HPB

Operational Description

August 9, 2013

GENERAL DESCRIPTION

The High Power Board (HPB) uses RF communications for building wide clock synchronization and is the "Master Transceiver" for the system. The HPM uses the 2.4 GHz ISM frequency band to provide communications clock to clock.

The HPB uses the Texas Instruments CC2500 RF Transceiver, the Texas Instruments CC2591 RF Front End, the Avago ALM-31222 Power Amplifier (PA) and the Texas Instruments MSP430F2252 microcontroller.

The antenna is external to the board. The antenna connector is an SMA type.

The board shall meet all FCC requirements for license free operation in the 2.4GHz ISM band. The receiver input sensitivity shall be better than 104 dBm while transmitter output shall be up to +30dBm.

1.1 Overview

The HPB is designed to connect to only Sapling Digital Systems. The HPB provides RF communications using the CC2500 RF transceiver chip as the basis for a complete RF transceiver. The CC2591 RF Front-End adds an LNA (Low-Noise-Amplifier) to improve receiver sensitivity and an output PA (Power-Amplifier) to increase the output power to +18dBm. The final power output of +30dBm is provided by the Avago ALM-31222 PA. The MSP430F2252 microcontroller controls the CC2500 through a SPI interface and also controls receiver and transmitter signal routing RF switches.

1.2 RF Section

The CC2500 is the heart of the RF section. It contains the input LNA, mixer, synthesizer, demodulator, IF amplifier, RSSI circuitry, and transmit PA in one chip. The CC2591 provides an additional receiver LNA and transmit PA while the Avago ALM-31222 boosts the transmit output power.

The required external antenna is a half-duplex, center-fed type, optimized for the 2.4GHz ISM frequency band. The antenna is provided by Sapling for the customer's use.

1.2.1 Receive

The input sensitivity of the CC2500 is typically -104 dBm. The antenna input is filtered and matched to the CC2500 input. The CC2591 provides additional signal gain by use of its LNA.

RF Network

The receiver turns ON 5 seconds before the estimated receive time and waits for up to 15 seconds to get the signal. During this time the receiver changes frequency every 3 ms. The receiver is on once a minute.

1.2.2 Transmit

The output of the CC2500 is matched and filtered to the CC2591. The maximum output power of the CC2500 is 0 dBm. This signal is amplified by the CC2591 and has a maximum output, after filtering, of 18 dBm and is presented to the ALM-31222. The ALM-31222 output of up to +30dBm is fed through RF switches to the antenna connector. The ALM-31222 is further filtered and matched ahead of the SMA antenna connector/antenna.

The transmit cycle is a sequence of 80 data strings on 76 different frequencies, each transmitted for 3 msec. Every transmit cycle is 240 msec in duration (80 x 3ms) and this occurs once each minute.

The frequency hopping pattern is proprietary to Sapling but covers the range from 2.433 Ghz to 2.449 Ghz. The transmitter's pseudorandom hoping sequence table is attached at the bottom of this document.

1. Detailed Operational Description:

There are 76 discrete channels used. There is a 200Khz separation between adjacent channels but due to the hopping table, the closest carrier frequencies are 400 KHz apart. At each transmission cycle (once every minute), 80 channels are transmitted. Assume the transmitter begins at line #1 in the table (channel 43). Channels associated with lines 1 through 76 are transmitted, followed by transmitting channels associated with lines 1 through 4, for a total of 80 channels. After one minute, channels associated with lines 5-76 are transmitted, followed by transmitting channels associated with lines 1-8, for a total of 80 channels. After another minute, channels associated with lines 9-76 are transmitted, followed by transmitting channels associated with lines 1-12, again for a total of 80 channels. And so on.

For example, after stopping at line 8 (channel 7), the next sequence starts at line 9 (channel 27).

To be clear, Sapling's clocks do not require receiving the time signal consistently because only a time correction is required. Each clock has an internal Real-Time-Clock that is reasonably accurate. Hence, the receivers are not synched to the transmitter in the normal use of frequency hopping systems. Any successfully received channel updates the internal Real-Time-Clock for the exact time. The system is much more random in terms of when the signal is received than standard hopping systems because so little data is exchanged (Time) and only one channel needs be successful in matching the receiver to the transmitter.

The receiver and transmitter have the same bandwidth. The receiver is open for a maximum of 7 seconds or until the data is received. The Receiver hops every 100ms.

Sapling Proprietary Psedo-Random Hopping Table

2.4GHz Channel Frequencies and Sequencing

Line #	Start Frequency	Step	Next Channel	Channel Frequency
1	2433	0.2	43	2441.6
2	2433	0.2	16	2436.2
3	2433	0.2	46	2442.2
4	2433	0.2	33	2439.6
5	2433	0.2	30	2439.0
6	2433	0.2	13	2435.6
7	2433	0.2	25	2438.0
8	2433	0.2	7	2434.4
9	2433	0.2	27	2438.4
10	2433	0.2	5	2434.0
11	2433	0.2	17	2436.4
12	2433	0.2	10	2435.0
13	2433	0.2	24	2437.8
14	2433	0.2	31	2439.2
15	2433	0.2	37	2440.4
16	2433	0.2	6	2434.2
17	2433	0.2	47	2442.4
18	2433	0.2	29	2438.8
19	2433	0.2	2	2433.4
20	2433	0.2	15	2436.0
21	2433	0.2	12	2435.4
22	2433	0.2	32	2439.4
23	2433	0.2	51	2443.2
24	2433	0.2	9	2434.8
25	2433	0.2	26	2438.2
26	2433	0.2	22	2437.4

Line #	Start Frequency	Step	Next Channel	Channel Frequency
27	2433	0.2	49	2442.8
28	2433	0.2	39	2440.8
29	2433	0.2	42	2441.4
30	2433	0.2	44	2441.8
31	2433	0.2	1	2433.2
32	2433	0.2	69	2446.8
33	2433	0.2	21	2437.2
34	2433	0.2	57	2444.4
35	2433	0.2	75	2448.0
36	2433	0.2	35	2440.0
37	2433	0.2	3	2433.6
38	2433	0.2	41	2441.2
39	2433	0.2	50	2443.0
40	2433	0.2	36	2440.2
41	2433	0.2	45	2442.0
42	2433	0.2	28	2438.6
43	2433	0.2	48	2442.6
44	2433	0.2	23	2437.6
45	2433	0.2	72	2447.4
46	2433	0.2	34	2439.8
47	2433	0.2	14	2435.8
48	2433	0.2	4	2433.8
49	2433	0.2	0	2433.0
50	2433	0.2	38	2440.6
51	2433	0.2	11	2435.2
52	2433	0.2	40	2441.0
53	2433	0.2	73	2447.6
54	2433	0.2	66	2446.2
55	2433	0.2	54	2443.8
56	2433	0.2	18	2436.6
57	2433	0.2	64	2445.8
58	2433	0.2	68	2446.6
59	2433	0.2	58	2444.6
60	2433	0.2	74	2447.8
61	2433	0.2	60	2445.0
62	2433	0.2	61	2445.2
63	2433	0.2	71	2447.2
64	2433	0.2	63	2445.6
65	2433	0.2	56	2444.2
66	2433	0.2	65	2446.0
67	2433	0.2	53	2443.6
68	2433	0.2	67	2446.4
69	2433	0.2	19	2436.8

Line #	Start Frequency	Step	Next Channel	Channel Frequency
70	2433	0.2	55	2444.0
71	2433	0.2	70	2447.0
72	2433	0.2	62	2445.4
73	2433	0.2	20	2437.0
74	2433	0.2	52	2443.4
75	2433	0.2	59	2444.8
76	2433	0.2	8	2434.6