LPM-24G-1 **Operational Description** **August 9, 2013**

GENERAL DESCRIPTION:

The Low Power Module (LPM) uses RF communications for building wide clock synchronization. The LPM uses the 2.4 GHz ISM frequency band to provide communications clock to clock.

The LPM board uses the Texas Instruments CC2500 RF transceiver and the Texas Instruments CC2591 RF Front End. 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 LPM is designed to connect only to the Sapling Digital Clock Main Board. The LPM 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 microcontroller on the Sapling Digital Main Board controls the CC2500 through a SPI interface. This external processor also handles all time keeping functionality.

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.

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 channels (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. The transmitter's pseudorandom hoping sequence table is attached at the bottom of this document.

Detailed Hopping Description:

There are 76 discrete channels used. There is a 200Khz separation between adjacent channels, but due to the hopping pattern, 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
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