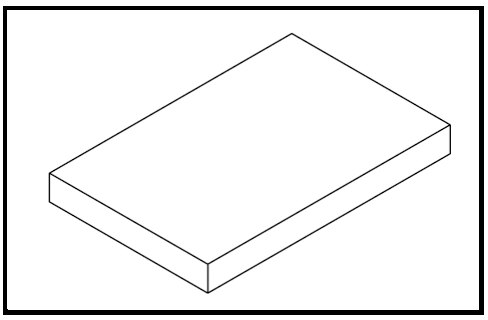
TOSHIBA CDMOS Integrated Circuit Silicon Monolithic

TC7761WBG

Qi Compliant Wireless Power Receiver Controller IC

1. Outline

The TC7761WBG is wireless power receiver (Rx) IC for Qi low power v1.1 compliant of Wireless Power Consortium (WPC). The TC7761WBG includes a rectifier circuit, a digital control circuit, a modulation circuit, a regulator circuit which controls the supply voltage to the load, and a load switch controller for supply selector. A digital control circuit realizes heat reduction and improvement of stabilization for load changes. The IC includes all Rx functions needed to construct a standalone wireless power system. The integrated loadswitch driver for external loadswitch allows to bypass the wireless power function when a USB or AC power source is connected to the mobile device.



S-XFLGA28-0304-0.50-001

2. Applications

Mobile devices (Smartphone, tablet), Battery pack, Mobile accessory

3. Features

- Full bridge rectifier circuit
  Auto switch for 3 modes : Synchronous rectification / Diode rectification / Diode bridge
  Low ON resistance : Hi Side 45mΩ(Typ.) / Low side 30mΩ(Typ.)
  Under Voltage Lockout (UVLO) / Over Voltage Detection (OVP) function

5V-output LDO
Maximum output current : 1.0A
2 step Over Current Detection (OCL) function

- Qi Low Power v1.1 compliant
  - Foreign Object Detection (FOD) function

  - External load switch driver for supply selector
    Current drive type startup function
    Under voltage lockout (UVLO) / Over voltage detection (OVLO) function
    Thermal shutdown function (TSD)
  - Package : S-XFLGA28-0304-0.50-001 (2.40mm*3.67mm*0.5mm, 0.5mm pitch)

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

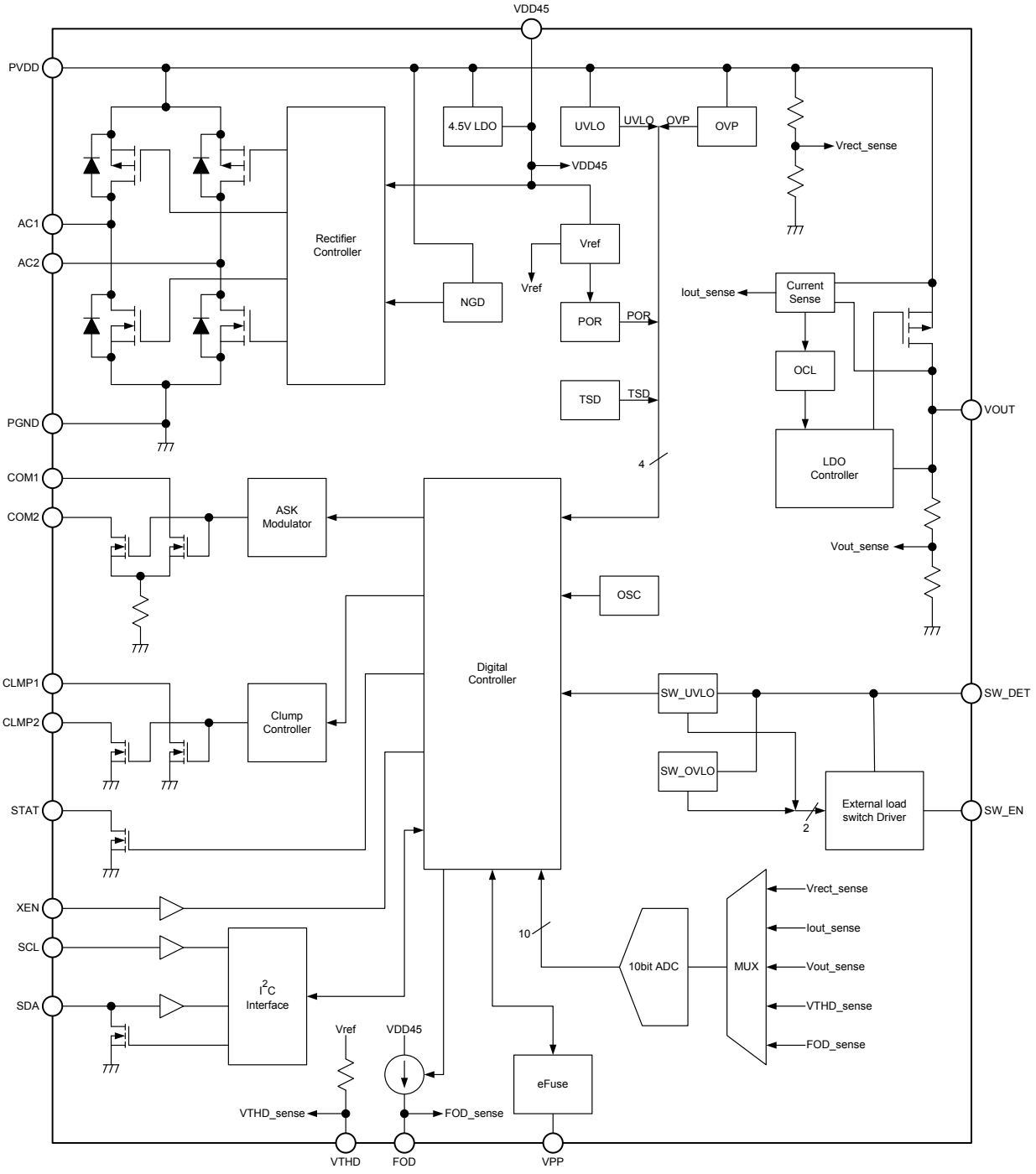


Figure 4.1 Block diagram

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	SW_EN	SW_DET
G	FOD	XEN	STAT	VTHD

(Top View)

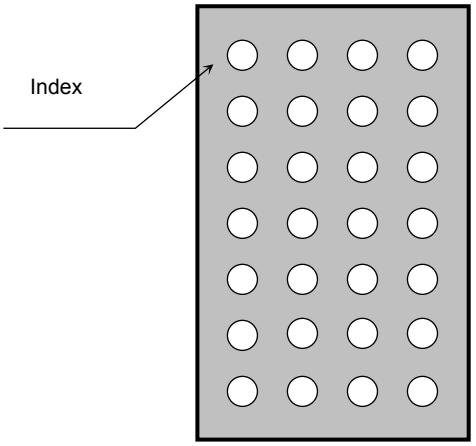


Figure 5.1 Pin assignment (Top View)

Note: The pin configuration figure is indicated that package ball side is located on the back and indicating pins from the surface view.

6. Pin function

Table 6.1 Pin function

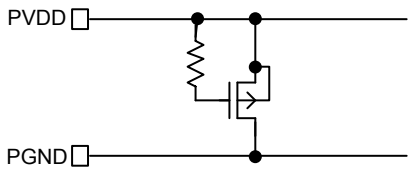
Pin Number	Pin symbol	I/O	Description
A1, A2 A3, A4	PGND	-	Power ground Connect to common ground (GND).
B1, B2	AC2	I	Antenna terminals for receiver 2
B3,B4	AC1	I	Antenna terminals for receiver 1
C1	CLMP2	O	Clamp terminal for over voltage protection 2 Open drain terminal. Connect capacitor of 0.47μF to AC2.
C2, C3	PVDD	-	Rectifier output and power supply terminal Output of bridge rectifier circuit and IC power supply terminal. Connect smoothing capacitor between PVDD and PGND.
C4	CLMP1	O	Clamp terminal for over voltage protection 1 Open drain terminal. Connect capacitor of 0.47μF to AC1.
D1, D2 D3, D4	VOUT	O	5V LDO output terminals Connect capacitor of more than 1.0μF 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 Open drain terminal. 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	4.5V- LDO output terminal 4.5V- LDO output terminal for internal circuit. Connect capacitor of more than 0.1μF to GND.
F2	VPP	I	eFuse writing terminal Short to VDD45 in normal use.
F3	SW_EN	O	External Load switch drive terminal Connect SW_EN to a gate of P-ch MOSFET for load switch. Please Open when you do not use it.
F4	SW_DET	I	External Load switch power supply monitor terminal It monitors input power supply of load switch. Connect SW_DET to second input power supply. Please connect GND when you do not use it.
G1	FOD	I	Offset terminal for Rx loss Loss offset terminal for FOD Connect resistor to GND.
G2	XEN	I	LDO enable input terminal When the terminal is "Open" or “L” level, LDO is tuned on. When the terminal is “H” level, LDO is turned off.
G3	STAT	O	Status output terminal Open drain terminal. Connect pull-up resistor.
G4	VTHD	I	Thermal detection terminal Thermistor connect terminal to monitor external temperature. Connect NTC thermistor to GND. Please connect resistance (51kΩ) when you do not use it.

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

7.1 Power supply terminal

Table 7.1 Equivalent circuits for power supply terminals

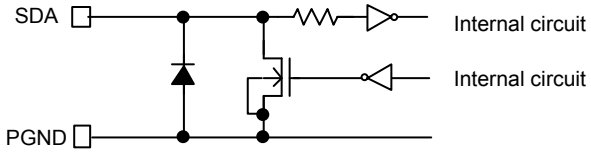
Note: Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
PVDD-PGND	

7.2 Input/output terminal

Table 7.2 Equivalent circuits for Input/output terminals

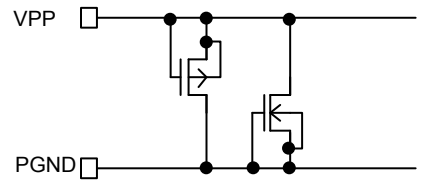
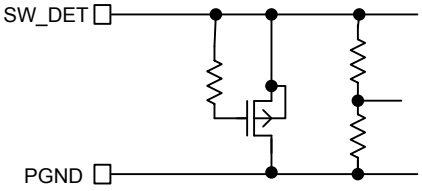
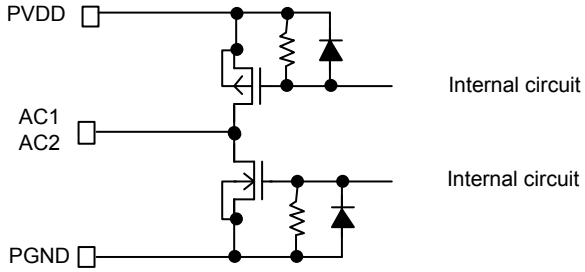
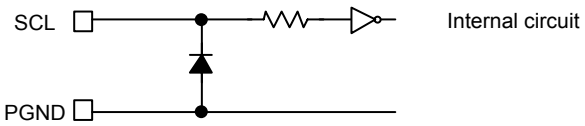
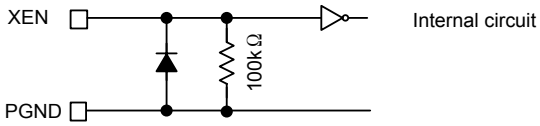
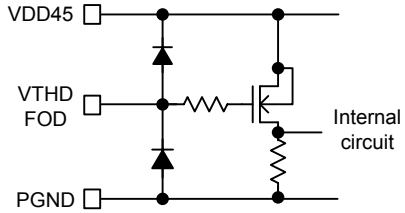
Note: Equivalent circuits may be simplified to illustrate circuits.

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	
SW_DET	
AC1 AC2	
SCL	
XEN	
VTHD FOD	

7.4 Output terminal

Table 7.4 Equivalent circuits for output terminals

Note: Equivalent circuits may be simplified to illustrate circuits.

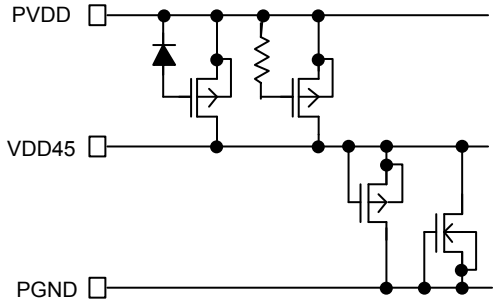
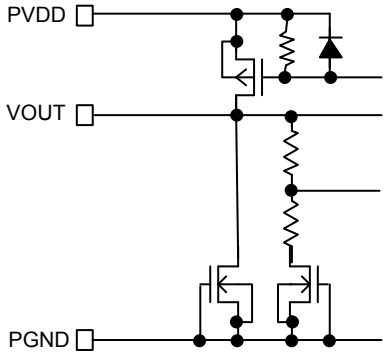
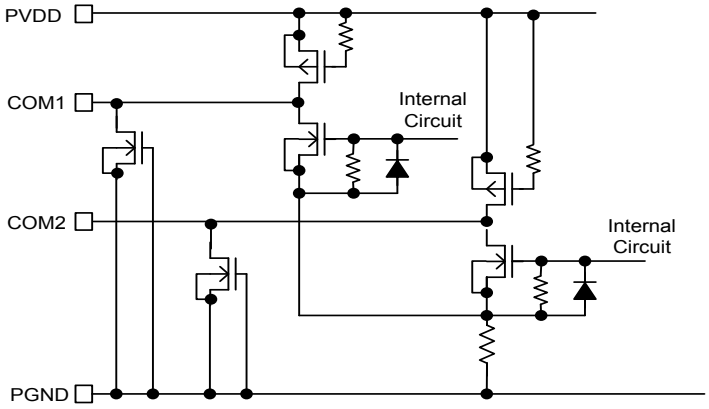
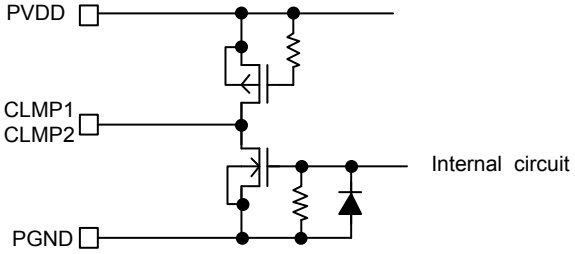
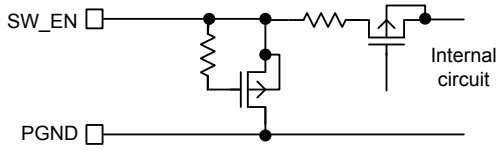
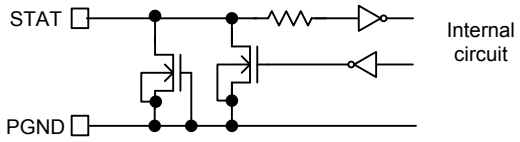
Pin name	Equivalent circuit
VDD45	
VOUT	
COM1 COM2	
CLMP1 CLMP2	

Table 7.5 Equivalent circuits for output terminals

Note: Equivalent circuits may be simplified to illustrate circuits.

Pin name	Equivalent circuit
SW_EN	
STAT	

8. Functions / Operation description

8.1 General outline of wireless power system

Qi compliant 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 Tx and Rx and by sharing and combining flux. Rx controls the power by monitoring receiving power and sending feedback signal to Tx. Tx controls the power by controlling transmitting power with feedback signal which is received from Rx. Configuration example of wireless power system is shown in Figure 8.1.
Communication signal from Rx to Tx is transmitted (modulated) by ASK modulation. The communication rate and its packet in this communication are defined by Qi compliant. Communication rate is 2kbps. Packets are ID, identification signal, error information, receive power, and stop signal.Tx stops its operation in normal mode. It is powered on intermittently and confirms the existence of Rx on the Tx pad. When Tx recognizes Rx and succeeds the identification, transmit operation starts. Tx continues transmit operation until Tx cannot recognize the existence of Rx or receives transmit stop signal from Rx.

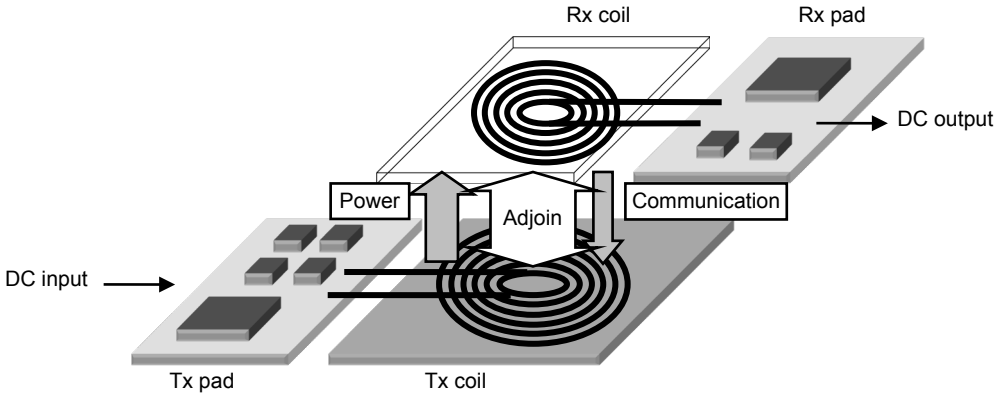


Figure 8.1 General outline of Wireless power system

8.2 General outline of wireless power Rx system

The TC7761WBG includes a rectifier circuit which smoothes necessary coil current for wireless power system, a digital control circuit, a modulation circuit which communicates between Rx and Tx, a regulator circuit which controls the load supply voltage, and a load switch control circuit which switches wired and wireless supply input. A wireless power system can be constructed easily without control of MCU because the TC7761WBG includes a digital control circuit which can operate in standalone mode. The digital control circuit corresponds to WPC v1.1 and transmits the received power from Rx to Tx after some calculations. By using the TC7761WBG as Rx, the Tx can manage received power of the Rx and a wireless power system can be constructed including FOD detection. Configuration example of Rx when wireless feeding and AC adapter are input is shown in the Figure 8.2. In the Figure 8.2, the TC7761WBG controls wireless feeding, detects wired AC adapter, and selects input power for load supply. When connection of AC adopter is detected, the TC7761WBG stops controlling wireless feeding and starts load supply through the load switch. Wireless power system is controlled only when wired connection is not detected.

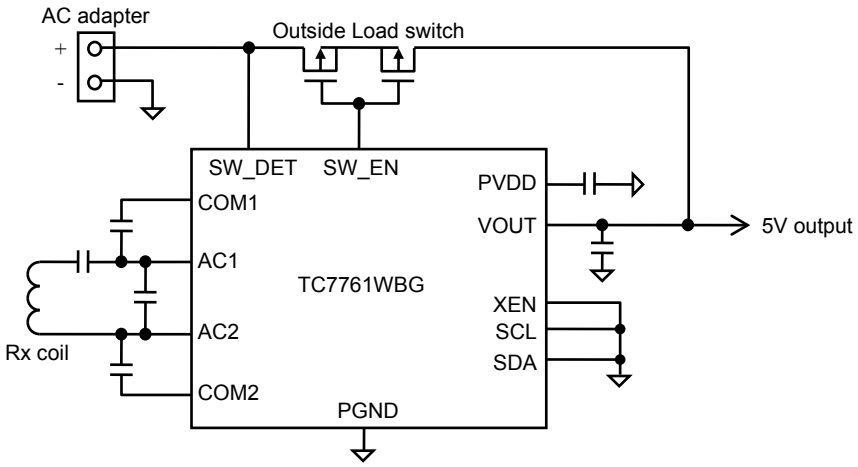


Figure 8.2 General outline of Rx with the TC7761WBG

8.3 Control of TC7761WBG

8.3.1 Basic operation

The TC7761WBG incorporates the digital control circuit to realize communication with Tx. The TC7761WBG starts Qi compliant communication when receieved power form Tx.

After a certain period of time with PVDD is no less than 7V at Power Transfer Phase, LDO can be turned on only at the time of STAT=L, LDO turns on only when STAT and XEN are "L". Figure 8.3 shows basic operation sequence using XEN signal by external control

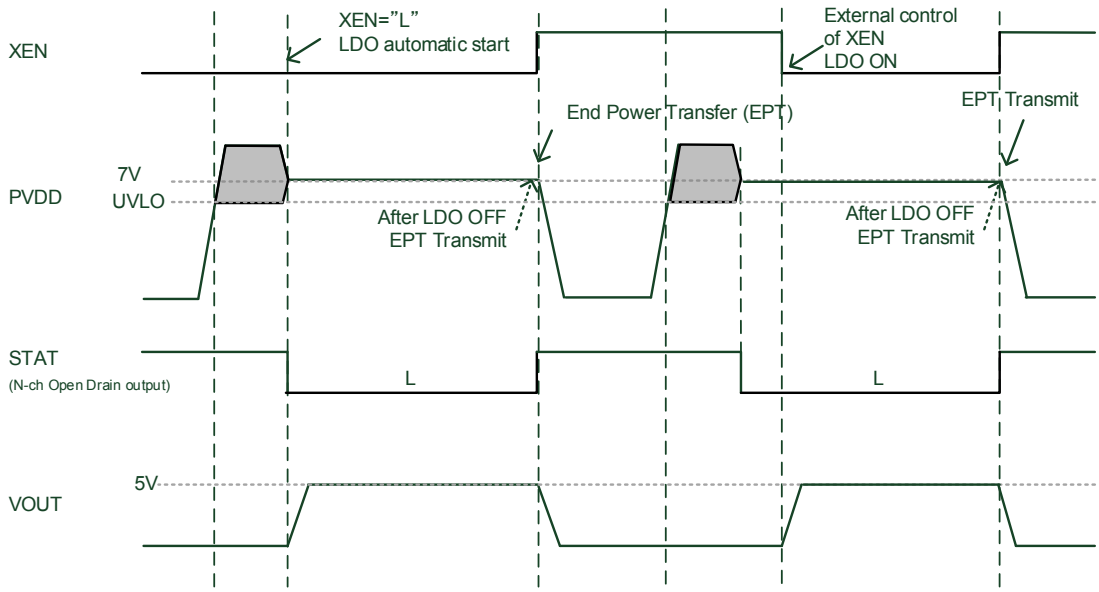


Figure 8.3 Basic operation (Using XEN control)

8.4 Control state Machine of wireless power

The state machine of wireless power with the TC7761WBG consists of SHUTDUWN mode, DISABLE mode, STARTUP mode OUTPUT mode and OVP mode. Wireless power system starts operation when Tx coil and Rx coil are adjoined without wired connection. The state transition diagram of the wireless feeding control of the TC7761WBG is shown in the Figure 8.4. The operation state of each circuit in each mode is shown in the table 8.1.

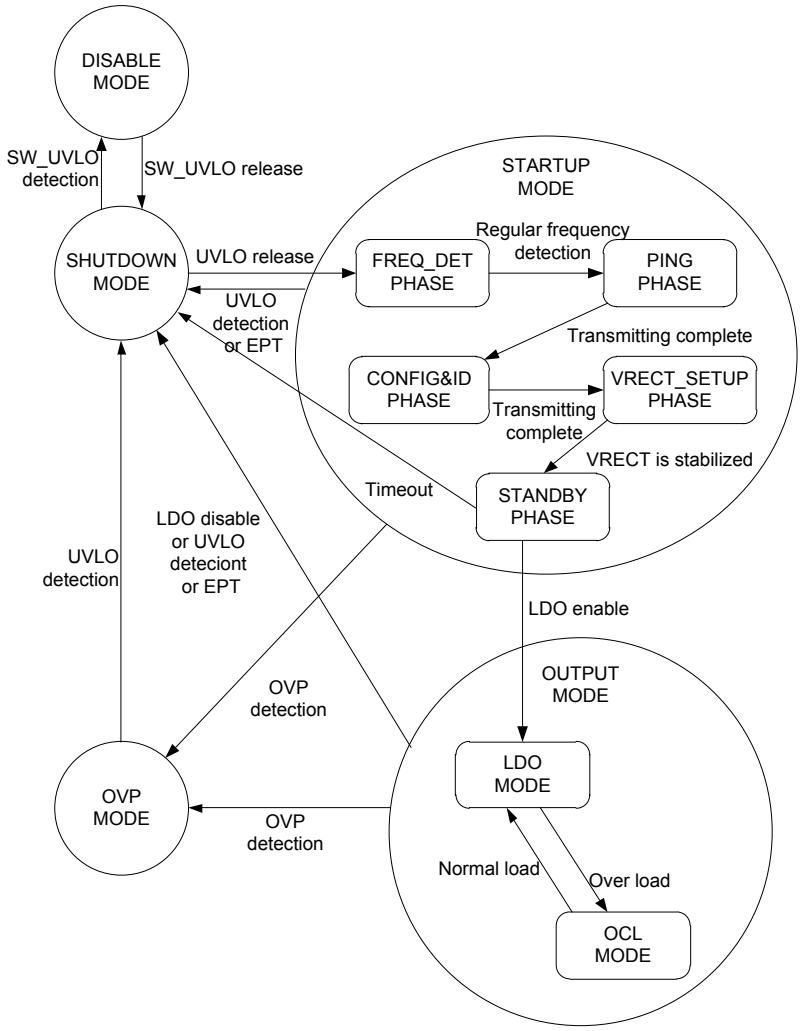


Figure 8.4 State transition diagram of TC7761WBG wireless power supply control

Table 8.1 Operating condition for each mode

Wireless charge control mode		Rectifier circuit	Packets (Header values)	VOUT output	UVLO	TSD	STAT output
SHUTDOWN		Diode bridge rectification	-	OFF	Valid	Invalid	Hi-Z
DISABLE		Diode bridge rectification + RECT_CLAMP	-	OFF	Invalid	Invalid	Hi-Z
STARTUP	FREQ_DET	Diode rectification	NA	OFF	Valid	Valid	Hi-Z
	PING	Diode rectification	01h	OFF	Valid	Valid	Hi-Z
	CONFIG&ID	Diode rectification	71h, 51h	OFF	Valid	Valid	Hi-Z
	VRECT_SETUP	Diode rectification	03h, 04h	OFF	Valid	Valid	Hi-Z
	STANDBY	Diode rectification	03h, 04h	OFF	Valid	Valid	L
OUPUT	LDO	Diode rectification or synchronous rectification	03h, 04h	5V	Valid	Valid	L
	OCL	Diode rectification or synchronous rectification	03h, 04h	Depending on load	Valid	Valid	L
OVP		Diode bridge rectifier + RECT_CLAMP	03h, 04h	OFF	Valid	Valid	Hi-Z

8.4.1 SHUTDOWN mode

SHUTDOWN mode is the status with non detection of wired power supply and wireless power supply. The detection judgment whether wireless power supply is on or not is done by monitoring PVDD terminal voltage (VRECT). When the VRECT is below UVLO release voltage, TC7761WBG enters SHUTDOWN mode. In SHUTDOWN mode, the rectifier circuit work as a diode bridge rectifier. At this time, all MOSFETs are off and the diode bridge rectifies through the MOSFET body diodes. The digital control circuit, communication circuit and regulator circuits are stopped. When the UVLO is released, TC7761WBG starts to operate the wireless power supply control and goes to STARTUP mode.

8.4.2 DISABLE mode

DISABLE mode is the status when TC7761WBG detects a wired power supply. The wireless power supply is stopped. When the TC7761WBG detects a wired connection, the RECT_CLAMP function becomes available to prevent providing wireless power by error.

8.4.3 STARTUP mode

STARTUP mode is the status when TC7761WBG detects wireless charging power, in which it certificates with Tx and stabilize VRECT. The status has 5 phases which automatically transit in the following sequence; FREQ_DET phase, PING phase, CONFIG&ID phase, VRECT_SETUP phase and STANDBY phase. In STARTUP mode the rectifier circuit works as diode rectifier in which the low-side MOSFET is fixed to off and only the high-side MOSFET works. After LDO works, the phase shifts to OUTPUT mode.

(1) FREQ_DET phase

In FREQ_DET phase, TC7761WBG determines if Tx is compliant to Qi product. After UVLO is released, TC7761WBG starts detection of frequency that is input to AC1 and AC2. When the range of the frequency is from 85 kHz to 286 kHz, TC7761WBG considers that the frequency is stable. The minimum time at regular operating is 0.7 ms and the time at abnormal operating is 3 ms. After confirming both the proper frequency and frequency stability, TC7716WBG shifts to PING phase.

(2) PING phase

In PING phase, TC7761WBG notifies detection of wireless power supply to Tx. After 28 ms have elapsed in this phase, TC7761WBG measure VRECT to determine received power and send a packet including header (01h) and the result of received power. After that, TC7761WBG automatically shifts to CONFIG&ID phase.

(3) CONFIG&ID phase

In CONFIG&ID phase, TC7761WBG notifies Rx information to Tx. After 7.5 ms have elapsed in this phase, TC7761WBG packet including header (71h), WPC version, maker code and serial code. Subsequently, after 7.5 ms, send a packet included header (51h), received power and timing code TC7761WBG measured. Then, TC7761WBG automatically shifts to VRECT_SETUP phase.

(4) VRECT_SETUP phase

In VRECT_SETUP phase, VRECT is converged to its target value. After 7.5 ms have elapsed in this phase, TC7761WBG calculates the error code. After 1 ms, TC7761WBG sends a packet including header (03h) and Control Error Packet(CEP) of the error code. Subsequently, after 40.5 ms, the TC7761WGB calculates received power and sends packet including header (04h) and received power. In this mode, the sending cycle of the error code is 62 ms. The sending cycle of the received power is one time per 29 sending cycles of the CEP. If the CEP continues twice, TC7761WBG makes judgment that VRECT is stable, and switches STAT to L. After that, TC7761WBG shifts to STANDBY phase.

(5) STANDBY phase

STANDBY phase is the status until LDO works. When LDO works, TC7761WBG shifts to OUTPUT mode. It is possible to select LDO start-up from the following settings; XEN terminal or automatic startup by eFuse setting. If the LDO doesn't work within 190 ms, TC7761WBG shifts to SHUTDOWN mode.

8.4.4 OUTPUT mode

In the OUTPUT mode, TC7761WBG provides power received from wireless power supply to the load. The OUTPUT mode has 2 modes; LDO mode that provides 5V and OCL mode that works with a 2 step constant current limit. If the output current is over 250 mA, rectifier circuit shifts to synchronous rectifier mode in this mode. If the output current is below 220 mA, rectifier circuit shifts to diode rectifier mode. In this mode, the sending cycle of the CEP is 192.5 ms. The sending cycle of the received power is one time per 8 sending cycles of the CEP.
If the VRECT is over 7V and after CEP are sent twice, TC7761WBG switches STAT to L and moves to the STANDBY phase.

(1) LDO mode

In LDO mode, VRECT generated by wireless power supply passes through the built-in LDO and give out a 5V constant voltage. The maximum current is set to 1.0A and OCL current(IOCL) is set to 1.3A.

(2) **OCL mode**

OCL mode is the status when the output current is limited by the 2 step OCL function. The 2 step OCL is a function in which the TC7761WBG switches IOCL according to VOUT. When VOUT is over 2.8 V, IOCL is set to 1.3A. When VOUT is below 2.5 V, IOCL is set to 0.35A. If VOUT is over 2.8 V with IOCL = 0.35 A, IOCL is reconfigured to 1.3A. Figure 8.5 shows the V-I characteristic.

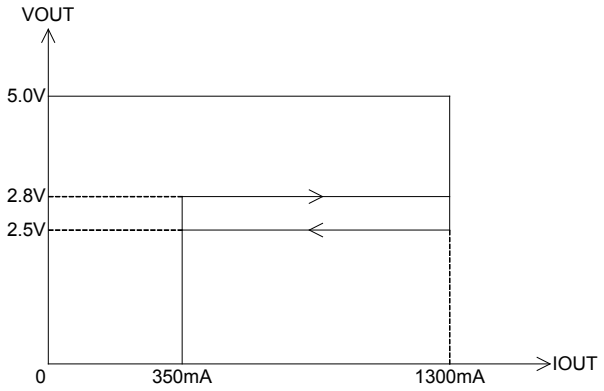


Figure 8.5 OCL function and V-I characteristic of LDO

8.4.5 VRECT automatic switching function

The VRECT automatic switching function sets the voltage of VRECT is automatically according to the output current. TC7761WBG divides the status of output current below Table 8.2. It is possible to reduce heat by reduction of difference between input and output voltage at heavy load and to reduce output voltage variations by controlling VRECT at load change.

Table 8.2 IOUT – VRECT setting voltages

Output current	VRECT setting voltage
less than 100mA	7.05 to 7.21V
More than 100mA less than 200mA	6.25 to 6.41V
More than 200mA less than 400mA	5.5 to 5.66V
More than 400mA	5.1 to 5.25V

8.4.6 OVP mode

OVP mode is the status that WPT_OVP function is powered by the wireless power supply. This function is to control the overvoltage of VRECT by over voltage detection function of VRECT and RECT_CLAMP function. If VRECT exceeds 15 V, TC7761WBG judges it as an over voltage. In such a case the TC7761WBG connects AC1 and AC2 to GND through the capacitors by switching CLMP1 and CLMP2 from Hi-Z to GND. The Rx coil current flows through the capacitors, so that TC7761WBG can reduce the value of VRECT. WPT_OVP function has a latching function that is reset through a UVLO condition.

8.4.7 Operation stop

Two methods can be used to stop the wireless power supply operation: EPT (End Power Transfer) messages and the communication timeout. When TC7761WBG activates any of its protection functions (OVP, LDO OFF, and timeout), 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 TC7761WBG 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 the range of 85 kHz to 286kHz, 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. TC7761WBG communicate with Tx by ASK modulation. The coil current is overlapped with the signals that TC7761 controls capacity load.

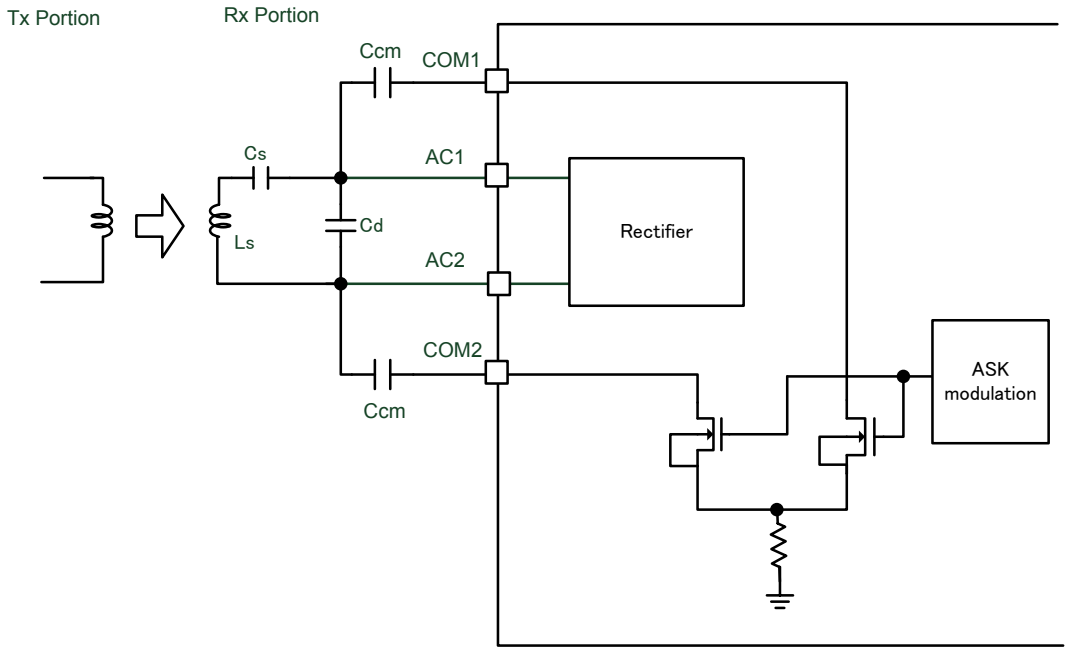


Figure 9.1 Connection diagram of ASK modulation

9.1.2 Communication protocol

(1) Bit Encoding Scheme

Bit chart of WPC communication is as follows.

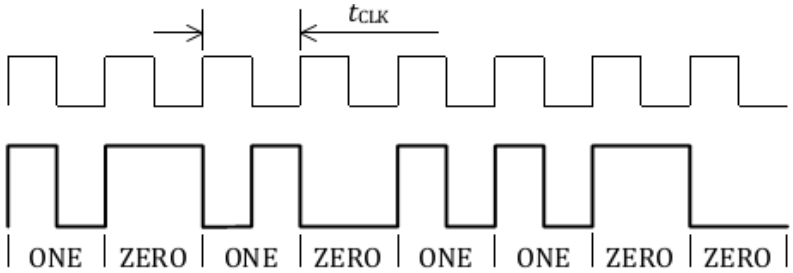


Figure 9.2 Example of the differential bi-phase encoding (WPC volume 1:Low power, part 1 Interface Definition)

tclk=0.5±4%[ms]

(2) Byte Encoding Scheme

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

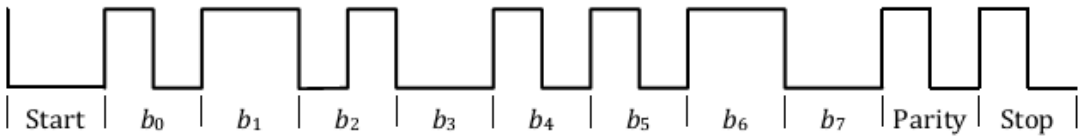


Figure 9.3 Example of the asynchronous serial format (WPC volume 1:Low power, part 1 Interface Definition)

(3) Packet Structure

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

Preamble: It sends 11bit (default) of ONE continuously.
Header: It indicates the kind of packet and specifies the size of the Massage that will be sent next.
Message: It sends the data of each packet type.
Checksum: It calculates the XOR of Header and Message.
Checksum=Header + Message(0) + Message(1) + ⋯ + Message (last)

Preamble	Header	Message	Checksum

Figure 9.4 Packet format (WPC volume 1:Low power, part 1 Interface Definition)

9.1.3 Communication packets

The TC7761WBG transmits each packet according to the next timing.

- 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 combinatnion between primary side and secondary side1, which is calcurated with moniroing 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 : It indicates Manufacture code. The code of Toshiba is ”0033h”.
EXT : Fixed to “EXT=“0”
Basic Device Identification
: It 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” (5W)
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: It 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 in the condition of the Table 9.7.

Table 9.7 End Power Transfer Value

Reason	Value	Condition
Unknown	00h	Low voltage of VOUT (VOUT<4.4V)
Charge Complete	01h	When LDO turns off if XEN="H" or EN_LDO="0" At Time out that LDO doesn't work in STANDBY Phase.
Internal Fault	02h	Unused
Over Temperature	03h	Internal and External Over Temperature Detection
Over Voltage	04h	Unused (Note 1)
Over Current	05h	At the detection of over current limitation
Battery Failure	06h	At the detection of VOUT overvoltage (VOUT>5.6V)
Reconfigure	07h	Unused
No Response	08h	When VRECT deviated from the setting voltage range at constant time

Note 1: TC7761WBG does not transmit OVP because it has RECT_CLAMP function.

9.2 Rectifier circuit

9.2.1 Rectifier modes

The rectifier circuit has 3 modes of the synchronous rectification, the diode rectification and the diode bridge. TC7761WBG 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 by the body diode.

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

In OUTPUT mode, when the output current becomes 250mA or more, the rectifier circuit operates in the synchronous rectification mode by turning on and off all MOSFET. In the synchronous rectification mode, when the output current decreases to 220mA or less, the rectifier circuit operates in the diode rectifier mode.

Table 9.8 Rectifier modes

The condition of VRECT voltage	Light load mode (Output current is below 220mA.(Note))	Normal mode (Output current is over 250mA.(Note))
VRECT < UVLO	Diode bridge mode	-
VRECT ≥ UVLO	Diode rectification mode	Synchronous rectification mode

Note: 30mV hysteresis

9.2.2 RECT_CLAMP function

RECT_CLAMP function suppresses the over voltage of VRECT. Rx coil current, which has flown in the rectifier circuit by making a circuitry of Figure 9.5, flows in the capacity load. And it suppresses the rise of VRECT.

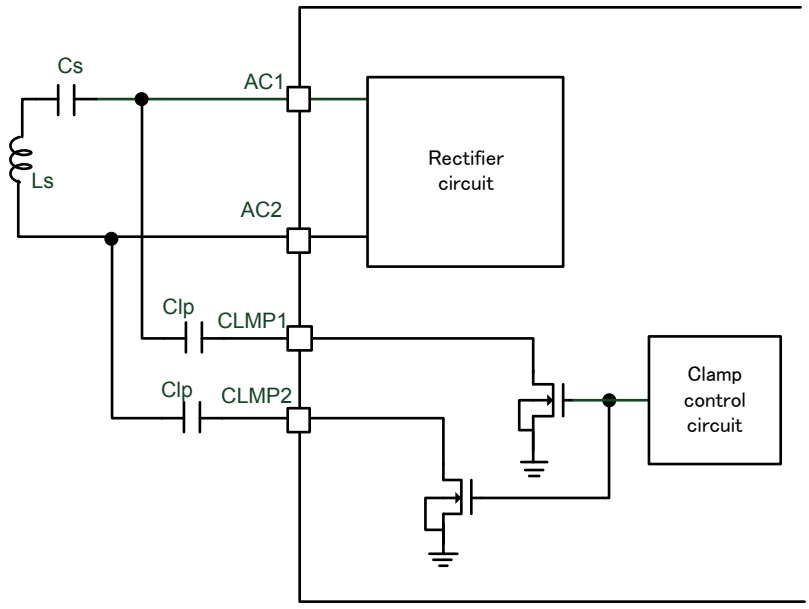


Figure 9.5 Connection diagram of clamp circuit

9.3 FOD function

FOD function is to calculate losses of received power. TC7761WBG can revise the received power by the resistance of the FOD terminal.

9.4 Thermal detection function

External temperature is monitored by connecting the NTC thermistor to VTHD terminal. Recommended thermistor is equivalent of the SEMITEC503FT.

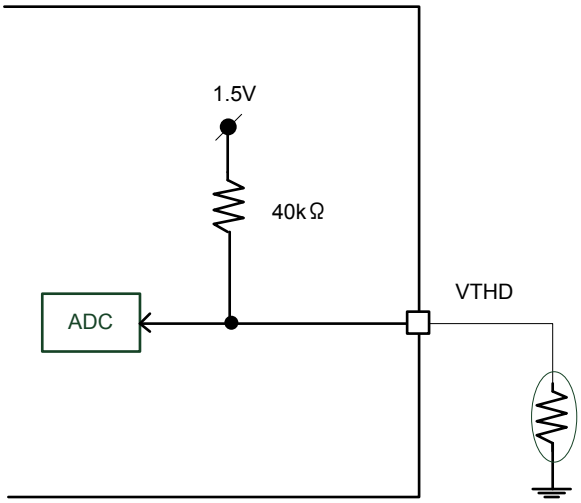


Figure 9.6 Connection diagram of thermal detection circuit

9.5 Outside Load switch control circuit

Outside Load switch control circuit monitors the voltage of SW_DET terminal and selects the wireless power output or USB input (AC adopter) by outside load switch. When secondary input power is connected to SW_DET terminal, below control is performed by the voltage of SW_DET terminal.

Table 9.9 Outside Load switch control

The conditions of SW_DET	Outside Load Switch	The voltage of SW_EN	Clamp circuit	LDO of the rectifier circuit	WPC operation
SW_DET<4V	OFF	The higher voltage of SW_DET or VOUT.	OFF	ON	Available
5.75V≥SW_DET≥4V	ON	0V	ON	OFF	Stop
SW_DET>5.75V	OFF	SW_DET, voltage	ON	OFF	Stop

9.6 Protection functions

9.6.1 Under voltage lockout (UVLO) function

Under voltage lockout (UVLO) function avoids the error which is caused by low voltage of PVDD terminal(VRECT). Detection condition of UVLO function is that the voltage of VRECT falls below 3.8V (typ.). UVLO function is released when the voltage of VRECT exceeds 4.0V (typ.). In operating UVLO function, output of LDO turns off and STAT terminal outputs Hi-Z.

9.6.2 Over voltage detection (WPT_OVP) function

Over voltage detection (WPT_OVP) function avoids the error which is caused by high voltage of PVDD terminal. Detection condition of WPT_OVP function is that the voltage of PVDD exceeds 15V (typ.). When WPT_OVP function operates, output of LDO is turned off and the clamp circuit of the rectifier is turned on. When WPT_OVP is detected, the voltage of PVDD terminal falls and wireless power operation stops because the output of internal detection signal is latched. WPT communication also stops.

9.6.3 Over current detection (OCL) function

Over current detection (OCL) function suppresses the output current of LDO. The detection condition of OCL function is that the current exceeds the output current limited by the voltage of VOUT (refer to the Figure 8.5).
In case the OCL detection time is 4ms(typ.) or more, transmitting power is finished by transmitting EPT signal (05h:Over Current). OCL detection current is 1.3A(typ.).

9.6.4 Thermal shutdown (TSD) function

Thermal shutdown (TSD) function avoids the IC destruction, which is caused by rising the 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. In case the TSD detection time is 200ms or more, output of LDO turns off and transmitting power is finished by transmitting EPT signal (03h:Over Temperature).

9.6.5 External over temperature protection (OTP) function

External over temperature protection (OTP) function avoids the IC destruction, which is caused by rising temperature, by monitoring the voltage of the external thermistor. The detection condition of OTP function is that the voltage of the external thermistor exceeds the voltage configured by SET_OVTEXT register. In case the OTP detection time is 1ms or more, output of LDO turns off and transmitting power is finished by transmitting EPT signal (03h:Over Temperature)

9.6.6 Select control of external power (SW_UVLO/SW_OVLO) function

SW_UVLO/SW_OVLO function selects the wireless power output and the external power input with the external load switch by monitoring the voltage of SW_DET terminal.
When the voltage of SW_DET terminal is less than 4.0V (typ.), SW_UVLO function turns off the external load switch and selects the wireless power output. When the voltage of SW_DET terminal rises to the voltage of SW_UVLO detection voltage or more, wireless power output is turned off by selecting the external power input and tuning on the external load switch.
SW_OVLO function turns off the external load switch when the voltage of SW_DET terminal is 5.75V (typ.) or more. It does not output the wireless power.

9.6.7 Abnormality detection for LDO output function

Abnormality detection for LDO output function detects abnormal operation by monitoring the output voltage of VOUT. When the voltage of VOUT falls below 4.4V (typ.) for 3.5s or more, output of LDO turns off and transmitting power is finished by transmitting EPT signal (00h:Unknown).
When the voltage of VOUT exceeds 5.6V (typ.) for 64ms or more, output of LDO turns off and transmitting power is finished by transmitting EPT signal (06h:Battery Failure).

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.

Note PGND=0V

Note 1: Apply to PVDD terminal

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

Note 3: Apply to SW_EN and SW_DET terminals

Note 4: Apply to VPP terminal

Note 5: Apply 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 = 7V, PGND = 0V, SW_DET = 0V, Ta = 25°C)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
Operation voltage		V_{OPE}		3.7	-	15	V	PVDD
UVLO detection voltage		V_{UVLO_ON}	VRECT = 7V to 0V	3.6	-	-	V	PVDD
UVLO release voltage		V_{UVLO_OFF}	VRECT = 0V to 7V	-	-	4.2	V	PVDD
Quiescent current		I_{CC}	VRECT = 7V AC1 = AC2 = Open 5V LDO off	-	2.5	6.0	mA	PVDD
Input voltage(1)	High level	V_{IH1}		1.4	-	-	V	XEN
	Low level	V_{IL1}		-	-	0.4		
Input current(1)	High level	I_{IH1}	$V_{IH1} = V_{OUT45}$	20	-	75	μA	XEN
	Low level	I_{IL1}	V_{IL1} = GND	-0.6	-	0.6		
Output voltage	Low level	V_{OL1}	I_{OUT} = -1mA	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 = 7.0V, PGND=0V, SW_DET = 0V, Ta = 25°C)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
Rectifier MOSFET on-resistance	High-side	R_{ONH_AC}	I_{DS} = -100mA	-	45	-	mΩ	AC1, AC2
	Low-side	R_{ONL_AC}	I_{DS} = 100mA	-	30	-		
Clamper MOSFET on-resistance		R_{ON_CLMP}	I_{DS} = 100mA	-	-	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 5V LDO

Table 11.3 DC Characteristics 5V LDO

(Unless otherwise specified, VRECT = 7.0V, PGND = 0V, SW_DET = 0V, Ta = 25°C)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
5V LDO output voltage accuracy	$AccV_{OUT}$	LDO MODE I_{OUT} = 10mA	-2	-	2	%	VOUT
5V LDO OCL current	I_{OCL1}	VOUT = 5V, SET_OCL=11b	1.1	1.3	1.5	A	VOUT
5V LDO short current	I_{OCL2}	VOUT = 0V, SET_OCL=11b	0.25	0.35	0.45	A	VOUT
OCL current change voltage threshold	V_{OCL}	VOUT falling	-	-	2.4	V	VOUT
Discharge resistance	R_{DCHG}		6	9	12	kΩ	VOUT

11.4 DC Characteristics Outside Load Switch Driver

Table 11.4 DC Characteristics Outside Load Switch Driver

(Unless otherwise specified, SW_DET = 5V, PGND = 0V, Ta = 25°C)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit	Terminal
SW_DET leakage current		I_{DET}	V_{OUT} = 0V	250	-	500	μA	SW_DET
SW_UVLO detection voltage		V_{SUVLO_ON}	SW_DET = 5V to 0V	3.8	-	-	V	SW_DET
SW_UVLO release voltage		V_{SUVLO_OFF}	SW_DET = 0V to 5V	-	-	4.4	V	SW_DET
SW_OVP detection voltage		V_{SOVP_ON}	SW_DET = 5V to 6V	-	-	5.9	V	SW_DET
SW_OVP release voltage		V_{SOVP_OFF}	SW_DET = 6V to 5V	5.55	-	-	V	SW_DET
SW_EN sink current 1		I_{SWEN1}	SW_DET = 5V	-	-	6.5	μA	SW_EN
SW_EN output voltage	High level 1	V_{OH_SWEN1}	SW_DET = 10V, VOUT = 0V I_{OUT} = 0.1mA	9.5	-	10	V	SW_EN
	High level 2	V_{OH_SWEN2}	SW_DET = 0V, VOUT = 5V I_{OUT} = 0.1mA	4.5	-	5	V	
	Low level	V_{OL_SWEN}	SW_DET = 5V, I_{OUT} = -1mA	-	-	0.4	V	
VOUT terminal leakage current		I_{LEAK_VOUT}		-	-	200	μA	VOUT

12. Application Circuit

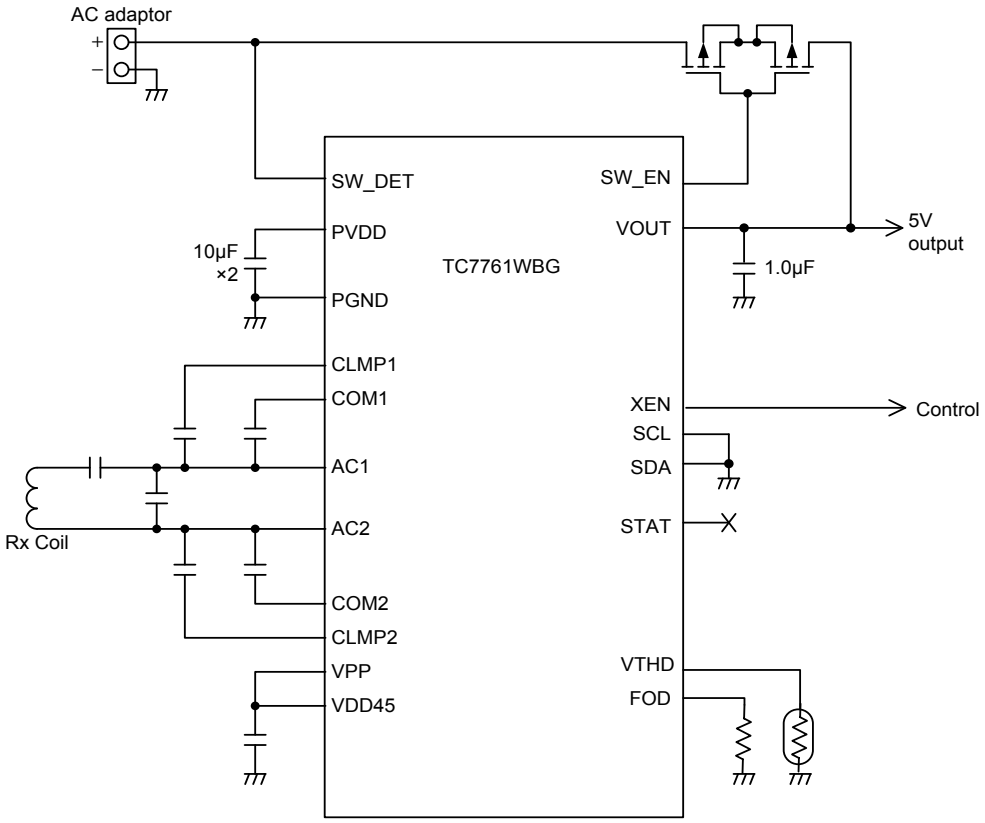
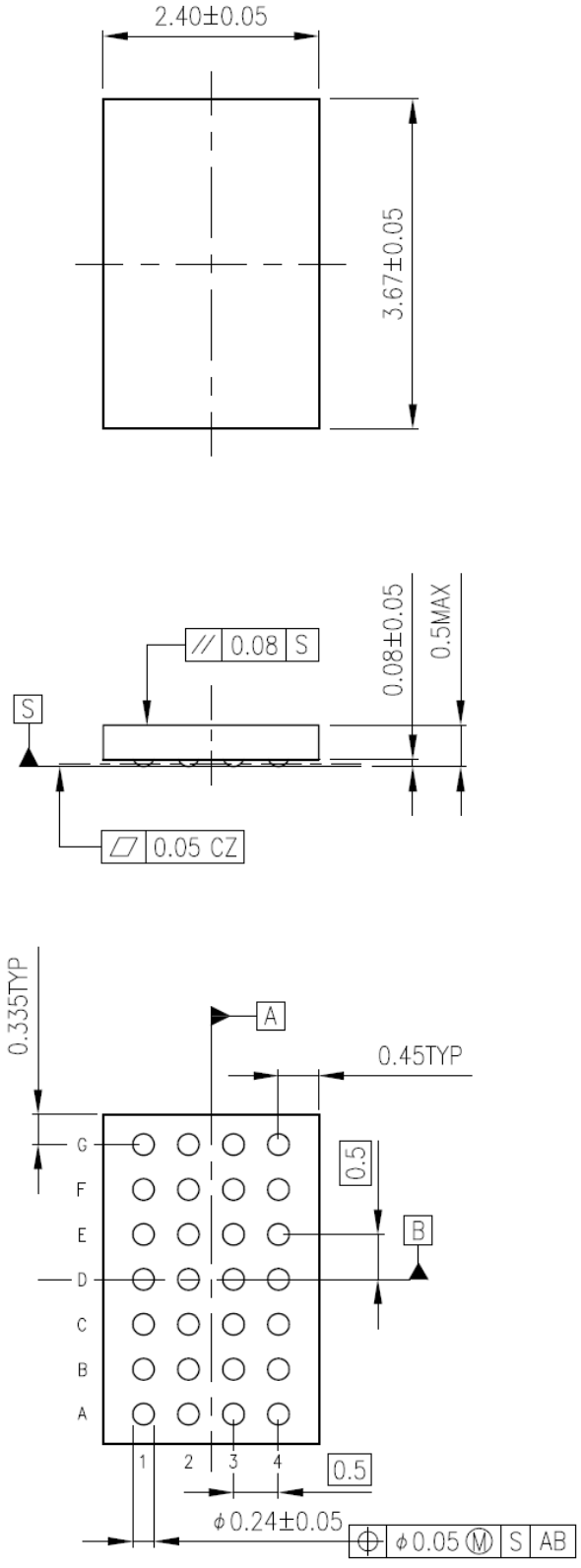


Figure 12.1 Application circuit

13. Package dimensions

S-XFLGA28-0304-0.50-001



Weight: 10mg (typ.)

Note 1: Unit: mm
Note 2: Outer size: After simulation

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