TOSHIBA CDMOS Integrated Silicon Monolithic Circuit

TC7765WBG

Wireless Power Receiver Controller IC

1. Outline

The TC7765WBG is wireless power receiver (RX) IC using communication protocol of wireless power consortium (WPC). The TC7765WBG has a rectifier circuit, a digital control circuit, a modulation circuit for communication which controls the supply voltage to the load. The IC includes all RX functions needed to construct a standalone wireless power system. The TC7765WBG can build a wireless power system by combining it with Exclusive version of TB6865AFG.
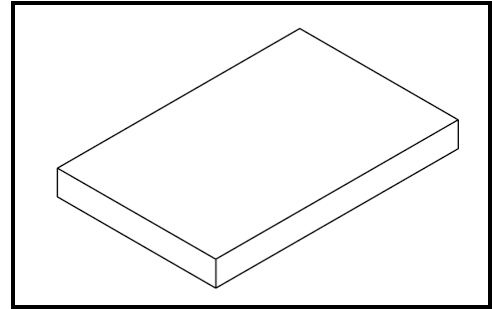
S-XFLGA28-0304-0.50-001

2. Applications

Mobile communication devices (Smartphone, Tablet, Wearable), battery pack, mobile accessory   etc.

3. Features

- Full bridge rectifier circuit
  Auto switch for 3 modes   : Synchronous rectification / Diode rectification / Diode bridge
  Low ON resistance   : High Side 45 mΩ (Typ.) / Low side 30 mΩ (Typ.)
  Under Voltage Lockout (UVLO) / Over Voltage Detection (OVP) function
- Output voltage   : 10 V (Max)
  Maximum output current   : 1.0 A
  Over Current Protector (OCP)   : 1.3 A
- Foreign Object Detection (FOD) function
- Under voltage lockout (UVLO) / Over voltage detection (OVLO) function
  Thermal shutdown function (TSD)
- Package   : S-XFLGA28-0304-0.50-001 (2.40 mm*3.67 mm*0.5 mm, 0.5 mm pitch)

> Please use this product in combination with exclusive version of TB6865AFG.
> This wireless power system incorporates a foreign object (exp. metal pieces) detection function, but a foreign object may generate heat in time before detecting it. About the foreign object, please be careful enough.

> This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge by using an earth strap, a conductive mat and an ionizer. Ensure also that the ambient temperature and relative humidity are maintained at reasonable levels.
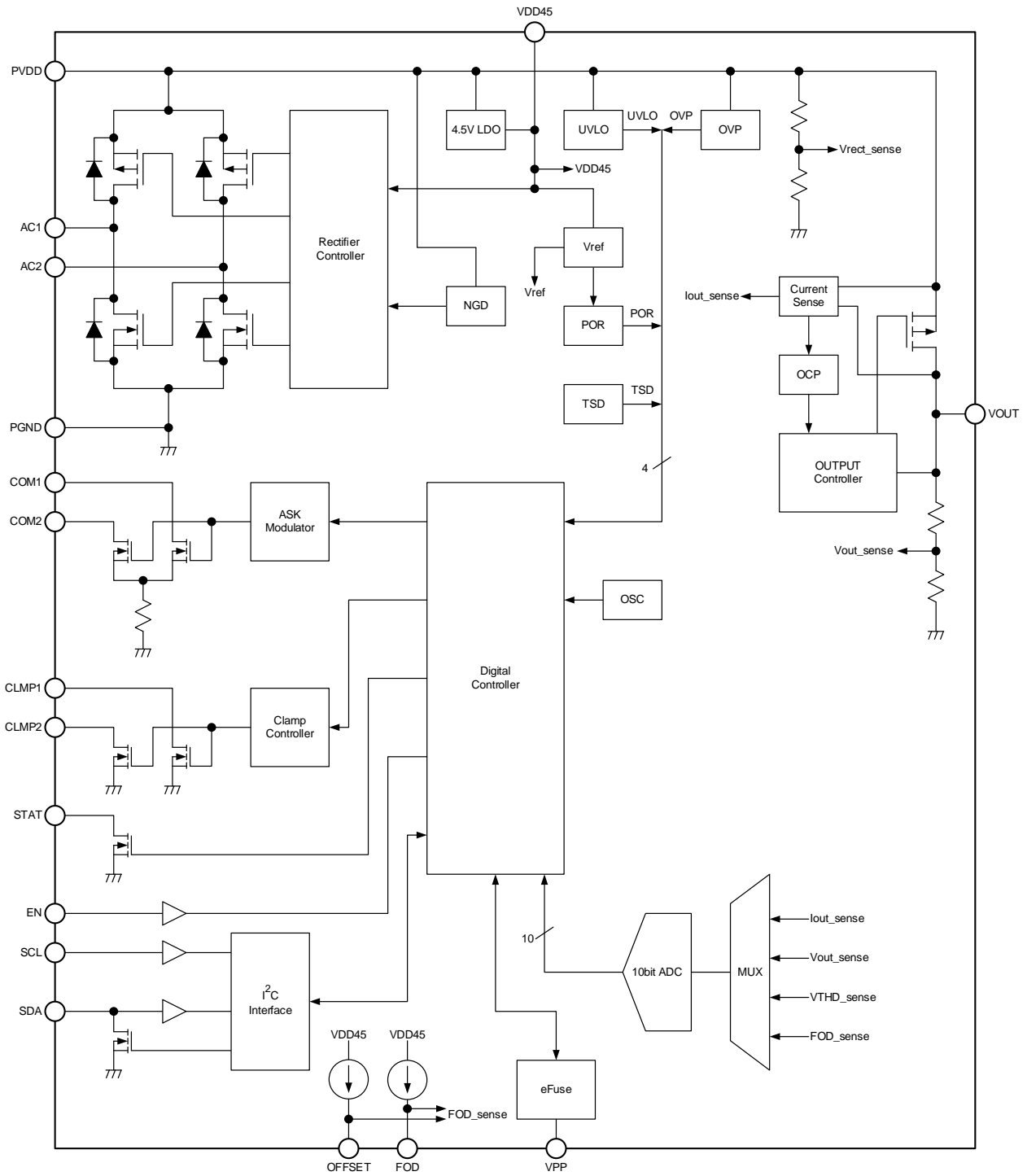
4. Block diagram

Figure 4.1 Block diagram

5. Pin assignment

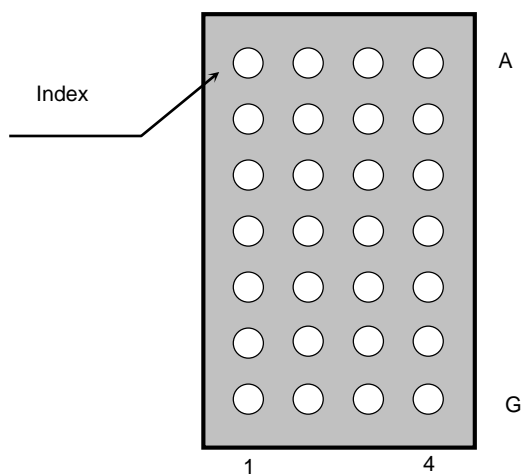|	1	2	3	4
A	PGND	PGND	PGND	PGND
B	AC2	AC2	AC1	AC1
C	CLMP2	PVDD	PVDD	CLMP1
D	VOUT	VOUT	VOUT	VOUT
E	COM2	SDA	SCL	COM1
F	VDD45	VPP	TEST1	TEST2
G	FOD	EN	STAT	OFFSET

(Top View)

Figure 5.1 Ball assignment (Top View)
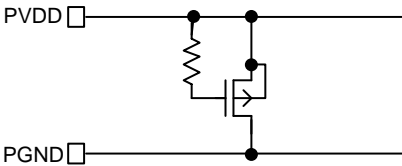
6. Pin function

Table 6.1 Pin function

Pin Number	Pin symbol	I/O	Description
A1, A2 A3, A4	PGND	-	Power ground Connect to common ground (GND).
B1, B2	AC2	I	Antenna terminals for receiver 2
B3, B4	AC1	I	Antenna terminals for receiver 1
C1	CLMP2	O	Clamp terminal for over voltage protection 2 Open drain terminal. Please connect a condenser of 0.47 µF to AC2 when use an internal clamping circuit.
C2, C3	PVDD	-	Rectifier output and power supply terminal Output of bridge rectifier circuit and IC power supply terminal. Connect smoothing capacitor. And connect zener diodes between PVDD and PGND when use an internal clamping circuit.
C4	CLMP1	O	Clamp terminal for over voltage protection 1 Open drain terminal. Please connect a condenser of 0.47 µF to AC1 when use an internal clamping circuit.
D1, D2 D3, D4	VOUT	O	Output terminals Connect capacitor of more than 1.0 µF to GND.
E1	COM2	O	Capacitor connect for ASK modulation 2 Open drain terminal. Connect capacitor to AC2.
E2	SDA	I/O	I^2C data I/O terminal for Toshiba tests Connect to GND.
E3	SCL	I	I^2C clock input terminal for Toshiba tests Connect to GND.
E4	COM1	O	Capacitor connect for ASK modulation 3 Open drain terminal. Connect capacitor to AC2.
F1	VDD45	O	4.5 V- LDO output terminal 4.5 V- LDO output terminal for internal circuit. Connect capacitor of more than 0.1 µF to GND.
F2	VPP	I	eFuse writing terminal Short to VDD45 in normal use.
F3	TEST1	O	Make this terminal open.
F4	TEST2	I	Connect to GND
G1	FOD	I	Offset terminal for RX loss adjustments. Loss offset terminal for FOD Connect appropriate resistor to GND.
G2	EN	I	Wireless charging enable input terminal with internal pull-up resistor. When the terminal is "H" or "Open", TC7765WBG is ready for wireless charging. When the terminal is "L". TC7765WBG wireless power receiver is disabled.
G3	STAT	O	Status output terminal Open drain terminal. Connect pull-up resistor.
G4	OFFSET	I	Offset terminal for RX loss adjustments Loss offset terminal for FOD. Connect appropriate resistor to GND.

7. Equivalent circuits for input/output/power supply terminals

7.1 Power supply terminal

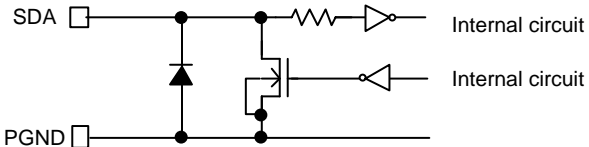**Table 7.1 Equivalent circuits for power supply terminals**

Note：Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
PVDD	

7.2 Input/output terminal
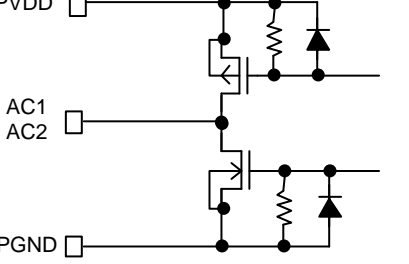
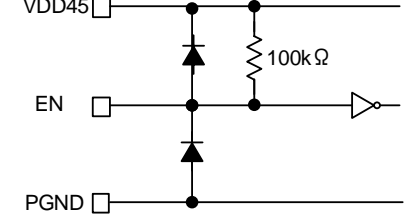**Table 7.2 Equivalent circuits for Input/output terminals**
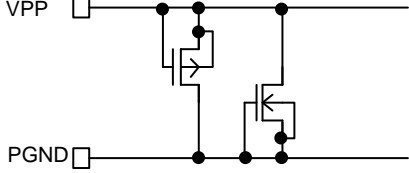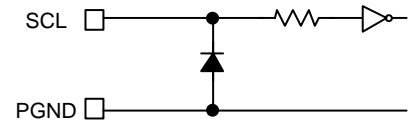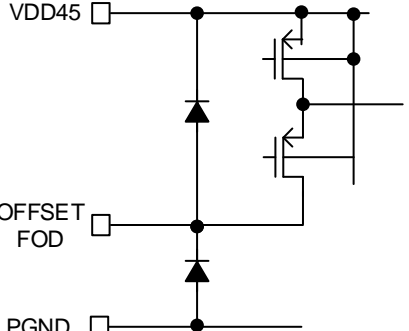
Note：Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
SDA	

7.3 Input terminal

Table 7.3 Equivalent circuits for input terminals

Note：Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
VPP	
AC1 AC2	
SCL	
EN	
OFFSET FOD	

7.4 Output terminal

Table 7.4 Equivalent circuits for output terminals

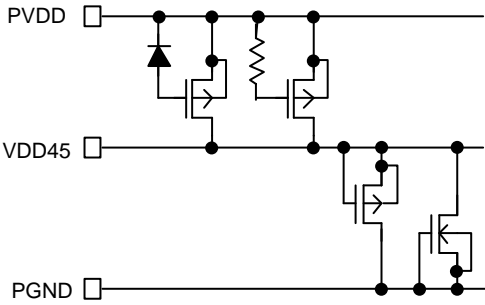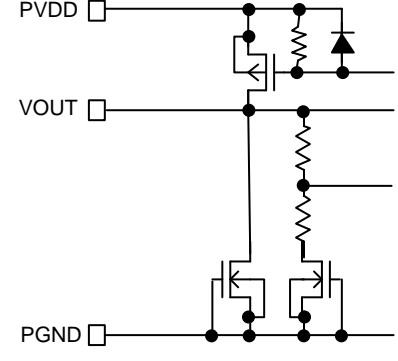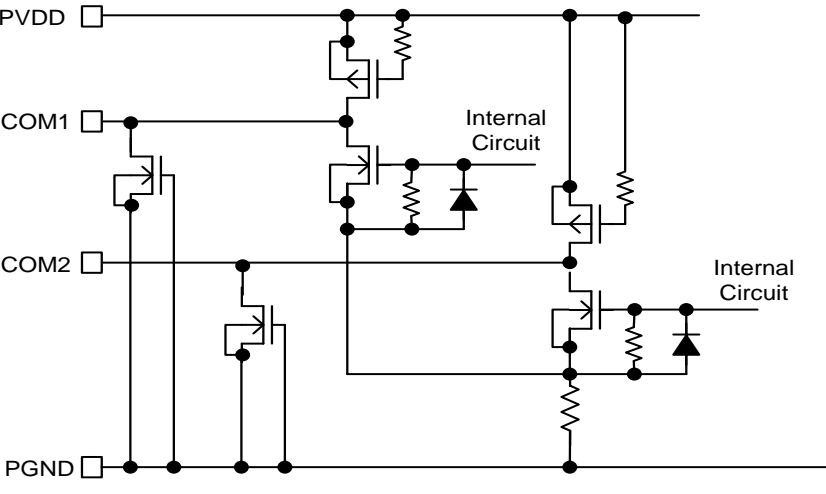Note: Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
VDD45	
VOUT	
COM1 COM2	

Table 7.5 Equivalent circuits for output terminals

Note: Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
CLMP1 CLMP2	
STAT	

8. Functions / Operation description

8.1 General outline of wireless power system

Wireless power system consists of the first side (TX) which transmits power and the second side (RX) which receives power. Power is transmitted by adjoining coils included in the TX and RX and by sharing and combining their electromagnetic flux. The RX controls the transferred power by monitoring the received power and sending feedback signals to the TX. The TX controls the power by controlling its transmitted power according to the feedback signal which is received from the RX. A configuration example of a wireless power system is shown in Figure 8.1.

Communication signals from RX to TX are transmitted (modulated) by ASK modulation. The communication rate and its packets are defined by the Qi standard. Communication rate is 2 kbps. Packets are ID, identification signal, error information, receive power, and stop signal. The TX is powered on intermittently and confirms the existence of a RX on the TX pad. When the TX recognizes a RX it succeeds to the identification phase; transmit operation starts after a compliant RX has been identified. The TX continues the transmit operation until it cannot recognize the existence of a RX or receives a transmit stop signal from the RX.
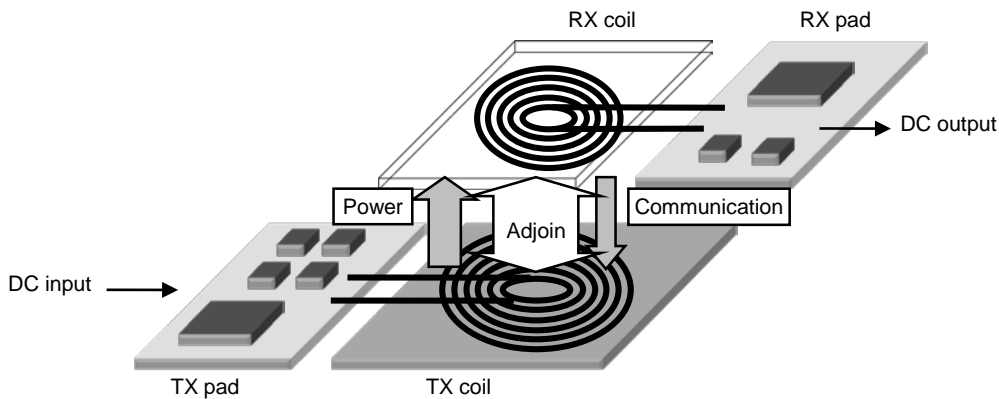

Figure 8.1 General outline of a wireless power system

8.2 General outline of wireless power RX system

The TC7765WBG includes a rectifier circuit which smoothes the RX coil current of the wireless power system; a digital control circuit; a modulation circuit which communicates between RX and TX.

A wireless power system can be constructed easily without the control of a MCU because the TC7765WBG includes a digital control circuit which can operate in standalone mode. The digital control circuit transmits the received power information to the TX after some calculations. By using the TC7765WBG as RX, the TX can take advantage of the received power information sent by the RX and a wireless power system can be constructed including FOD detection.
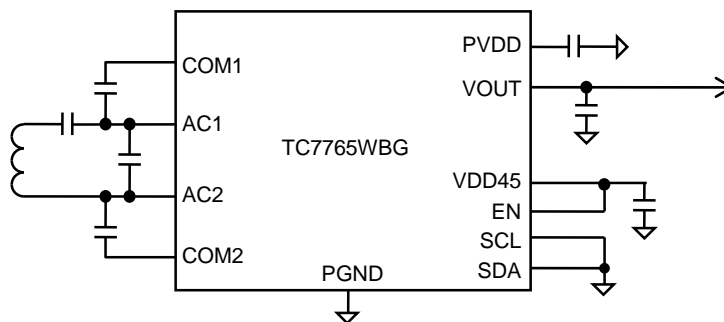

Figure 8.2 General outline of RX with the TC7765WBG

8.3 Control of TC7765WBG

8.3.1 Basic operation

The TC7765WBG incorporates a digital control circuit to realize communication with a TX. The TC7765WBG starts communication using WPC communication protocol when it receives power from a TX.

After entering the Power Transfer Phase, the output switch turnes on. And STAT signal turns to "L". The condition of enabling output is when EN is "H" or "Open". Figure 8.3 shows a basic operation sequence.
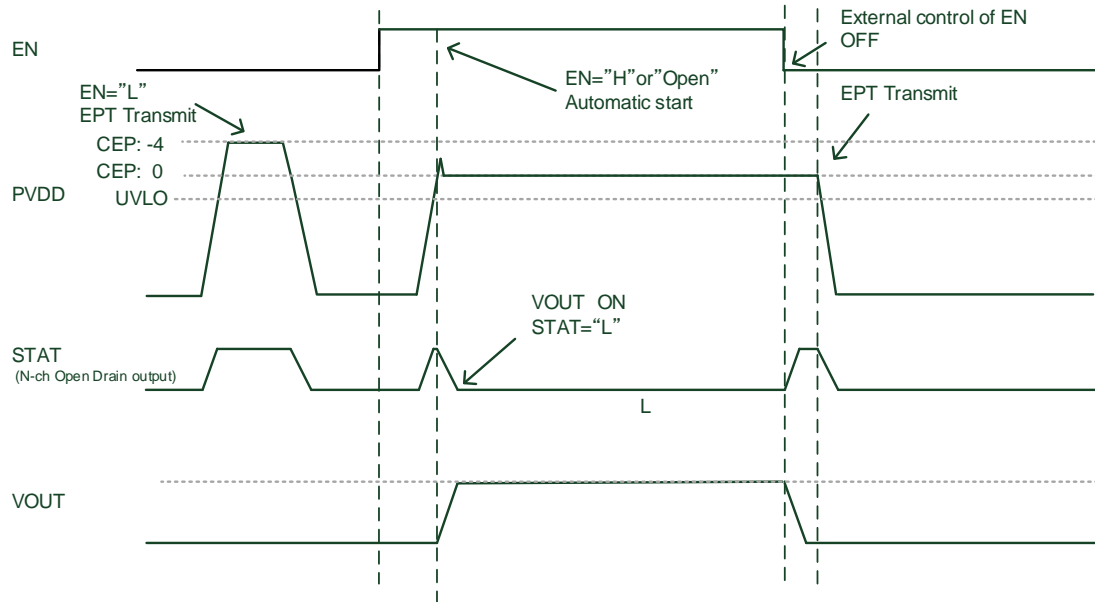

Figure 8.3 Basic operation (using EN control)

8.4 Control state machine

The state machine of the TC7765WBG consists of SHUTDOWN mode, STARTUP mode, OUTPUT mode and OVP mode. The wireless power system starts operation when transmitters TX coil and the TC7765WBGs RX coil are adjoined.

The state transition diagram of the wireless feeding control of the TC7765WBG is shown in the Figure 8.4. The operation state of each circuit in each mode is shown in the table 8.1.
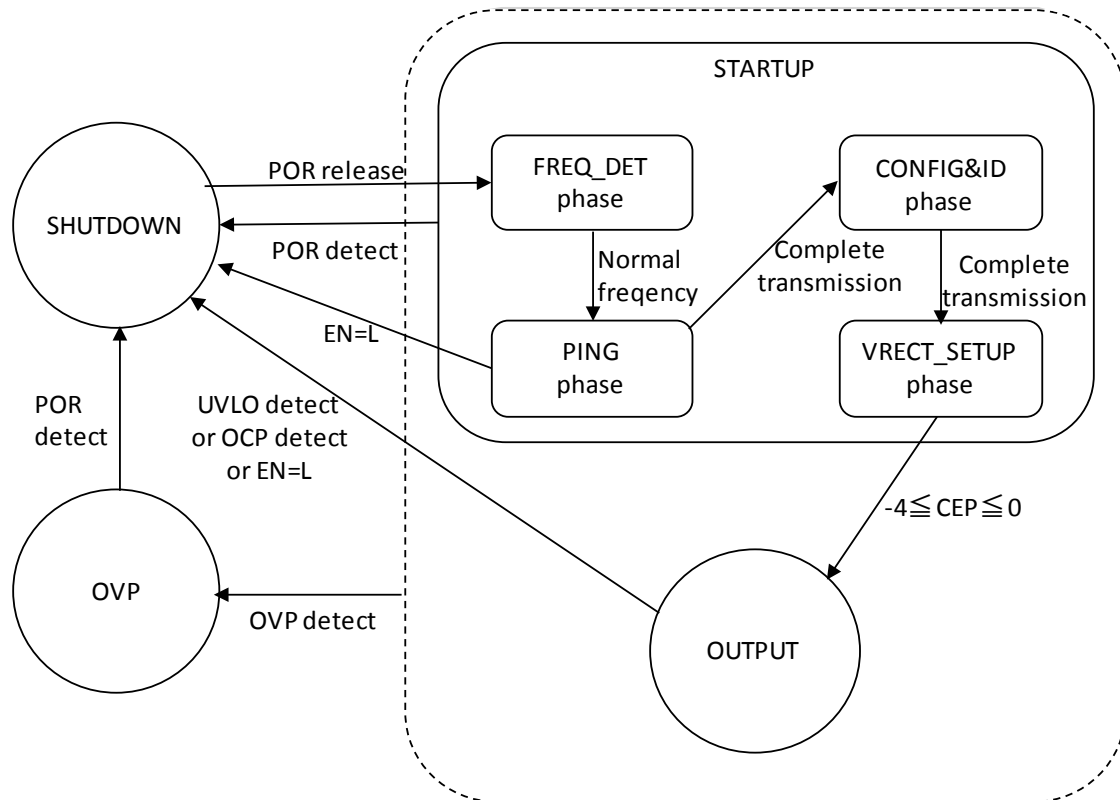

Figure 8.4 State transition diagram of TC7765WBG wireless power supply control

Table 8.1 Operating condition for each mode

Wireless charge control mode		Rectifier circuit	Packets (Header values)	VOUT output	UVLO	TSD	I²C control	STAT output
SHUTDOWN		Diode bridge rectification	-	OFF	Valid	Invalid	Invalid	Hi-Z
STARTUP	FREQ_DET	Diode rectification	NA	OFF	Valid	Valid	Valid	Hi-Z
	PING	Diode rectification	01h, 02h	OFF	Valid	Valid	Valid	Hi-Z
	CONFIG&ID	Diode rectification	51h, 71h	OFF	Valid	Valid	Valid	Hi-Z
	VRECT_SETUP	Diode rectification	02h, 03h 04h	OFF	Valid	Valid	Valid	Hi-Z
OUTPUT		Diode rectification or synchronous rectification	02h, 03h, 04h	ON	Valid	Valid	Valid	L
OVP		Diode bridge rectifier + RECT_CLAMP	02h	OFF	Valid	Valid	Valid	Hi-Z

8.4.1   SHUTDOWN mode

SHUTDOWN mode is the status without detection of wired or wireless power supply. The detection judgment whether wireless power supply is on or not is done by internal monitoring of the PVDD terminal voltage (VRECT; the voltage generated by rectifying the RF wireless power).
When the VRECT is below the UVLO release voltage, TC7765WBG enters SHUTDOWN mode.
In SHUTDOWN mode, the digital control circuit, communication circuit and regulator circuits are stopped.
When the UVLO is released, TC7765WBG starts to operate the wireless power supply control and goes to STARTUP mode.

8.4.2   STARTUP mode

STARTUP mode is the status when the TC7765WBG detects wireless power, in which it certificates with TX and stabilizes VRECT. The status has 4 phases which automatically transit in the following sequence: FREQ_DET phase, PING phase PING phase, CONFIG&ID phase and VRECT_SETUP phase.
In the STARTUP mode the rectifier circuit works as diode rectifier in which the low-side MOSFETs are fixed to off and only the high-side MOSFETs work.
The condition of shifting to OUTPUT mode are:
    Over two CEP have transmitted to Tx,
    CEP value is from -4 to zero.

(1)   FREQ_DET phase

In the FREQ_DET phase, TC7765WBG determines if the TX is compliant to the Qi standard. After UVLO is released, TC7765WBG starts detection of the frequency on AC1 and AC2. When the range of the frequency is over 80 kHz, TC7765WBG considers that the frequency is stable.
After confirming both the proper frequency and frequency stability, TC7765WBG shifts to the PING phase.

(2) PING phase

In the PING phase, TC7765WBG notifies detection of wireless power supply to the TX. TC7765WBG measures the rectifier output VRECT to determine its received power and sends a packet including header (01h) and the result of the received power calculation to the TX. After that the TC7765WBG automatically transitions to the CONFIG&ID phase.

In case of EN='L', TC7765WBG sends End Power Transfer Packet (Data:charge complete) instead of header 01h.

(3) CONFIG&ID phase

In the CONFIG&ID phase, TC7765WBG sends RX information to the TX. After it has elapsed in this phase, TC7765WBG sends a packet including header (71h), WPC version, maker code and serial code. Subsequently, after it sends a packet including header (51h), received power and timing code measured by the TC7765WBG.

Then TC7765WBG automatically shifts to VRECT_SETUP phase.

(4) VRECT_SETUP phase

In the VRECT_SETUP phase, VRECT is converged to its target value. After it has elapsed in this phase, TC7765WBG calculates an error value. After, TC7765WBG sends a packet including header (03h) and Control Error Packet (CEP) including the error value.

The condition of shifting to OUTPUT mode are:

    Over two CEP have transmitted to Tx,

    CEP value is from -4 to zero.

8.4.3 OUTPUT mode

In the OUTPUT phase, TC7765WBG provides power received from a wireless power supply to the load. In this mode, VRECT is controlled by Tx which is receiving CEP from TC7765WBG. Periodically, the TC7765WGB calculates the received power and sends a packet including header (04h) and received power. Maximum output current is 1.0 A. OCP current (IOCP) is set to 1.3 A. TC7765WBG sends EPT (Data:Over Current) when over current is detected.

8.4.4 OVP mode

This function is to avoid overvoltage of VRECT by the over voltage detection function of VRECT and the RECT_CLAMP function. If VRECT exceeds 15 V, TC7765WBG judges it as an over voltage. In such a case the TC7765WBG connects AC1 and AC2 to GND through external capacitors by switching CLMP1 and CLMP2 from Hi-Z to GND. The RX coil current flows through the capacitors, so that TC7765WBG can reduce VRECT.

When VRECT is less than 10V, from OVP mode is canceled.

8.4.5 Operation stop

Two methods can be used to stop the wireless power supply operation: EPT (End Power Transfer) messages and the communication timeout. When TC7765WBG activates any of its protection functions, it transmits an EPT message to the TX. The TX then stops its power transmission.

The communication timeout means that the TX does not receive any packet which TC7765WBG transmitted for a fixed period. Then the TX stops power transmission automatically.

9. Descriptions of functional details

9.1 Communication function of the wireless power system

In the STARTUP mode, when the UVLO is released and the frequency of rectifier is more than 80 kHz, the input is judged normal and communication (PING Phase) of the wireless power system automatically starts.

9.1.1 ASK modulation

Capacitors are connected between COM1 and AC1 and between COM2 and AC2. TC7765WBG communicate with TX by ASK modulation. The coil current is overlapped with the signals that TC7765WBG controls capacity load.
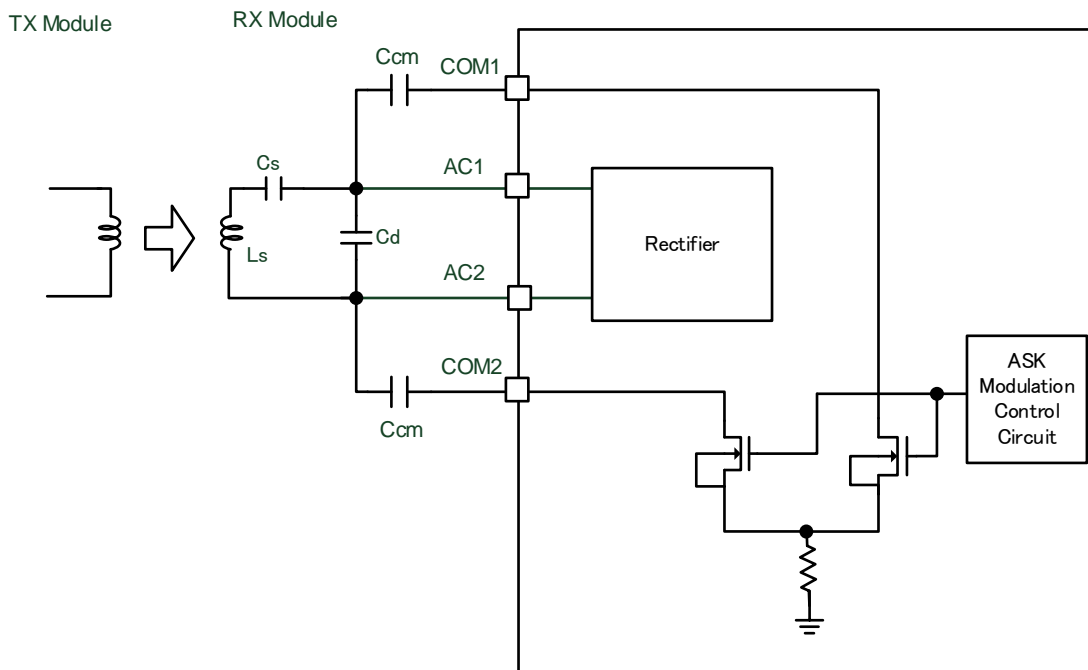
Figure 9.1 Connection diagram of ASK modulation

9.1.2   Communication protocol

(1) Bit Encoding Scheme

Bit chart of communication is as follows.

$tclk = 0.5 \pm 4\%$ [ms]

| ONE | ZERO | ONE | ZERO | ONE | ONE | ZERO | ZERO |
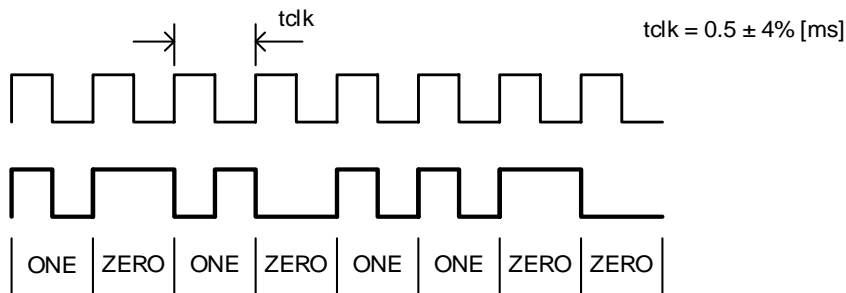
Figure 9.2 Example of the differential bi-phase encoding

(2)   Byte Encoding Scheme

Byte chart of communication is as follows. Start bit: "ZERO", Stop bit: "ONE".
The order of the data bits is lsb first.

| Start | b0 | b1 | b2 | b3 | b4 | b5 | b6 | b7 | Parity | Stop |
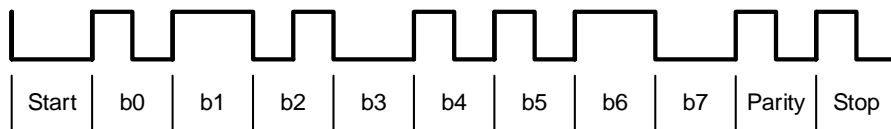
Figure 9.3 Example of the asynchronous serial format

(3)   Packet Structure

Packets of communication consist of four parts; Preamble, Header, Message, and Checksum.

Preamble: 11bit (default) of ONE continuously.
Header: Indicates the kind of packet and specifies the size of the message that will be sent next.
Message: Data of each packet type.
Checksum: XOR value of Header and Message.
              Checksum = Header + Message(0) + Message(1) + ⋯ + Message (last)

Preamble	Header	Message	Checksum
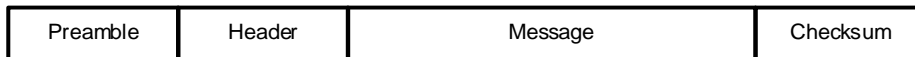
Figure 9.4 Packet format

9.1.3 Communication packets

The TC7765WBG transmits packets according to the following definitions.

- PING Phase

    (1) **Signal Strength Packet (01h)**

    Table 9.1 Strength Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
Signal Strength Packet	01h	B0	Signal Strength Value							

Signal Strength Value:
It indicates the strength of the coupling between primary side and secondary side, which is calculated by monitoring VRECT.

- CONFIG & ID Phase

    (2) **Identification Packet (71h)**

Table 9.2 Identification Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
Identification Packet	71h	B0	Major Version				Minor Version			
		B1	(msb)	Manufacturer Code						
		B2								(lsb)
		B3	EXT	(msb)						
		B4		Basic Device Identifier						
		B5								
		B6								(lsb)

Major Version	: Fixed to "01h"
Minor Version	: Fixed to "01h"
Manufacturer Code	: Indicates manufacture code. The code of Toshiba is "0033h".
EXT	: Fixed to "EXT = "0"
Basic Device Identification	
	: Indicates the individual device ID.

(3) **Configuration Packet (51h)**

Table 9.3 Configuration Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
Configuration Packet	51h	B0	Power Class		Maximum Power					
		B1	Reserved							
		B2	Prop		Reserved				Count	
		B3	Window Size					Window Offset		
		B4	Reserved							

Power Class   : "00h"
Maximum Power   : "0Ah" (5 W)
Prop   : "00h"
Count   : "00h"
Window Side   : "04h"
Window Offset   : "01h"

- VRECT_SETUP Phase / STANDBY Phase
    (4) **Control Error Packet (03h)**

Table 9.4 Control Error Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
Control Error Packet	03h	B0	Control Error Value							

(5) **Received Power Packet (04h)**

Table 9.5 Received Power Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
Received Power Packet	04h	B0	Received Power Value							

Received Power Value: Indicates received power including FOD compensation.

(6) **End power transfer packet (02h)**

Table 9.6 End Power Transfer Packet

Packet	Header		b7	b6	b5	b4	b3	b2	b1	b0
End Power Transfer Packet	02h	B0				End Power Transfer Value				

End Power Transfer Value: Signal of End Power Transfer is transmitted according to Table 9.7.

Table 9.7 End Power Transfer Value

Reason	Value	Condition
Unknown	00h	Unused
Charge Complete	01h	When wireless charging off due to EN = "L"
Internal Fault	02h	Unused
Over Temperature	03h	Internal and external over temperature detection
Over Voltage	04h	At the detection of over voltage limitation
Over Current	05h	At the detection of over current limitation
Battery Failure	06h	Unused
Reconfigure	07h	Unused
No Response	08h	Unused

9.2 Rectifier circuit

9.2.1 Rectifier modes

The rectifier circuit has 3 modes: synchronous rectification, diode rectification, and diode bridge mode. TC7765WBG automatically switches the modes.

In SHUTDOWN mode, the rectifier operates in the diode bridge mode. In this mode, all MOSFETs are fixed to OFF and the rectifier operates over the MOSFETs body diode.

In STARTUP mode, the rectifier operates in the diode rectifier mode. In this mode, the low side MOSFETs are fixed to OFF. The rectifier operates by turning on and off only the high side MOSFETs.

In OUTPUT mode, the rectifier operates in the synchronous rectification mode by turning on and off all MOSFETs. When output current is low, the rectifier operates in the diode rectifier mode.

9.2.2 RECT_CLAMP function

The RECT_CLAMP function suppresses over voltages of VRECT. The clamping functions circuitry can be seen in Figure 9.5. Excessive coil current potentially generating an over voltage at the internal recitfier output will be shunted to GND through a capacitive load connected to the IC's CLMP terminals and the IC internal MOSFETs. This suppresses the excessive rise of VRECT.
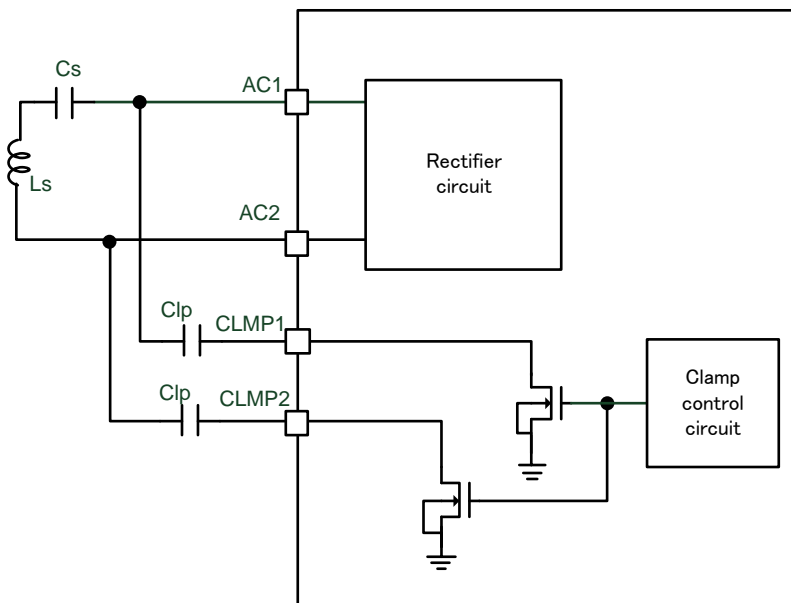
Figure 9.5 Connection diagram of clamp circuit

9.3 FOD function

The FOD function is used to calculate losses of received power in the mobile device. TC7765WBG can revise the actual received power, measured by the rectifier current, with two external resistors in the FOD and OFFSET terminals.

9.3.1 FOD Terminal

It is possible to change the slope of received power.
Connect resistor (0 to 1.25 kΩ) to GND.

9.3.2 OFFSET Terminal

It is possible to change the offset of received power.
Connect resistor (0 to 20 kΩ) to GND.

9.4   Protection functions

9.4.1   Under voltage lockout (UVLO) function

Under voltage lockout (UVLO) function avoids errors caused by too low VRECT voltages. Rectifying circuit UVLO detection condition is that the voltage of VRECT falls below 2.6 V (typ.). UVLO function is released when the voltage of VRECT exceeds 2.7 V (typ.).

9.4.2   Over voltage detection (WPT_OVP) function

Over voltage detection (WPT_OVP) function avoids errors caused by too high VRECT voltages. Detection condition of WPT_OVP function is that the voltage of PVDD exceeds 15V (typ.). When WPT_OVP function worked, TC7765WBG transmit overvoltage EPT three times and finish communication control of the wireless power. In addition, when VRECT is over 15 V, the clamping circuit of the rectifier is turned on, and a clamping circuit is off when VRECT is less than 10 V.

9.4.3   Over current protection (OCP) function

Over current detection (OCP) function is a function to control an output current. A detection condition of the OCP function is to exceed a limited output current. The OCL detection current is 1.3 A (typ.).

9.4.4   Thermal shutdown (TSD) function

Thermal shutdown (TSD) function avoids the IC destruction caused by rising chip internal temperature. The detection condition of TSD function is that the internal temperature exceeds 150°C (typ.). When TSD is detected, the output of LDO is turned off. In case the internal temperature falls below 130°C (typ.), TSD function is released automatically and LDO is turned on again. In case the TSD status continues for 200ms or more, the output of the LDO turns off and power transmission is finished by transmitting an EPT message to the TX (03h: Over Temperature).

10. Absolute Maximum Ratings (Ta = 25°C)

Table 10.1 Absolute Maximum Ratings

Characteristics	Symbol	Rating	Unit	Remarks
Supply voltage	$VRECT_{MAX}$	-0.3 to 18	V	(Note 1)
Input voltage (1)	V_{I1}	-0.3 to 18	V	(Note 2)
Input voltage (2)	V_{I2}	-0.3 to 30	V	(Note 3)
Input voltage (3)	V_{I3}	-0.3 to 8	V	(Note 4)
Input voltage (4)	V_{I4}	-0.3 to 5.6	V	(Note 5)
Operating temperature	T_{opr}	-40 to 85	°C	
Junction temperature	T_j	150	°C	
Storage temperature	T_{stg}	-55 to 150	°C	

Note: The absolute maximum ratings of a semiconductor devices are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings. Exceeding the rating(s) may cause the device to break down, damage, and may result injury by explosion or combustion. Please use the IC within the specified operating ranges.

In addition, please assume it "PGND = 0 V".

Note 1: Applies to PVDD terminal only

Note 2: Applies to AC1, AC2, COM1, COM2, CLMP1, CLMP2 and VOUT terminals

Note 3: Applies to TEST1 and TEST2 terminals

Note 4: Applies to VPP terminal

Note 5: Applies to terminal except above terminals

11. Electrical Characteristics

11.1 DC characteristics Common Circuit, Digital Controller

Table 11.1 DC characteristics Common Circuit, Digital Controller

(Unless otherwise specified, VRECT = 7 V, PGND = 0 V, Ta = 25°C)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
Operation voltage		V_{OPE1}	-	3.5	-	15	V	PVDD
UVLO detection voltage		V_{UVLO_ON}	VRECT = 7 V to 0 V	2.5	-	2.7	V	PVDD
UVLO release voltage		V_{UVLO_OFF}	VRECT = 0 V to 7 V	-	-	2.9	V	PVDD
Quiescent current		I_{CC}	VRECT = 7 V AC1 = AC2 = Open 5 V LDO off	-	2.5	6.0	mA	PVDD
Input voltage	High level	V_{IH1}	-	1.4	-	-	V	EN
	Low level	V_{IL1}	-	-	-	0.4		
Input current	High level	I_{IH1}	$V_{IH1} = V_{OUT45}$	20	-	75	μA	EN
	Low level	I_{IL1}	V_{IL1} = GND	-0.6	-	0.6		
Output voltage	Low level	V_{OL1}	I_{OUT} = -1 mA	0	-	0.4	V	STAT
VDD45 voltage		VDD45	-	4.25	-	4.75	V	VDD45
Oscillator frequency		f_{CLK}	-	3.84	4.0	4.16	MHz	
TSD detection temperature		T_{TSD_ON}	-	135	150	165	°C	
TSD release temperature		T_{TSD_OFF}	-	120	-	-	°C	

11.2 DC Characteristics Rectifier, Modulator

Table 11.2 DC Characteristics Rectifier, Modulator

(Unless otherwise specified, VRECT = 7 V, PGND = 0 V, Ta = 25°C)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
Rectifier MOSFET on-resistance	High-side	R_{ONH_AC}	I_{DS} = -100 mA	-	45	-	mΩ	AC1, AC2
	Low-side	R_{ONL_AC}	I_{DS} = 100 mA	-	30	-		
Clamper MOSFET on-resistance		R_{ON_CLMP}	I_{DS} = 100 mA	-	-	1.5	Ω	CLMP1, CLMP2
Modulator output resistance 1		R_{COM1}	COM2 open Resistance between COM1 and PGND	45	-	65	Ω	COM1
Modulator output resistance 2		R_{COM2}	COM1 open Resistance between COM2 and PGND	45	-	65	Ω	COM2

11.3 DC Characteristics of OUTPUT

Table 11.3 DC Characteristics OUTPUT

(Unless otherwise specified, PGND = 0 V, Ta = 25°C)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
OCP current	I_{OCP1}	SET_OCL = 11b	1.1	1.3	1.5	A	VOUT
Discharge resistance	R_{DCHG}	-	-	8	-	kΩ	VOUT

11.4 AC Characteristics I^{2}C Interface
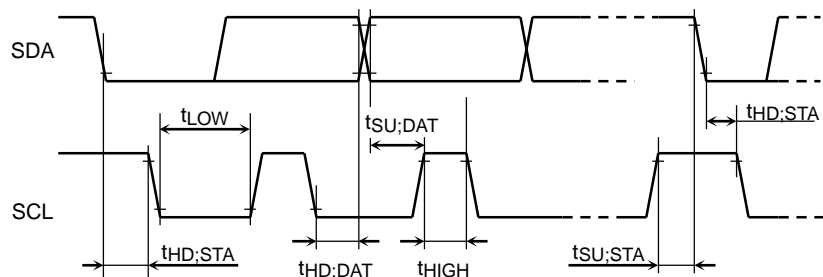
Table 11.4 AC Characteristics

Unless otherwise specified, VRECT = 7 V, PGND = 0 V, Ta = 25°C

Characteristics	Symbol	Min	Typ.	Max	Unit
Operation clock frequency	f_{SCL}	-	-	400	kHz
Hold time of repeated start	$t_{HD:STA}$	0.6	-	-	μs
Setup time of repeated start	$t_{SU:STA}$	0.6	-	-	μs
Data hold time	$t_{HD;DAT}$	0	-	0.9	μs
Data setup time	$t_{SU;DAT}$	100	-	-	ns
Low term of SCL signal	t_{LOW}	1.3	-	-	μs
High term of SCL signal	t_{HIGH}	0.6	-	-	μs

12. Application Circuit
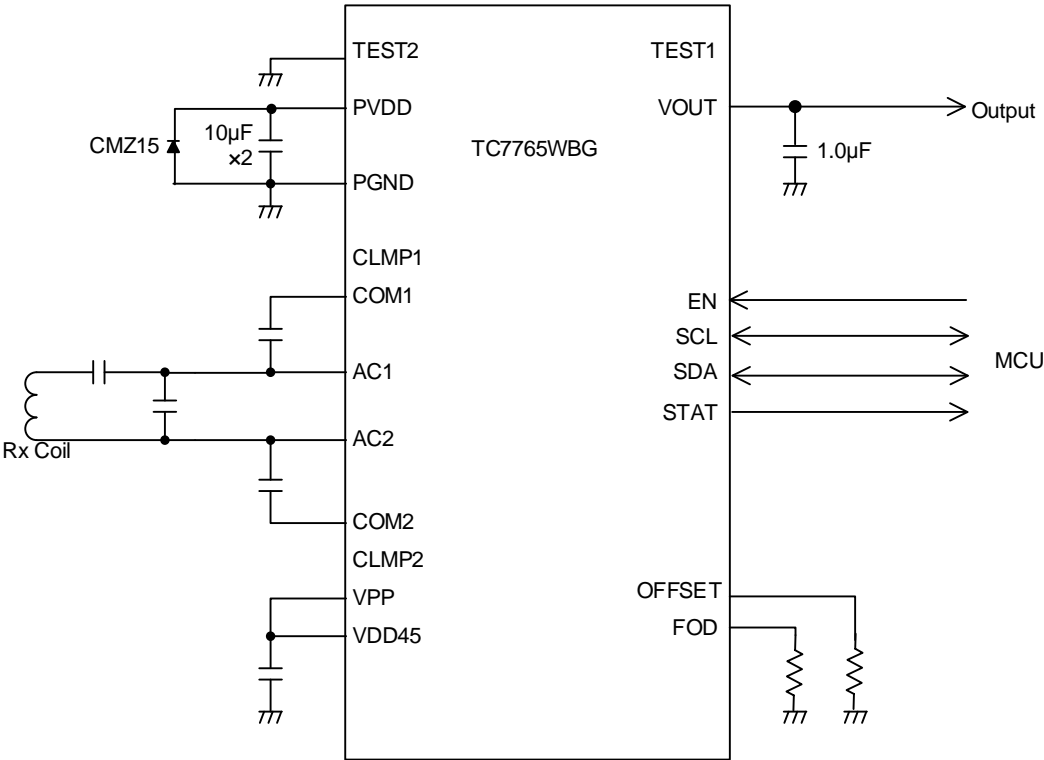
Figure 12.1 Application circuit

13. Package dimensions

S-XFLGA28-0304-0.50-001

Unit: mm

2.40±0.05

3.67±0.05

// 0.08 S

S

0.08±0.05

0.5MAX

◇ 0.05 CZ

0.335TYP

A

0.45TYP

G F E D C B A

1 2 3 4

0.5

B

0.5

φ0.24±0.05

⊕ φ0.05 Ⓜ S AB
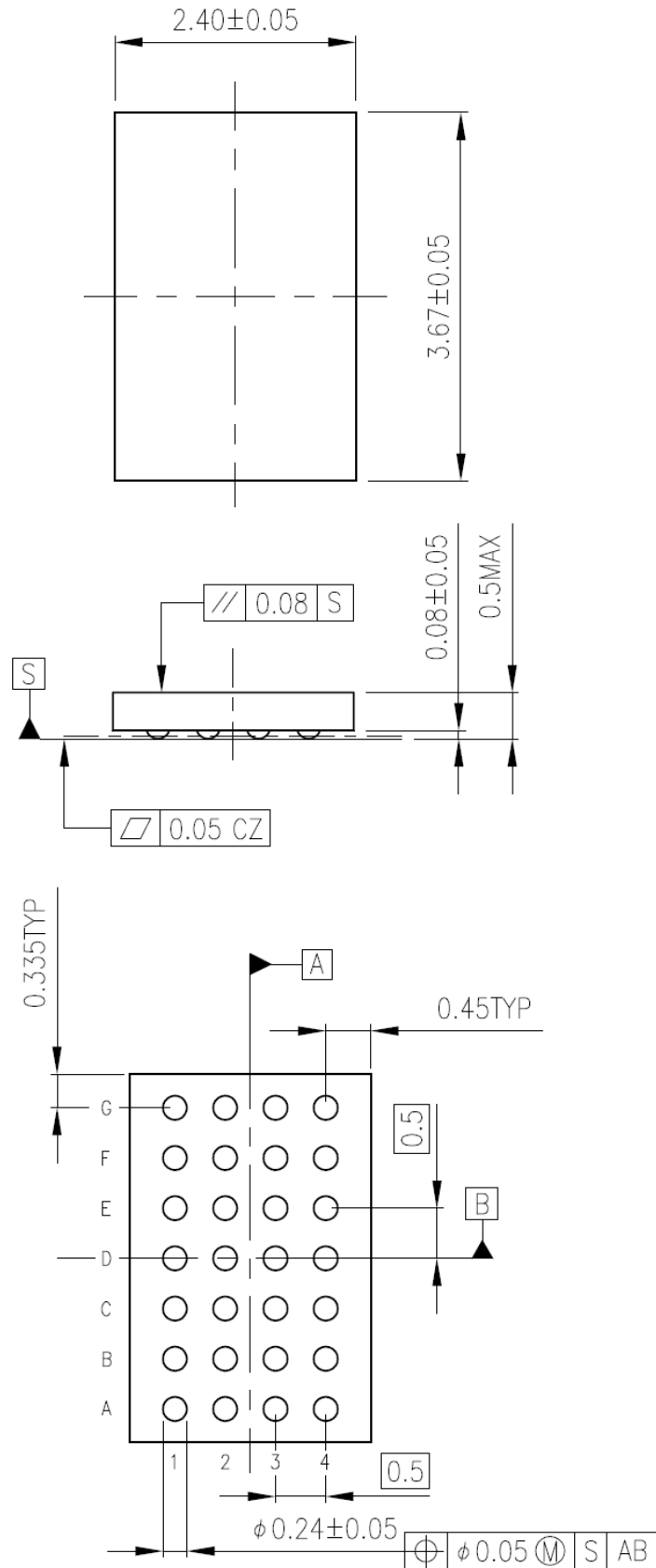
Weight: 10 mg (typ.)

RESTRICTIONS ON PRODUCT USE

2015-11-04