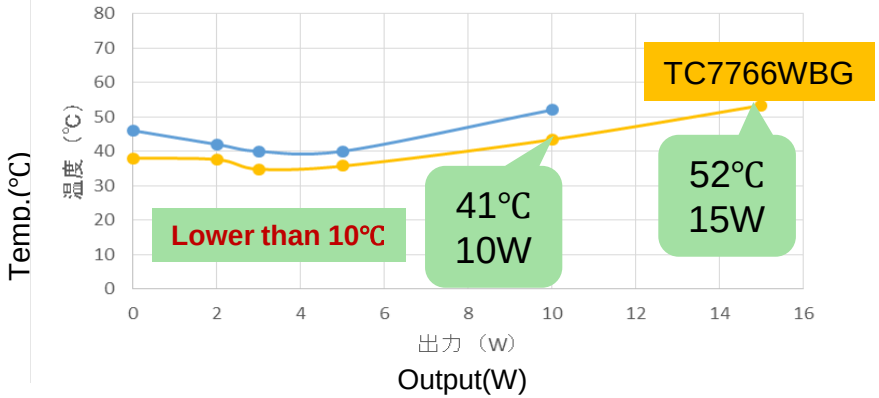
■ Receiver LSI ; Rx　Rx

TC7766WBG-M000：15W

TC7766WBG-M010： 5W

High efficiency and Low temp. concept

Mid power RX IC temp. performance



Output(W)

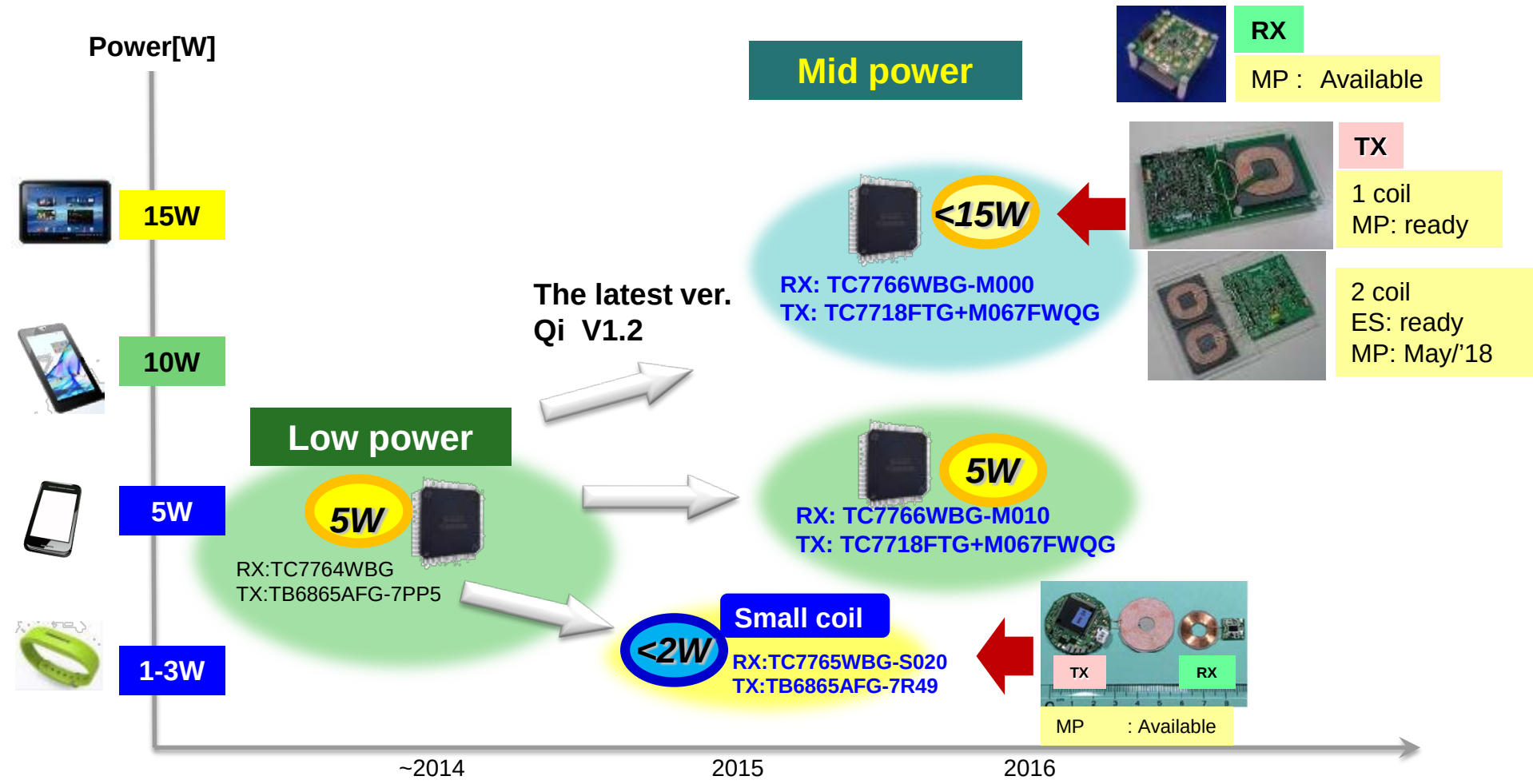
TC7764WBG-L000 :～5W

TC7765WBG-S020 :～2W

Wireless Power Road Map

Rx Tx

We would like to propose Mid-Power & Small coil solution.



Toshiba Wireless products

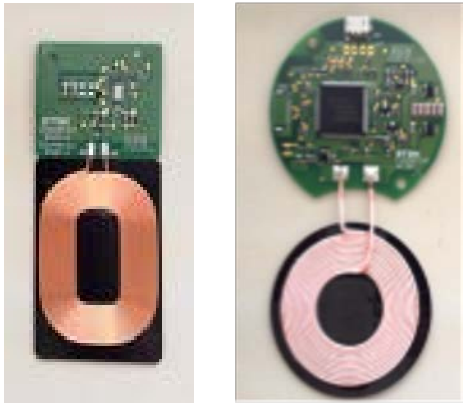
Toshiba Wireless Power 1W to 15W in the market.

Ring (<1W)

Smart watch (<1. 0 W)

Smart shoes (<2.0 W)

Module (5W)



Smartphone (5W)

Smartphone accessory (10W-15W)

Toshiba 15W solution

1st Qi certified 15W RX and TX

Toshiba 15W EVB has passed Qi V1.2 EPP

TX: TC7718FTG


WIRELESS POWER CONSORTIUM

SGS

Declaration of compliance to part 3 of Qi specification.

Hereby declares Authorized Test Lab:

SGS Korea

SGS Building 3FL, 18-34, Sanbon-dong

Gunpo, Gyeonggi-do, 435-043

Korea

That the following product with Qi-id: 1674

Product Name: TC7718FTG-EVM

Type number: TC7718FTG-EVM

ATL sample number: G-45-2016-02554A

from WPC member: Toshiba Corporation

address: 580-1, Horikawa-cho, Saiwai-Ku

City and Postal: Kawasaki 212-8520

Country: Japan

has passed all compliance requirements as described in part 3 of the Wireless Power Consortium specification.

Version: Qi v1.2.3 qi-pc0-part3-v122 Date: June 2016

Power Profile: Extended Power Profile <=15 Watt

Active Notal(s): 20160823-1

Signature Date: 25-8月-2016

Jessica Baek

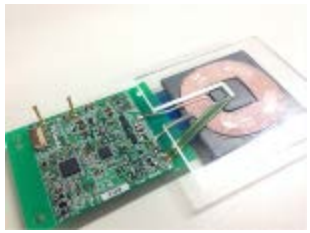
Name Test Engineer:

Signature Date: 29-8月-2016

Elvin Lee

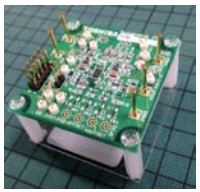
Name Reviewer:

ATL Declaration Version 20160617 Confidential Page 1 of 2

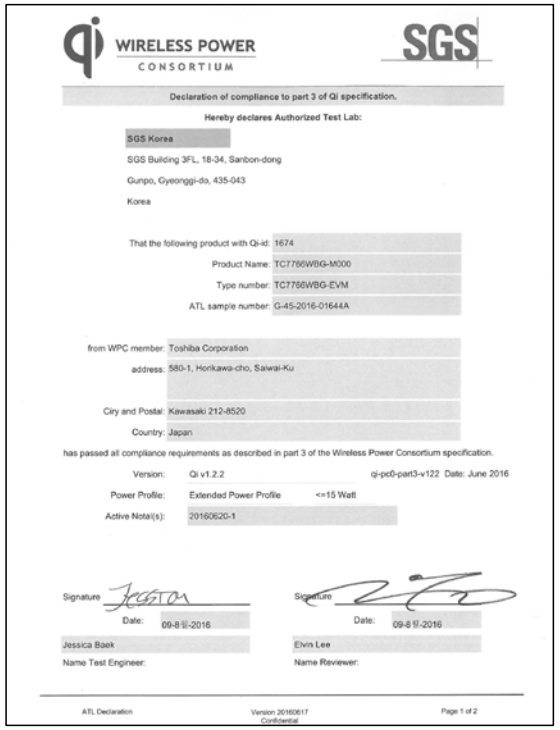


TC7718EVB is 1st registered TX as MP-A2 15W

TC7766EVB is 1st registered RX as 15W



RX: TC7766WBG-M000


WIRELESS POWER CONSORTIUM

SGS

Declaration of compliance to part 3 of Qi specification.

Hereby declares Authorized Test Lab:

SGS Korea

SGS Building 3FL, 18-34, Sanbon-dong

Gunpo, Gyeonggi-do, 435-043

Korea

That the following product with Qi-id: 1674

Product Name: TC7766WBG-M000

Type number: TC7766WBG-EVM

ATL sample number: G-45-2016-01644A

from WPC member: Toshiba Corporation

address: 580-1, Horikawa-cho, Saiwai-Ku

City and Postal: Kawasaki 212-8520

Country: Japan

has passed all compliance requirements as described in part 3 of the Wireless Power Consortium specification.

Version: Qi v1.2.2 qi-pc0-part3-v122 Date: June 2016

Power Profile: Extended Power Profile <=15 Watt

Active Notal(s): 20160620-1

Signature Date: 09-8月-2016

Jessica Baek

Name Test Engineer:

Signature Date: 09-8月-2016

Elvin Lee

Name Reviewer:

ATL Declaration Version 20160617 Confidential Page 1 of 2

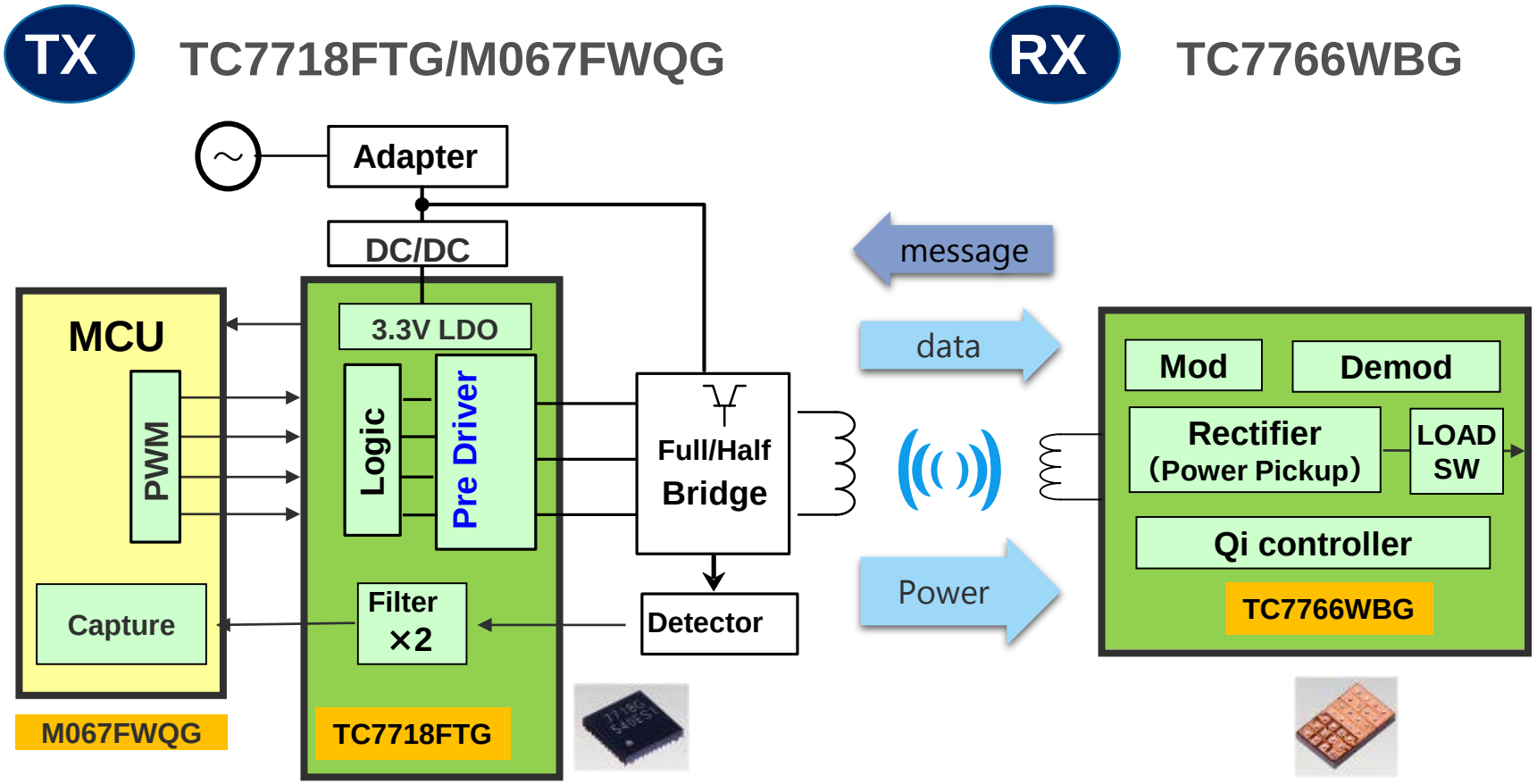
Mid Power (15W) Solution

Wireless Power Transfer IC

Solutions for 15W(Max) application

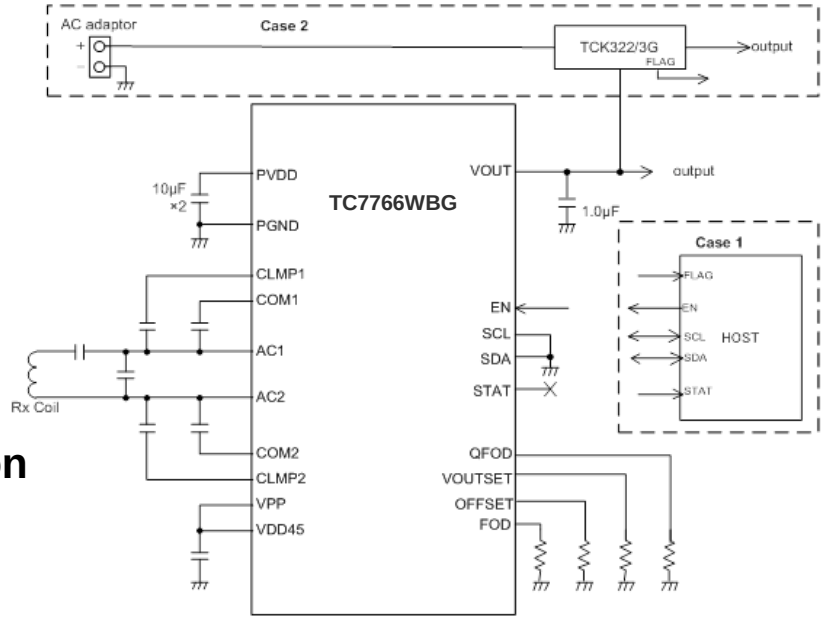
We would like to propose the Toshiba 15W wireless power solution for Smartphone and Charger PAD

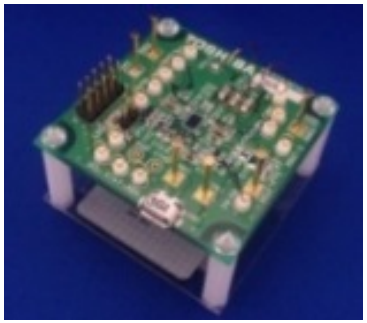
Mid power (15W) Wireless power solution based on WPC ; Qi standard



15W Receiver TC7766WBG-M000

- **Compliant to Qi v1.2 EPP/ got Qi v1.2.2 EPP certified**
- **Maximum output power : 15W**
- **Maximum OCL :2.0A**
- **Output voltage**
  - **LDO mode :5V, 5.1V. 5.2V, 7V**
  - **SW mode :5V~14.8V**
  - ***Possible to set the output power via I2C**
- **Low Rds**
  - **(High side:45mOhm/Low side 30mOhm) on synchronous rectifier**
- **I2C Interface**
  - **Possible to register access**
- **FOD adjustment with external resistors**
  - **QFOD**
  - **Power difference**
- **Protection function**
  - **Under voltage Lockout**
  - **Over voltage protection and clamper function**
  - **Over current limitation**
  - **Thermal shutdown**
- **WCSP28 2.4 x 3.67mm (0.5mm pitch)**





TC7766WBG-M000 advantages

Rx

Advantage 1
High eff.

- **High efficiency**
  - TC7766WBG temperature is around 46.5 deg.C @15W (12VSW/1.25A condition)

Advantage 2
Simple

- **The most compact, simple and flexible design**
  - ➢ The most compact
    - The smallest package and thickness in WPT; 2.4mmx3.67mm, 0.5mm
  - ➢ The most simple
    - Qi V1.2.2 protocol is implement with hard logic
      - No need any SW and FW about the Qi protocol
    - Just only connect resistors for FOD adjustment. (FOD, OFFSET and QFOD terminals)
  - ➢ The most flexible (Some examples are shown in following pages.)

Advantage 3-1
Flexible design(SW)

    - Host control (soft) point of view
      - Enable to monitor the TC7766WBG status and check the Tx information

Advantage 3-2
Flexible design(HW)

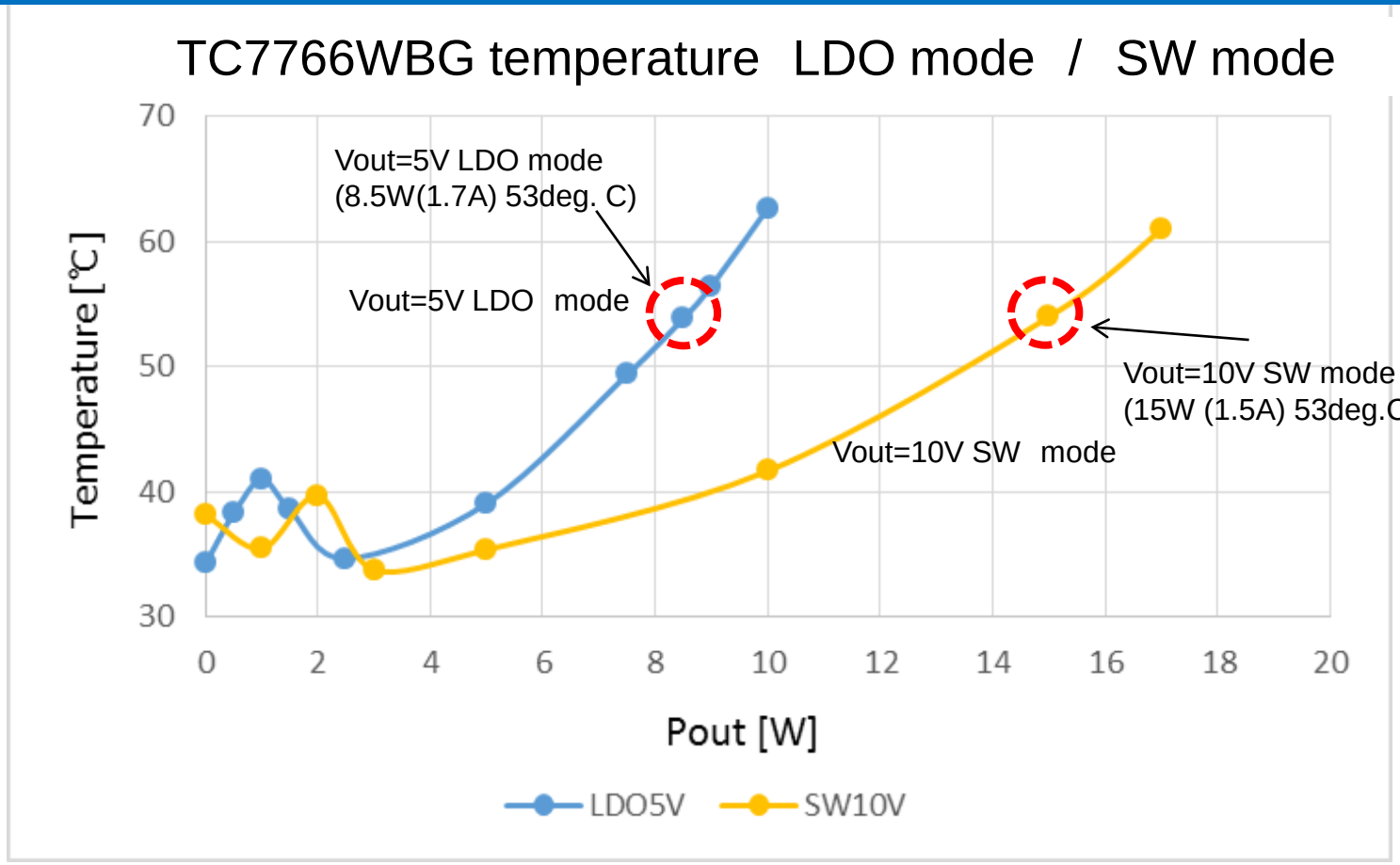
    - System (hard) point of view
      - TC7766WBG provides flexible systems.
      - LDO mode, SW mode, SW mode+ DCDC/LDO, + load switch etc..

TC7766WBG characteristic

Advantage 1
High eff.

Rx

The IC has 2 output modes；LDO mode and Switch(SW) mode.
The SW mode is effective to reduce temperature and enable to output 15W power

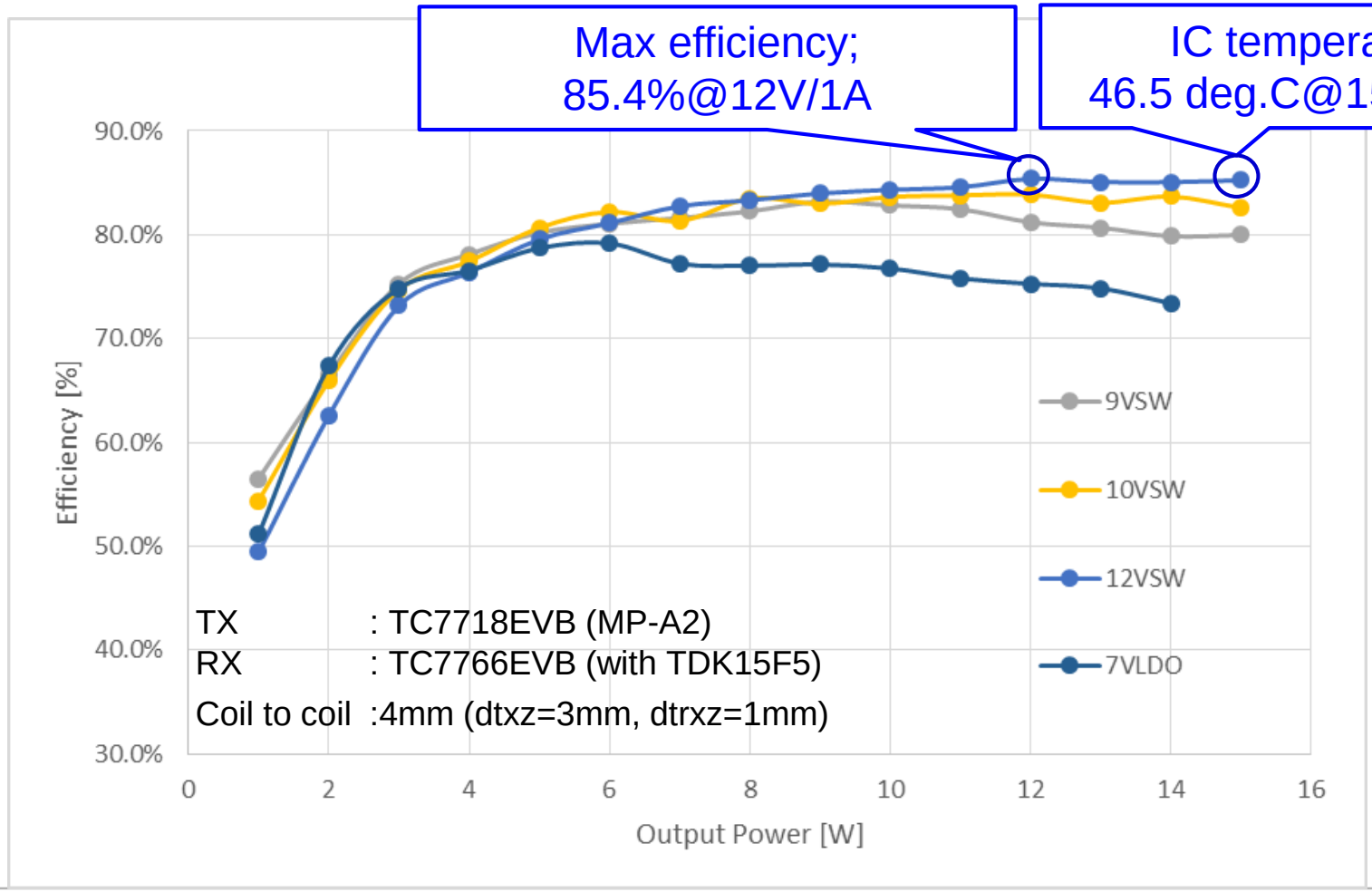


*Measured point are TC7766 surface on the EVB
*Transmitter : TC7718EVB (MP-A1) prototype
*Receiver : TC7766EVB (RX coil TDK15F5)

System efficiency (SW;9V/10V/12V, LDO7V)

Advantage 1
High eff.

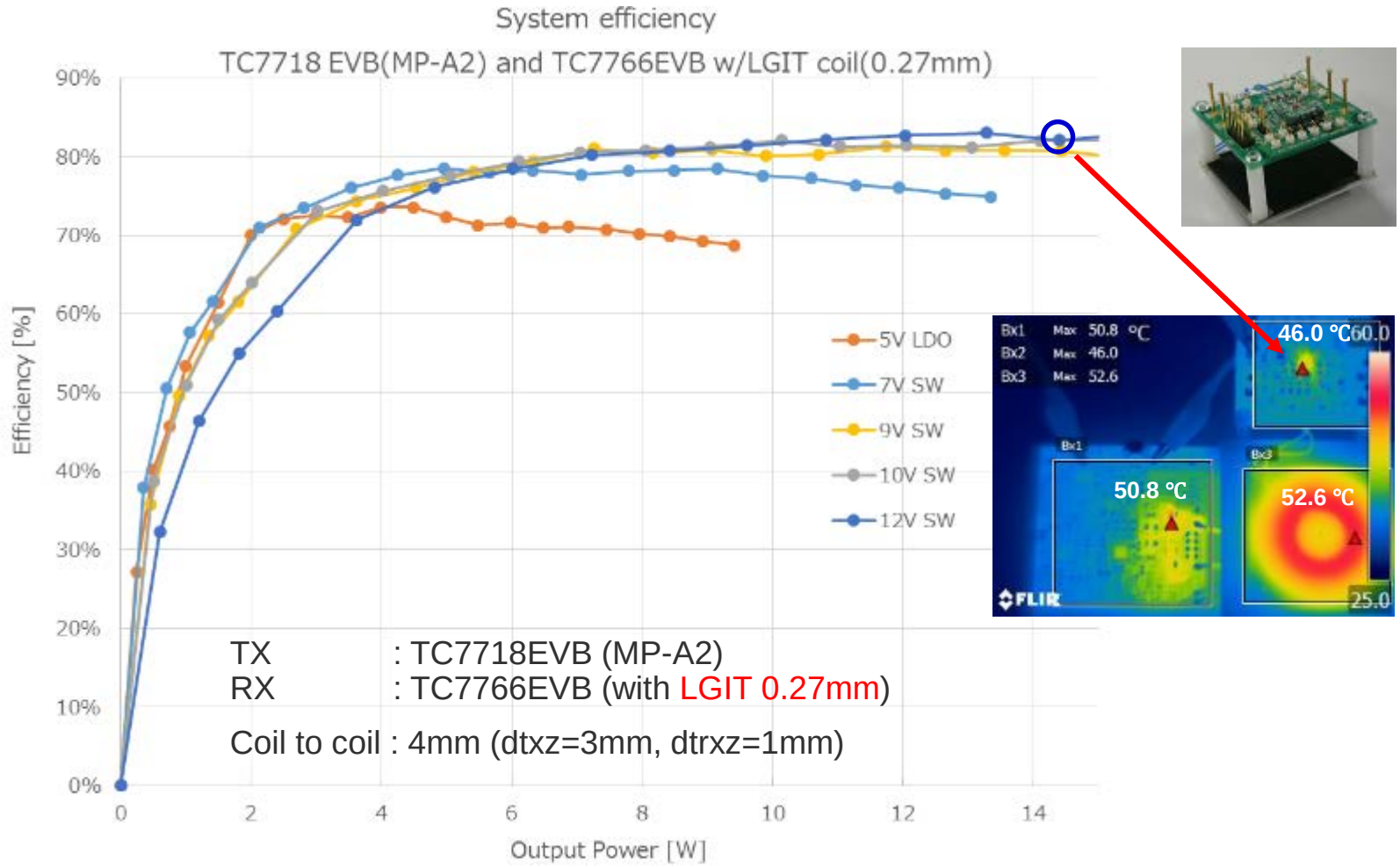
The best condition of system efficiency and RX IC temp. is RX output 12V SW mode



System efficiency with LGIT thin Rx coil

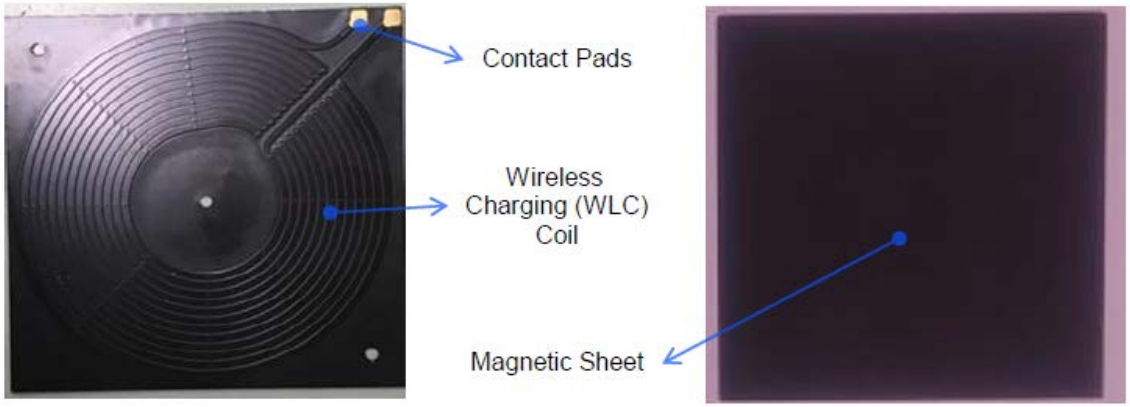
Rx

LGIT RX coil is very thin and has a high performance



New RX Coil（LG Innotek） thickness: 0.27mm

Reference data



Dimension	48.0 x 48.0 mm
Thickness	0.27 mm +/− 0.03 mm(without adhesive)
Frequency (Wireless Charging Coil)	110 ~ 205 kHz (WPC Standard)
Output (Wireless Charging Coil)	15 watt (Max.)
Weight	2.9 gram +/−10%

NO	ITEM	RATING	UNIT	Remark
1	Inductance (L)	8.5 ± 1.0 (TBD)	uH	Measurement at 100kHz @Room Temperature
2	Resistance (Rac)	0.35 ± 0.15 (TBD)	Ω	Measurement at 100kHz @Room Temperature

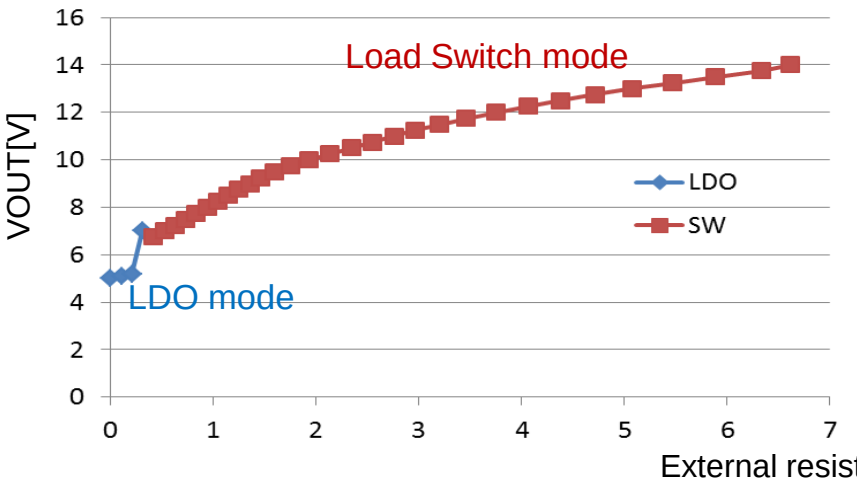
Easy setting (VOUT/FOD/Q-FOD)

Rx

Advantage 2
Simple

- **Variable setting for VOUT (1. VOUTSET)**
  - Output voltage: 5V to 14V selectable by external resistance

    (Note)possible to set it by accessing internal registers via I2C.



VOUTSET Resistance[Ω]	Operation Mode	VOUT Voltage[V]
0	LDO Mode	5.0
100		5.1
200		5.2
300		7.0
510	SW Mode	7.0
430+510		8.0
1.2k+150		9.0
1.8k+120		10.0
2.4k+360		11.0
3.6k+150		12.0

- **Easily adjustment for FOD (2. FOD, 3. OFFSET, 4. QFOD)**
  - FOD/ OFFSET : Received Power adjustment
  - QFOD : Q value adjustment

TC7766WBG register

Rx

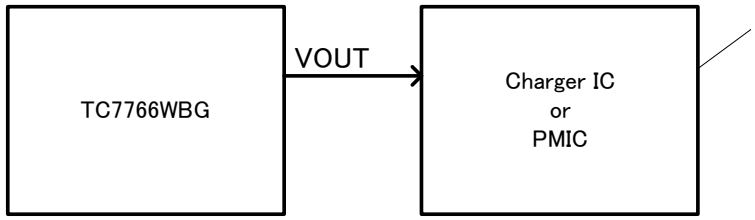
Advantage 3-1
Flexible design(SW)

- **Monitor TC7766WBG register via I2C**
  - ➢ Enable to monitor following values;
    - VRECT, frequency, phase, error , Tx capability, Tx manufacture code, negotiated power etc.
  - ➢ Enable to send following packet with designated value.
    - Renegotiation packet (~0x1E)
    - End power transfer packet (0x00～0x0F) (Note)Please follow Qi spec.
    - Charge status packet (0～100)
  - ➢ Enable to set output mode and voltage
    - LDO :5V, 5.1V, 5.2V, 7V
    - SW :5V~14.8V

RX Flexible design

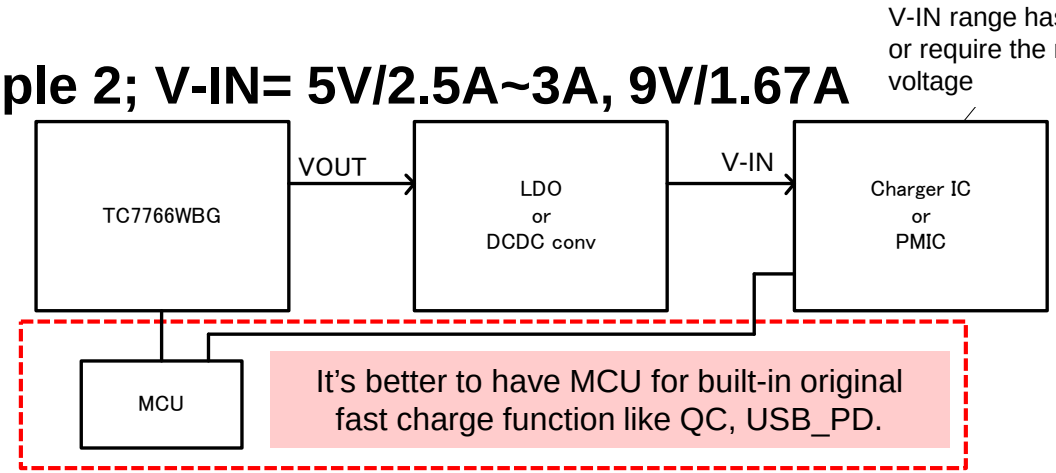
Advantage 3-2
Flexible design(HW)

- **Example 1; Simple** **(This system can reduce the power loss up to maximum)**



EVB Ver 1.1
50mmx50mm

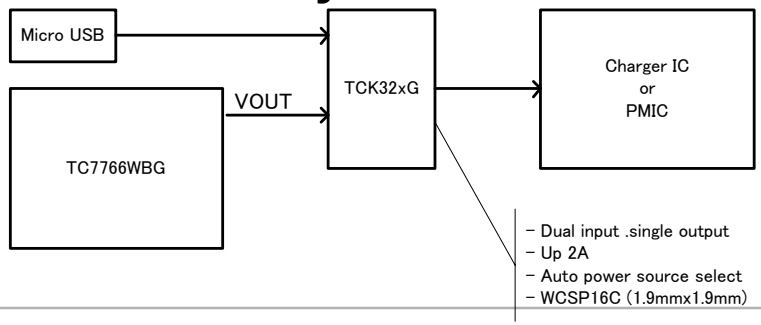
- **Example 2; V-IN= 5V/2.5A~3A, 9V/1.67A**



EVB Ver 2.0

30mmx40mm

- **Example 3; with wired system**

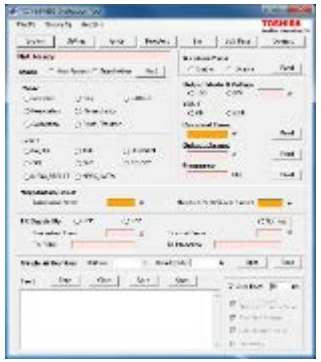


TC7766WBG development support tools

Rx

- **Documents**
  - Datasheet
- Evaluation board
  - TC7766EVB V1.1

  - TC7766EVB V2.0 (+ DCDC) + load switch system
  - Application note
- **GUI**
  - GUI tool kit
  - GUI user manual
- **System Design support**
  - How to control TC7766WBG with 5W Tx and 15W Tx
  - How to pass Qi v1.2.2 certification
  - How to design the receiver system



15W Transmitter TC7718FTG・M067

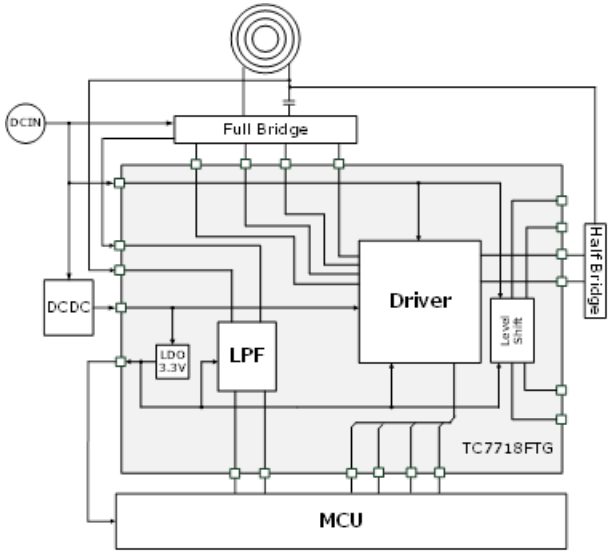
Tx

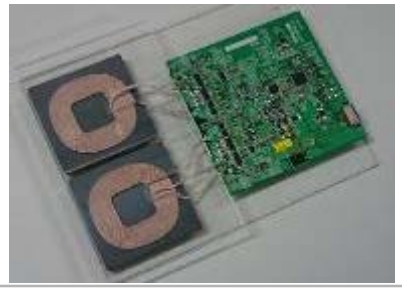
TC7718FTG / M067-xxxx

◆ Specification

- Compliant to Qi V1.2 EPP
- Support MP-A2 (15W EPP) / A11 (5W BPP)
- Sequential 2 device charging function
- Input voltage range : 4.5V to 25V
- Built-in full and half bridge gate driver : each 1ch
- Built-in LPF for demodulation of ASK signal : 2ch
- Built-in 3.3VLDO
- Built-in level shifter : 2ch
- Some I/O for LED and parameter settings

- TMPM067 outline is following;
  - ARM Cortex-M0
  - I2C interface
  - ROM128kB, RAM 16kB
  - 10 bit AD conv.
- PKG
  - TC7718FTG :P-VQFN36 (5mmx5mm, 0.4mm pitch)
  - TMPM067 :QFN48(7mmx7mm,)





< Firmware version>

◆ Ver : M067-7RF4

1. MP-A2 (15W)/ A11 (5W) selectable
2. Support the internal register access via I2C

➢ Status : MP

◆ Ver :M067-xxxx

1. Based on M067-7RF4
2. Fast charge function
3. QC2.0 AC adaptor control for 12V input.
4. Support 2 coil operation (select either one of 2 coil)

➢ Status : ES: ready, MP: 1Q / '18

TC7718FTG+M067 advantages

Tx

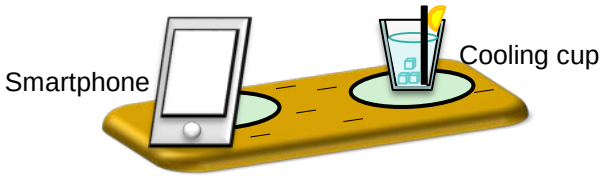
- **1st Qi v1.2.2 EPP certified MP-A2 Tx**
  - No need to development software. (Toshiba provides the MCU built in the software.)
  - The control method won't conflict with EU and China regulatory.
  - The lower BOM system than the certified TX MP-A5.

Advantage 1
Regulation

Advantage 2
Low cost system

- **Multi charging (& sequential charging)**
  - TC7718FTG is able to drive 2 coil.
  - The number of component of 2 coil system is around 1.5 times from 1 coil

Advantage 3
Multi charging



Sequential charging


Vertical Horizontal

- **QC2.0 (12V) input**
  - Do not need bundling the adaptor in your products.
    - Recommendation of adaptor input current is over 1.5A for 10W, and 2.3A for 15W.

Advantage 4
QC2.0 input

- **Flexible settings for some parameters with external resistors.**
  - LED lighting methods
  - FOD parameters (power difference adjustment)
- **Allow more flexible design using I^2C communication**
  - Status, errors and some settings

15W (EPP) TX types defined by WPC

- **Control methods of EPP Tx types**

Advantage 1
Regulatory

	EPP TX	MP-A1	MP-A2	MP-A3	MP-A4	MP-A5	MP-A6	MP-A7	MP-A8	MP-B1
Control	Bridge	Full ⇔ Half	Full ⇔ Half	Full	Full ⇔ Half	Full	Full	Full ⇔ Half	Full	Full
	Frequency (kHz)	110-205	110-145	110-205	110-205	130	140-150	110-205	110-205	115
	Duty (%)	10 to 50	5 to 50	0 to 50	10 to 50	50	50	10 to 50	10 to 50	-
	Phase shift (°)	0 to 135	-	-	0 to 133	-	-	0 to 90	0 to 133	0 to 180
	Voltage (V)	19	12	2.5 to 11.5	12	1 to 12	1 to 18	19	12	15
	Certified Tx	Rohm (V1.2.0)	Toshiba (V1.2.2)	-	NXP (V1.2.2)	TI (V1.2.2)	-	Rohm (V1.2.2)	-	-

As of Jan 1, 2017

- **Regulation trend in WW**
  - EU : need to operate below 148.5kHz
  - China : need to operate below 190kHz
  - Japan : it's not necessary to care about the regulatory until 50W.

Advantage 2
Low cost system

- **Toshiba solution**
  - TC7718+M067 is 1st MP-A2 Tx certified by WPC.
    - Regulation and cost points of views, Toshiba adopted MP-A2 System

TX FW release（iPhone fast charge）update

■ Phase 1

- ☐ Product number: M067FWQG-7RF4(EL,Z
- ◆ Specification
  1. MP-A2 (15W) : EPP
  2. Selectable A11 (5W) : BPP
  3. Support the internal register access via I2C
- ➢ Status : MP

New TX firmware

■ Phase 1.1

- ☐ Product number: M067FWQG-7RH6
- ◆ Specification
  1. Based on Phase 1（MPA2 EPP）
  2. Apple and Samsung Fast charge
  3. QC2.0 AC adaptor detection for 12V input.
  4. Support 2 coil operation (select either one of 2 coil)
  5. 5V / 9V input operation
  6. Support the internal register access via I2C (high speed)
- ➢ Schedule :

  Apple Fast charge demo :E/ Jan, ES FW release :M/Feb,
  Final FW release : E/Mar, Target MP: M/May/2018

RX line-up

Rx

Power	~2W		5W New	5W~15W New
Product number	TC7765WBG-S020	TC7764WBG-L011	TC7764WBG-L000/L010/L013	**TC7766WBG-M010**	**TC766WBG-M000**
Standard	-	-	Qi V1.1.2	**Qi V1.2.2 BPP**	**Qi V1.2.2 EPP**
PKG	WCSP28	WCSP28	WCSP28	**WCSP28**	**WCSP28**
Size. Pitch	2.4x3.67, 0.5	2.4x3.67, 0.5	2.4x3.67x0.5	**2.4x3.67, 0.5**	**2.4x3.67, 0.5**
Thickness	0.5	0.5	0.5	**0.5**	**0.5**
Output circuit	SW	LDO	LDO	**LDO/SW**	**LDO/SW**
Output voltage	5V	5V	5, 5.1, 5.2V	**5, 5.1, 5.2, 7V/ 5V~14.84V**	**5, 5.1, 5.2, 7V/ 5V~14.84V**
Max current (A)	0.3	0.3	1.0	**1.0**	**1.7**
OCL (A)	0.5	0.5	1.3	**1.3**	**2.0**
Software	No needed.	No needed.	No needed.	**No needed.**	**No needed.**
Status	MP	MP	MP	**MP**	**MP**
Adoption example	Ring, smart shoes and other wearable products etc.		Smartphone, accessary, industry and medical		**Some projects are on going.**

(Note)The pictures are image




TX line-up

Power	~2W		5W	15W New
Product number	TB6865AFG-7R49	TB6865AFG-xxx(2 device)	**TB6865AFG-7PP5**	**TC7718FTG +TMPM067**
Standard	-	-	**Qi V1.1.2/Qi V1.2.2BPP**	**Qi V1.2.2 EPP**
Tx system	-	-	**A11**	**MP-A2**
PKG	LQFP100	LQFP100	**LQFP100**	**QFN36**
Size, pitch	14x14, 0.5	14x14, 0.5	**14x14, 0.5**	**5.0x5.0, 0.4**
Thickness	1.7	1.7	**1.7**	**1.0 / 0.9**
Charge number	1	2 (Simultaneously)	**1 (possibility 2 coils simultaneously)**	**1 (possibility 2 coil sequentially)**
Input voltage			**5V**	**12V**
Software	Implemented	Implemented	Implemented	Implemented
Sys. Efficiency			**75%**	
Status	**MP**	**CS**	**MP**	**MP**
Adoption example	Ring, wearable products etc. 	Smart shoes 	**Smartphone, accessary, industry and medical**    	**Some projects are on going.**

Wearable (<2W) Solution

TOSHBA WPT IC Application

TOSHIBA is adopted as various application.

Mass production

Smart Ring
Design: Japan Maker
Market: USA
MP: 4Q/2015

Position detection
Design: Chaina Maker
Market: USA
MP: 3Q/2016

Design Won and new Application

Smart Shoes
Design: Taiwan Maker
Market: World Wide
MP: 1Q/2017

Position detection
Design: Russia Maker
Market: Europe
MP: 1Q/2016

Watch
Design: Japan Maker
Market: World Wide
MP: 3Q/2017

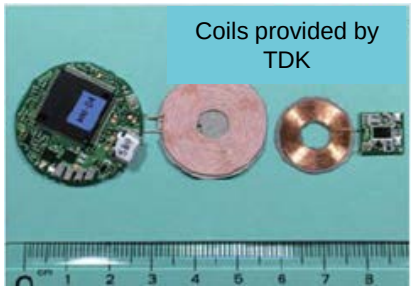
Small Coil Application reference Model

Reference

Toshiba prepare 2 type solution for wearable products

1. 2W Solution
   Application: Smart Watch, etc

2. 1W Solution
   Application: Active Tracker, etc

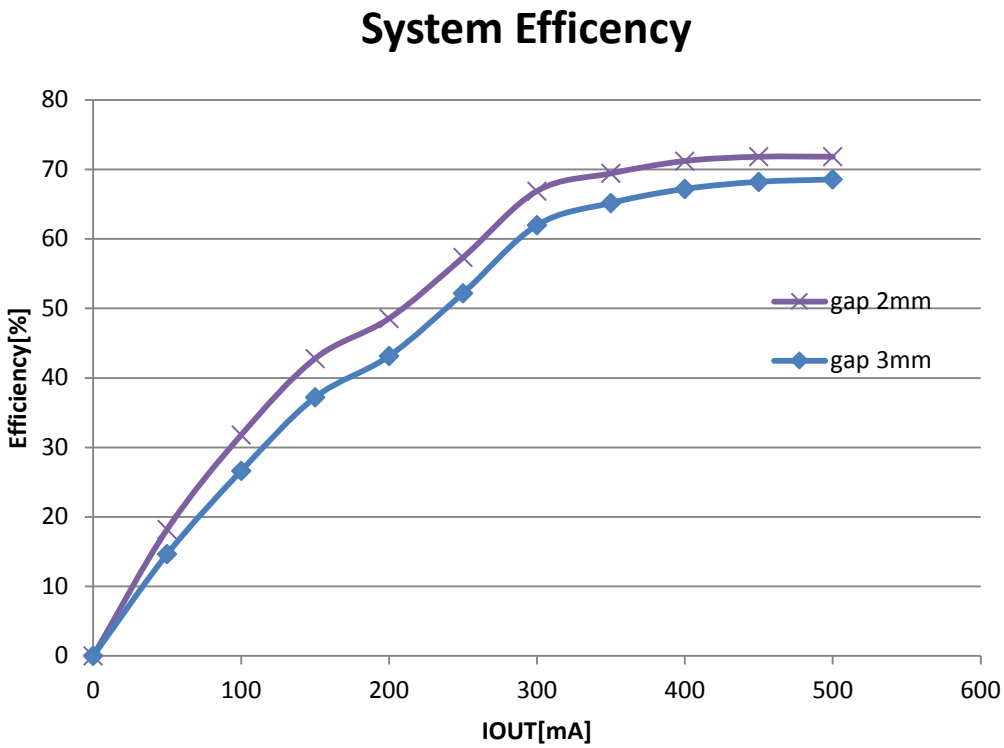


Small Coil
Turn Key Solution

<Difference Point>

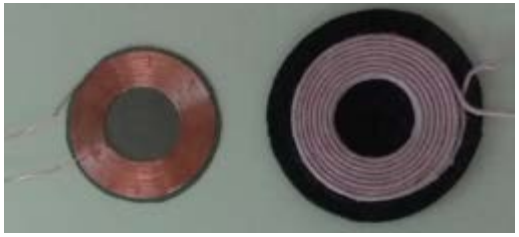
Solution	Max Load	RX Coil Size	TX Coil Size
2.0W	~400mA	20mmΦ Thick: 0.6mm	28mmΦ Thick: 2.6mm
1.0W	~200mA	11mmΦ Thick: 1.6mm	24mmΦ Thick: 2.5mm

2W Solution System Efficiency

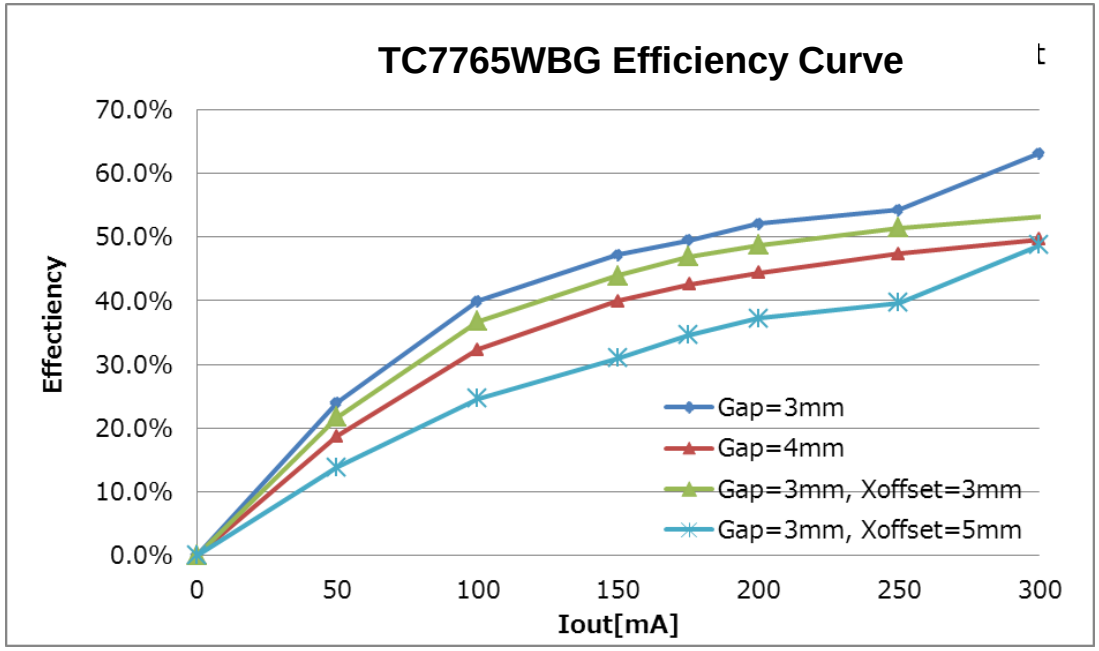


<Condition>

- RX Coil : TDK New Coil Size :20mm Φ
- TX Coil : TDK New Coil Size :28mm Φ
- Coil Gap : 2, 3 mm



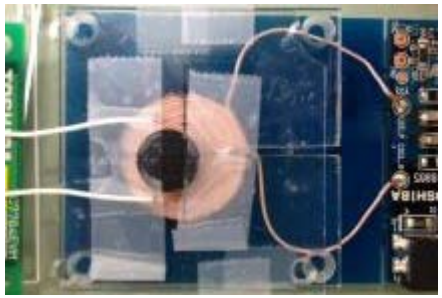
1W Solution System Efficiency



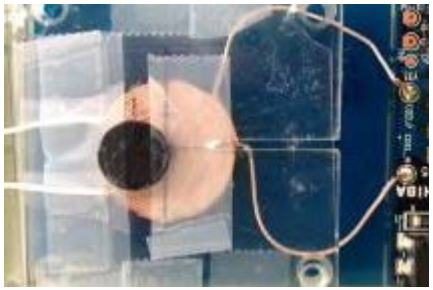
■ Condition
- Tx: Sanji /TB6865A EVB(Cs=122nF)
  TDK WT232390-30F2 coil
- RX:TC7765WBG-S020 EVB （Cd Open)
  TDK WR111180-49F5-B1
  Cs=47nF, Gap: 3.0mm
- Electronic Load Model PLZ 152WA KIKUSUI

	Rx TDK WR111180-49F5-B1	Tx WT232390-30F2
WLC Outer size(mm)	Φ11mm	Φ24mm
L(uH) @100 kHz	28.5	14.9
Rs(ohm) @100 kHz	1.34	0.19
		

X-offset 3mm



X-offset 5mm



Good efficiency !!
→ possible to use USB power
Flexible Coil position !!
→ easy to make mechanical Design

Receiver IC line Up

Toshiba offers Receiver IC of the biggest efficiency according to the power and the coil necessary to Set.

Active Tracker

Smart Watch

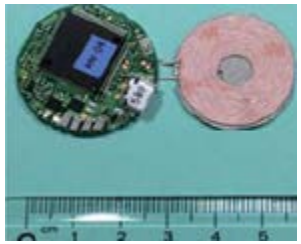
■Receiver IC For Small Size application

Recever Series	Usage IOUT[mA] @5V						Note
	50	100	200	300	400	500	
TC7765WBG-S020	■	■	■				5V SW mode OCL:500mA
TC7764WBG-L011	■	■	■	■	■	■	5V LDO mode OCL:500mA

Receiver IC is chosen by a load current.

Transmitter System Lineup

Transmitter system lineup (TB6865AFG series)

Item	Wearable		
ROM Code	7R49	7R49	NICO10mm
EVB image Application Image	 Coil Size 11mmΦ		 Coil Size 30mmΦ
Application	small output current wearable RING	Smart Watch wearable	Coil Gap 10mm Wearable application
Method	TOSHIBA Original based on WPC		
Input Voltage	5V	5V	5V
Power	Under 1W	Under 2W	Under 1.5W x 2devices

Transmitter System is chosen by Coil size and distance.

Small Coil Solution for Wearable

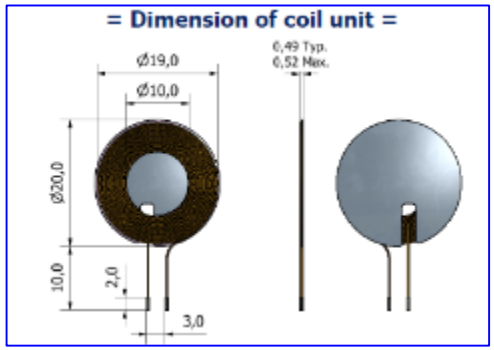
Reference Coil idea

Toshiba prepare 2 type coil for wearable products

- 2W Solution

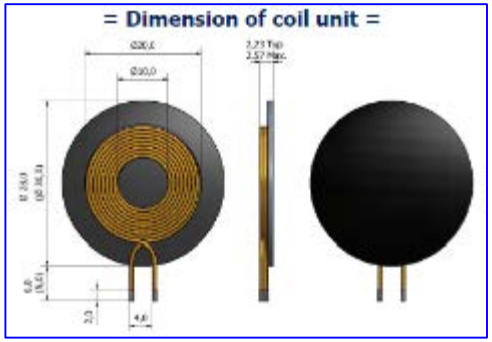
TDK Stacking Proposal (Rx) :

WR202020-19M8-G



TDK Stacking Proposal(Tx)

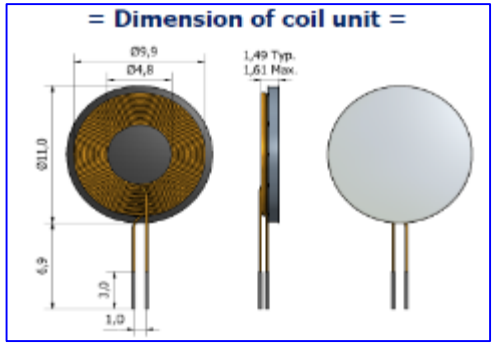
WT282890-16F2-G



- 1W Solution Coil

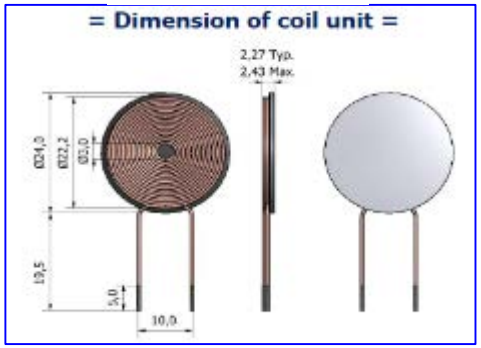
TDK Stacking Proposal (Rx) :

WR111180-49F5-G



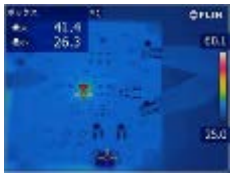
TDK Stacking Proposal (Tx) :

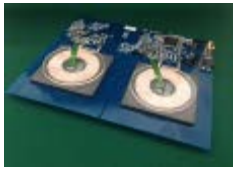
T242490-30F2-G



Summary Toshiba Wireless solution

Rx Tx





• Advantages

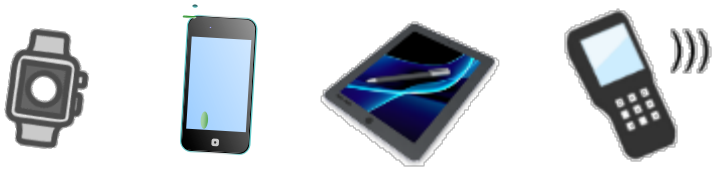
- RX :"Simple" High efficiency, the most simple and allows flexible design
- TX :"Multi" Dual charging (5W x2) or sequential charging (15W one by one)

• Solution line-up

Toshiba covers up to 15W.

Our existing solution is adopted in some applications.

- 15W : smartphone accessory
- 5W : smartphone, medical and industry applications
- <2.0W(Wearable/IoT) : ring, smart shoes etc.



• Support

- Support total system
- Almost 6 years experience and got qi certification for both of 5W and 15W.
- Have great tool to reduce the development term
  - TC7766 GUI tool according to development status.
  - TAcS tool for wearable solution.

TOSHIBA

Leading Innovation