Standalone Multiband WSPR beacon transmitter (MEPT)

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SPECIFICATIONS

Modulation:
4-FSK,
WSPR broadcast (Layland-Lushbaugh polynomials for a K=32, r=1/2 convolutional code)

Impedance:
50 Ohm

Power Output:
10mW (for SI570 output), or
500mW (for BS170 PA)

Operating frequencies:
3.5926MHz, 5.2872MHz[1], 7.0386MHz, 10.1387MHz,
14.0956MHz, 18.1046MHz, 21.0946MHz, 24.9246MHz,
28.1246MHz, 50.293MHz[2], 144.488MHz[3]

Interface:
USB 1.1

System Requirements:
Intel, Windows (for configuration purpose only)

Supply:
12V, 500mA

SCHEMATIC

The following is a design of a standalone MEPT beacon used for WSPR broadcasts [2]. It is based on a Si570 programmable crystal oscillator (silabs.com) which is controlled by means of an AVR attiny45 microcontroller. The Si570 device is FSK modulated by the AVR via a sequence of I2C control commands that are sent to slightly change the frequency for every transmitted WSPR symbol. The Si570 device outputs a power of 10mW which is sufficient for WSPR operation (i.e. an antenna with some LPF can be directly attached). For increased power up to 500mW, a small BS170 based power amplifier may be added. As the beacon alternately changes

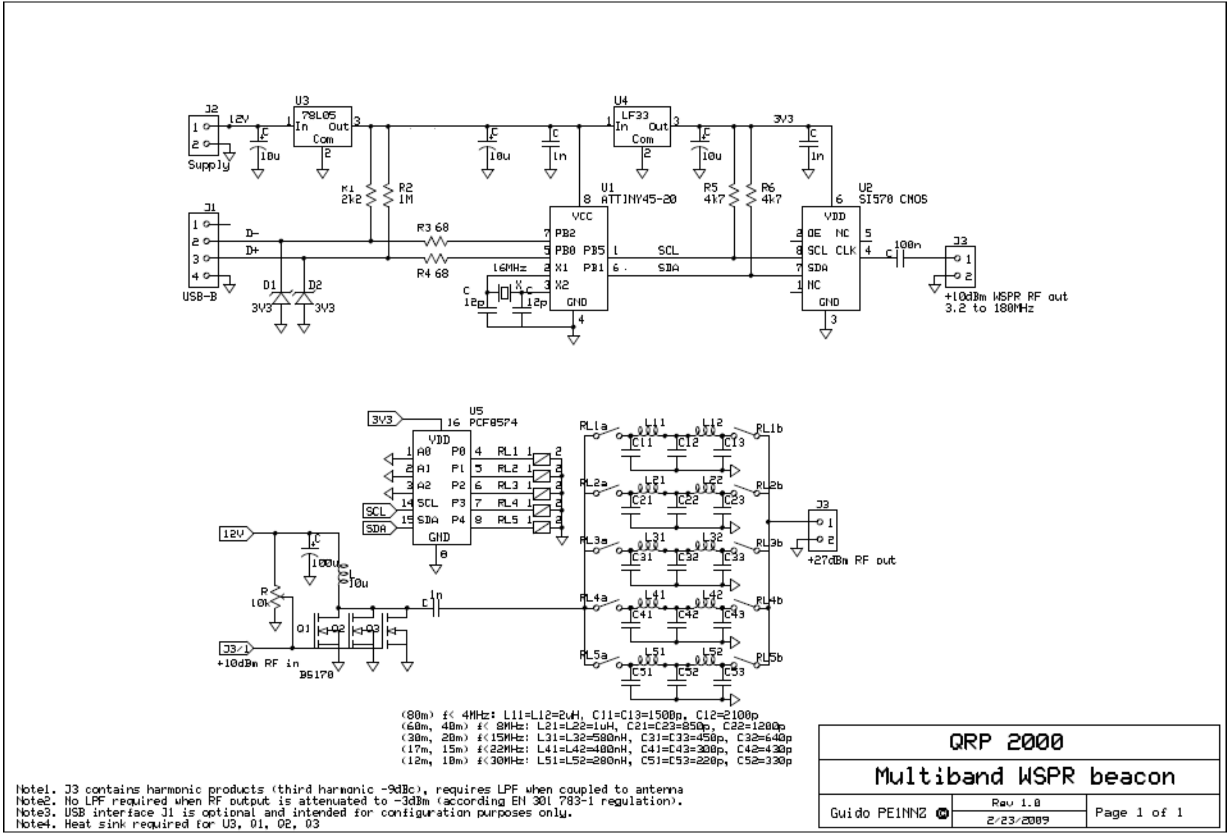
[1]

[2]

[3] currently disabled in firmware

frequencies, the filters should be made switchable. Optionally this filter switching could be controlled by the microcontroller via I2C and a PCF8574 device (not supported by supplied firmware).

The following kits can be used as a foundation for the beacon: USB Synth (www.sdr-kits.com), FA-SY1 (www.funkamateur.de), Softrock Lite+USB XtallV9.0 or USB I2C XTALL Interface Board (www.kb9yig.com). Be aware that the wiring in this beacon is slightly different; an additional crystal is used and some lines to the AVR pins have been modified. The crystal is required in order to get an accurate two minute interval clock (the internal high frequency PLL oscillator is too inaccurate).



(80m) f< 4MHz: L11=L12=2uH, C11=C13=1500p, C12=2100p
(60m, 40m) f< 8MHz: L21=L22=1uH, C21=C23=850p, C22=1200p
(30m, 20m) f<15MHz: L31=L32=580nH, C31=C33=450p, C32=640p
(17m, 15m) f<22MHz: L41=L42=400nH, C41=C43=300p, C42=430p
(12m, 10m) f<30MHz: L51=L52=280nH, C51=C53=220p, C52=330p

Note1. J3 contains harmonic products (third harmonic -9dBc), requires LPF when coupled to antenna
Note2. No LPF required when RF output is attenuated to -3dBm (according EN 301 783-1 regulation).
Note3. USB interface J1 is optional and intended for configuration purposes only.
Note4. Heat sink required for U3, Q1, Q2, Q3

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OPERATING

The AVR microcontroller should be programmed with a dedicated firmware (AVR-FirmwareV14\output\out.hex). The source code of the firmware can be compiler with AVR studio (www.atmel.com) and programmed with an AVR High Voltage programmer. The following fuse settings apply:

```
/*
 * Fuse bit information:
 * Fuse high byte:
 * 0xdd = 0 1 0 1   1 1 0 1
 *        ^ ^ ^ ^   ^ \-+-/
 *        | | | |   |    +------ BODLEVEL 2..0 (brownout trigger level -> 2.7V)
 *        | | | |   +---------- EESAVE (preserve EEPROM on Chip Erase -> not preserved)
 *        | | | +-------------- WDTON (watchdog timer always on -> disable)
 *        | | +---------------- SPIEN (enable serial programming -> enabled)
 *        | +------------------ DWEN (debug wire enable)
 *        +-------------------- RSTDISBL (disable external reset -> disabled)
 *
 * Fuse low byte:
 * 0xe1 = 1 1 1 0   1 1 1 1
 *        ^ ^ \+/   \--+--/
 *        | |  |       +------- CKSEL 3..0 (clock selection -> >8MHz Crystal Osc.)
 *        | |  +--------------- SUT 1..0 (BOD enabled, fast rising power)
 *        | +------------------ CKOUT (clock output on CKOUT pin -> disabled)
 *        +-------------------- CKDIV8 (divide clock by 8 -> don't divide)
 */
```

The AVR microcontroller can be interfaced with a PC via an USB port. A driver needs to be installed according chapter 4 of USB Synth assembly manual [1]. When connected the device to the PC:

a. the frequency of the si570 crystal oscillator can be calibrated against a reference source by using the USB_Synth tool by DG8SAQ (see chapter 10 of USB Synth assembly manual [1]), and:
b. the WSPR message to be transmitted on each frequency can be programmed in EEPROM, either by wsprcfg, or by writing manually the message in EEPROM (on addresses $50 and further) via SI570_USB_Test tool. The WSPR broadcast contains 162 symbols containing a callsign, location grid and the effective intrinsic radiated power. Grid is expressed in longitude/latitude where positive values mean respectively west/north and negative values mean east/south. Valid power values are: 0, 3, 7, 10, 13, 17, 20, 23, 27, 30, 33, 37, 40, 43, 47, 50, 53, 57 and 60 dBm. An example usage of using wsprcfg tool is shown below:

```
D:\temp\wsprcfg\Debug>wsprcfg k1jt 1 52 2
Symbols for callsign= K1JT ;lon=1;lat=52;dbm=27
3,3,2,0,2,2,2,2,1,0,2,0,3,3,3,2,2,0,3,2,0,3,0,3,1,1,3,0,0,2,2,0,0,0,1,0,0,3,2,3,
2,2,2,0,0,0,3,0,1,3,2,0,3,1,2,1,0,0,0,3,1,2,1,2,2,2,0,1,3,2,1,2,3,0,1,0,1,0,0,3,
2,0,1,0,1,3,2,2,0,3,3,0,3,0,1,0,2,2,3,0,2,0,0,2,1,0,0,3,2,0,1,1,1,0,1,3,2,0,1,3,
2,1,2,2,2,1,1,3,2,2,2,0,0,1,2,3,2,0,3,1,0,0,0,0,2,2,0,3,3,0,1,0,3,3,2,2,2,1,3,0,
2,2
```

The firmware source code has list of frequencies `freq_table` (AVR-FirmwareV14\main.c) on which the beacon sequentially transmits its WSPR broadcast. The table can be updated to specify the exact frequency to be transmitted in the 200Hz WSPR band, or to select to bands of interest to transmit on.

The beacon starts broadcasting when there is no USB attached and the beacon should be powered on at exactly one second after each even minute with respect to atomic time (www.time.gov). An error of about +/- 2 seconds is still acceptable. Once started, connected to an antenna and sufficient propagation, the beacon should show up in wsprnet.org.

Using the beacon over a longer period of time (days) can show some drift in the two minute beacon interval. It can be corrected in the firmware by modifying the number 3789 in the `T_INC` definition, or by changing some capacitor values near the crystal.

REFERENCES

[1] SDR-Kits.net, “QRP2000 USB-Controlled Synthesizer”, http://www.sdr-kits.net/USB-Synth-assembly.pdf

[2] G4JNT, “Non-normative specification of WSPR protocol”, http://www.g4jnt.com/Coding/WSPR_Coding_Process.pdf