

P9261-3C-CRBv2

Power-Loss and FOD Tuning Guide

This application note describes the functionality of the P9261 Automotive CRB 2.0 Wireless Power Transmitter (Tx) and its Foreign Objects Detection (FOD) by measuring the power that is being absorbed by the object.

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1. Introduction

The P9261 Automotive CRB 2.0 Wireless Power Transmitter (Tx) is used to transmit wireless power to wireless power receivers (Rx) devices following WPC specifications and protocols. An important operating attribute of all WPC systems is the ability to detect Foreign Objects (FO) by measuring the power that is being absorbed by the object. In standard operating mode, the Rx device will send a Received Power Packet (RPP) approximately every 500ms. The RPP informs the Tx how much power the Rx is currently receiving and includes the estimate of the power loss in the Rx device due to friendly metal energy absorption. Once the RPP is received, the Tx compares this power to the Tx_{POWER} (see Equation 1) and if three consecutive results of PDiff (see Equation 2) are above the PThreshold, then the Tx will shut down due to FOD alarm.

 $Tx_{POWER} = VBRG(mV)x IBRG(mA)/1000$

Equation 1

where,

VBRG = input voltage to the Tx controller IC (measured at VBRG_IN (pin 40) of the P9261) IBRG = DC average current in the Tx Full Bridge (measured across RSNS (R18) on P9261 EVK)

The VBRG and IBRG values are directly measured by the P9261 during operation and the values that need to be tuned are the various power loss levels due to friendly metal associated with the Tx device under design at the various power levels. The P9261 FOD tuning includes tuning the Tx losses out of the equation used to determine if a FO is present or not. The Renesas solution uses regions with gain and offset to change the threshold based on the latest value of the RPP packets received. If RPP is larger than T_{XPOWER} , PDiff will be treated as 0.

 $PDiff = Tx_{POWER} - RPP$

After PDiff is calculated, the P9261 calculates the thresholds used to determine if FOs are present or if normal power transfer can continue safely. The thresholds can be calculated using the following formulas and the value of the threshold is dependent upon the most recently received RPP value:

FOD Pthreshold = (PRX*Gain_{REGION} + FOD_Offset_{REGION}) + Offset_FOD

Equation 3

Equation 2

Once the FOD power thresholds are calculated, they are compared to the calculated P_{DIFF} result and the result is used based on the following FW code snippet:

```
If PDIFF > PThreshold
{
        Count_FOD++
        IF Count_FOD > 3
        {
            FOD Shutdown
        }
    }
Else
{
        Count_FOD = 0
}
```

2. P9261 Power-Loss FOD Tuning Overview

This section describes how to tune the P9261 Power Loss FOD using the registers available for this purpose.

Cena P9261 C	RB 2.0 (Disconnected)																- 0	×
File Conne	ct View Window I	Help																
Control	Q Configuration	System Info	Flash I	Programmer	FOD Tuning	× Realtime D	ata											₹
BPP									5W EPP									
Read A	All Write All								Read Al	I Write All								
		Coil 1		Coil 2		Coil 3					Coil 1		Coil 2		Coil 3			
	FOD POWER L1	820	mW	1640	mW	820	mW	BPP Region		FOD POWER L1	2140	mW	2110	mW	2140	mW g	W EPP	
	FOD POWER L2	3860	mW	3400	mW	3860	mW	Control		FOD POWER L2	4100	mW	3900	mW	4100	mW F	Region Co	ntrol
	FOD GAIN L0 (+/-)	9369		2022		9369	R	P Gain Pegion		FOD GAIN L0 (+/-)	5065		1995		5065			
	FOD GAIN L1 (+/-)	2541		1024		2541	Dr	-r Gainkeyion		FOD GAIN L1 (+/-)	1735		1004		1735		SW EPP GainRegic	n
	FOD GAIN L2 (+/-)	2939		1661		2939				FOD GAIN L2 (+/-)	2082		1885		2378			
	FOD OFFSET L0 (+/-)	1645	mW	468	mW	1645	mW	RDD		FOD OFFSET L0 (+/-)	1866	mW	79	mW	1566	mW		
	FOD OFFSET L1 (+/-)	2188	mW	632	mW	2188	mW	OD_OffsetReg	on	FOD OFFSET L1 (+/-)	2578	mW	288	mW	2278	mW	OD offse	tRegion
	FOD OFFSET L2 (+/-)	2043	mW	415	mW	2043	mW			FOD OFFSET L2 (+/-)	2386	mW	-55	mW	2100	mW		
	FOD HOLDOFF TIME	3	Counts	3PP FOD ALA	RM Confirm	n Times				FOD HOLDOFF TIME	3	Counts	5W EPP F		1 Confirm Ti	mes		
- EPP									FOD Disable	2								
Read /	All Write All								Read	All Write All								
		Coil 1		Coil 2		Coil 3												
	FOD POWER L1	1500	mW	1740	mW	1500	mW	EPP Region		0	FOD D	Disable						
	FOD POWER L2	3630	mW	5850	mW	3630	mW	Control	FOD Disab	Q FOD Disable	Conto	rl						
	FOD POWER L3	7800	mW	9780	mW	7800	mW			Ploss FOD Disab	ble							
	FOD POWER L4	12150	mW	13000	mW	12150	mW											
	FOD GAIN L0 (+/-)	4438		2436		3594												
	FOD GAIN L1 (+/-)	721		316		967	EP	P GainRegion										
	FOD GAIN L2 (+/-)	820		1577		1151												
	FOD GAIN L3 (+/-)	1712		2423		1473												
	FOD GAIN L4 (+/-)	2277		3879		2289												
	FOD OFFSET L0 (+/-)	1400	mW	-173	mW	1455	mW											
	FOD OFFSET L1 (+/-)	2015	mW	196	mW	1742	mW	EPP										
	FOD OFFSET L2 (+/-)	1980	mW	-550	mW	1665	mW	FOD_OffsetReg	ion									
	FOD OFFSET L3 (+/-)	1257	mW	-1569	mW	1387	mW											
	FOD OFFSET L4 (+/-)	573	mW	-3700	mW	407	mW											
	FOD HOLDOFF TIME	3	Counts	EPP FOD AL	ARM Confi	rm Times												
Host Log																		▼ X
line																		Save
Host Log	GUI Log																	

Figure 1. P9261 Automotive CRB 2.0 GUI Screen Capture FOD Tuning Tab

The Power Difference (P_{DIFF}) thresholds are segmented by power regions and are programmed by the Region Control registers and are entered based on the most recent RPP value. For example, In BPP mode there are two regions that must be programmed. Region 1 (L0) applies for RPP values from 0W up FOD_POWER_LP_L1_Coiln (0x0890), Region 2 (L1) applies to FOD_POWER_LP_L1_Coiln < RPP < FOD_POWER_LP_L2_Coiln (0x0892) values and Region 3 (L2) applies for RPP values greater than FOD_POWER_LP_L2_Coiln (0x0892). Equation 3 can be used to calculate the threshold that is compared to PDIFF based on the current region being used for the FOD_{Pdiff} calculation.

In order to tune the PowerLoss FOD, use the RPP value to select the Region that the OFFSET and GAIN will be applied to, and to select which OFFSET and GAIN will be used for the calculation. The FOD_Offset should be programmed, and this parameter shifts the threshold up or down for specific. The GAIN is used to set the slope for the specific region being tuned. The primary purpose of these tunable parameters is to try to match (or account for) the efficiency changes of the system as the load changes from no load to full load.

3. Step-by-Step Power-Loss FOD Thresholds Tuning

- Connect the P9261's coil#2 to an BPP Rx (calibrated WPC-Certified Rx recommended) and sweep the load from 0A up to 10% beyond the full-scale output load (for example, 5W BPP Rx, sweep the load up to 5.5W or 1.1A), and record TxPOWER (PTx), RXPOWER (PRx) and PowerDiff at each load.
- 2. Disable power loss FOD and put the FO between Rx and Tx, then record the PRx, PRx and PowerDiff the same as step 1.

Coil#2		BPP RxBPP Rx and FO					Threshold
Load	PTx(mW)	PRx(mW)	PowerDiff	PTx (mW)	PRx (mW)	PowerDiff	(mW)
0mA	430	468	0	920	507	413	206.5
100mA	1100	1105	0	1520	1100	420	210
200mA	1500	1520	0	1960	1520	440	220
300mA	2100	2030	70	2600	2030	570	300
400mA	2610	2500	110	3100	2500	600	355
500mA	3170	3000	170	3700	3000	700	435
600mA	3800	3590	210	4360	3550	810	530
700mA	4430	4140	290	5040	4100	940	615
800mA	5080	4690	390	5760	4690	1070	730
900mA	5780	5310	470	6480	5270	1210	840
1000mA	6490	5890	600	7250	5870	1380	1000
1100mA	7200	6440	760	8030	6450	1580	1170

Table 1. Power Data with Rx, Rx and FO, and Threshold

3. Calculate the threshold from the power data in "BPP Rx" and "BPP Rx and FO" as (Equation 4). Usually, we make the threshold similar to PowerDiff_{BPP_RX_and_FO} by Adjust_Offset and make the Trendline Curve linearly.

Threshold = (PowerDiff_{BPP_RX} + PowerDiff_{BPP_RX}_and_FO)/2 ± Adjust_Offset Equation 4

- 4. Draw "PowerDiff_{BPP_RX} vs PRx_{BPP_RX}", "PowerDiff_{BPP_RX_and_FO} vs PRx_{BPP_RX_and_FO}" and "Threshold vs PRx_{BPP_RX}" in the same chart. From the chart below (see Figure 2), we can see slope changes, then we can get the Region Control setting: the 3rd and 10th point's PRx will be used as the "FOD Power L1" and "FOD Power L2".
- 5. Now the threshold line has been separated into 3 regions, with each region getting a linear trendline. From the trendline's equation, we can get each region's Gain_{REGION} and FOD_Offset_{REGION}. Gain_{REGION} = Slope * 10000 and FOD_Offset_{REGION} = y-Intercept in mW.



Figure 2. Measurements Needed to Tune FOD with P9261

6. After obtaining all the FOD parameters, they can then be written to the 9261 via the GUI (see Figure 3).

WPT Control	WPT Q Configuration	WPT System Info	Flash	WPT Programmer	WPT FOD Tunii	ng×	WPT Realtime I	Data	WPT Memory Logging
Read A	II Write All	6.11		6.12			0.12		
	FOD POWER L1	820	mW	1520	mW		820	mW	
	FOD POWER L2	3860	mW	5310	mW 2		3860	mW	
	FOD GAIN L0 (+/-)	9369		122			9369		
	FOD GAIN L1 (+/-)	2541		1628	3		2541		
	FOD GAIN L2 (+/-)	2939		2919			2939		
	FOD OFFSET L0 (+/-)	1645	mW	199	mW		1645	mW	
	FOD OFFSET L1 (+/-)	2188	mW	-41	mW 4		2188	mW	
	FOD OFFSET L2 (+/-)	2043	mW	-712	mW		2043	mW	

Figure 3. Set the FOD Parameters via the GUI for BPP Coil 2

7. By putting Rx and FO together on Tx, see how the new parameters have taken effect. RPP 3750 is in the region L1, so the threshold should be 3750 * 0.1628 – 41 = 569mW.

•••• P9261 CRB 2.0 ×							
ile Connect Vie	w Window Help						
Control Q Configuration System Info Flash Programmer FOD Tuning Realtime Data							
Tx_State	Q-Measurement (3)		QCoil3	1591			
Tx_Status	24		FreqCoil1	125			
Coil_Num	3	-	FreqCoil2	116			
Exit Code	54]	FreqCoil3	116			
FPwm_Duty	15	%	POWER_TX	4863	mW		
FPwm_Freq	120	kHz	POWER_RX	3750	mW		
VBRG	5528	mV	POWER_DIFF	1113	mW		
Current	130	mA	FOD_THRESHO	569	mW		
Tx_VIN	12028	mV	RX_TYPE	1			
Coil_Peak_Volt	23	V	RX_ID	0x0000			
QCoil1	1318		RX_QF	0			
QCoil2	1436		RX_RF	0			
Host Log						•	
						Sav	
Host Log GUI Log							

Figure 4. Verify the New Parameters

8. Save the FW onto a new hex file. Go to the "WPT Flash Programmer" tab and click on "Save to hex file" (see Figure 5). A dialog box will be open. Choose the name of the file and the location to save it.

P9261 CRB 2.0					- 🗆 ×
WPT WPT Control FOD Tuning Q	WPT Configuration	WPT System Info Flas	WPT × Rea	WPT Itime Data	
Program File: D:\Profile\Deskt	op\p9261_CRB_2p0	_Release_Build -v0.0	.21.0-2022-1-20.hex		Select
Erase Flash	Save To Hex	3 Click save t	o hex		1 Load the correc
Configuration					original hex
Read All Write All					
Customer CFG Info	01 2 En	ter the correc	t cfg info		
Save File					×
$\leftarrow \rightarrow \checkmark \uparrow \blacksquare$ > This PC	> Desktop >			✓ C Sear	rch Desktop
Organize 👻 New folder					⊾ - ?
This PC	^				
3D Objects		2	2		
Desktop Decuments					
Downloads		Doc	GUI	p9261_CRB_2p0_	save.hex
Music				Release_Build -v0.0.21.0-2022-1	
E Pictures				-20.hex	
🚪 Videos					
🕮 Windows (C:)	~				
File name: save.hex	4 Chose a	a name			~
Save as type: Hex files (*.ł	nex)				~

Figure 5. Windows Dialog Box to save.hex File under New User Defined Name

9. Repeat steps 1 through 7 to obtain the parameters for coils 1 and 3. Then use the same methods to obtain the parameters for 5W EPP and EPP; 5W EPP is similar to BPP. EPP is similar as well, with the only difference being EPP's power range is 0 to 15W, so EPP uses 5 regions.

4. P9261 Power-Loss FOD Applicable Registers

Refer to document <u>P9261-3C-CRB2.0 Command/Status Registry</u>, "Table 9. Power Loss FOD' in section "4.6 Power Loss FOD".

5. Revision History

Revision	Date	Description
1.00	May 2, 2022	Initial release.

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan www.renesas.com

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