LPA-24G-1

Operational Description August 9, 2013

GENERAL DESCRIPTION:

The Low Power Analog Board (LPA) uses RF communications for building wide clock synchronization. The LPA uses the 2.4 GHz ISM frequency band to provide communications clock to clock.
The LPA board uses the Texas Instruments CC2500 RF transceiver, the Texas Instruments CC2591 RF Front End and the Texas Instruments MSP430F2252 microcontroller.

Other features include an "Inverted F" printed circuit board (PCB) pattern antenna design. The board shall meet all FCC requirements for license free operation in the 2.4GHz ISM band. The receiver input sensitivity shall be better that 104 dBm while transmitter output shall be up to 18 dBm.

1.1 Overview

The LPA integrates the analog clock driver gearbox with an RF communications interface using the CC2500 RF transceiver chip as the basis for a complete RF transceiver. The microcontroller handles all time keeping functionality; it controls the hand movement of the gearbox and also controls the RF transceiver. It's normally in sleep mode until an update is required, keeping the average power consumption very low in order to extend battery life.

1.2 RF Section

The CC2500 is the heart of the RF section. It contains the input Low Noise Amplifier (LNA), mixer, synthesizer, demodulator, IF amplifier, RSSI circuitry, and transmit Power Amplifier (PA) in one chip. The CC2591 provides an additional LNA and transmit PA to boost the output further.

The "Inverted F" PCB pattern antenna is used for both the transmit and receive paths. Provisions will be made for an optional SMA connector so that an external antenna can be attached for in-house testing only. This connector is not added to the circuit board in production.

1.2.1 Receive

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

RF Network

The transceiver is only on for few seconds every 2 hours for the battery clocks, or once a minute for line-powered clocks.
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.

1.2.2 Transmit

The output of the CC2500 is connected to the PCB antenna through matching and filtering circuitry. 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 presented to the 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).

The frequency hopping pattern is proprietary to Sapling but covers the range from 2.433 Ghz to 2.449 Ghz.

1. **Operational Description:**

There are 76 discrete channels used.
The transmitter's pseudorandom hoping sequence table is attached at the bottom of this document. There is a 200Khz separation between
adjacent channels but because of the hopping, 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.

2. **External photos:** Please provide clearer external photos, show the power and data or other connections. (Show All Sides)

3. **Block diagram:** Please show electrical and data connection to host devices.

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
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
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