VSRT MEMO #075

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September 9, 2014

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To: VSRT Group

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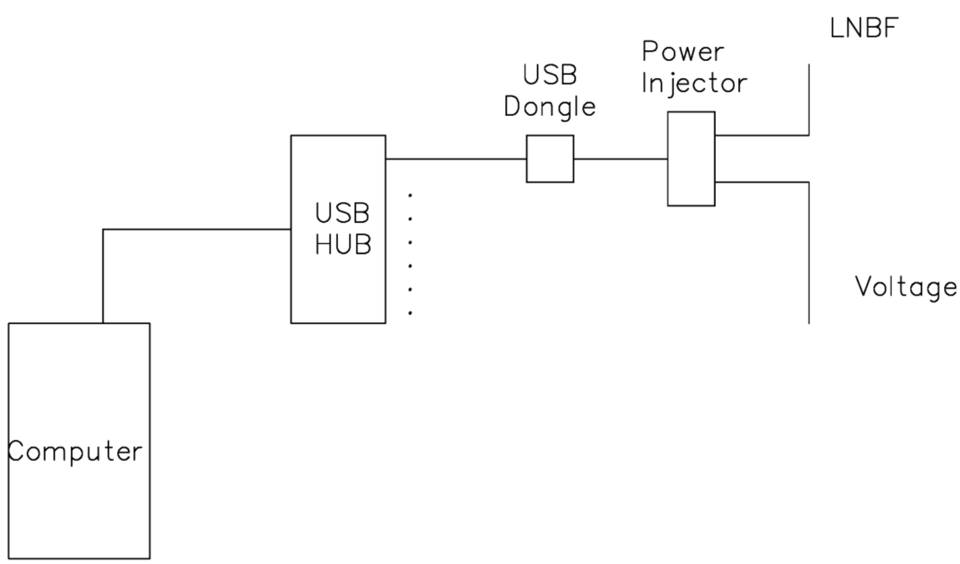
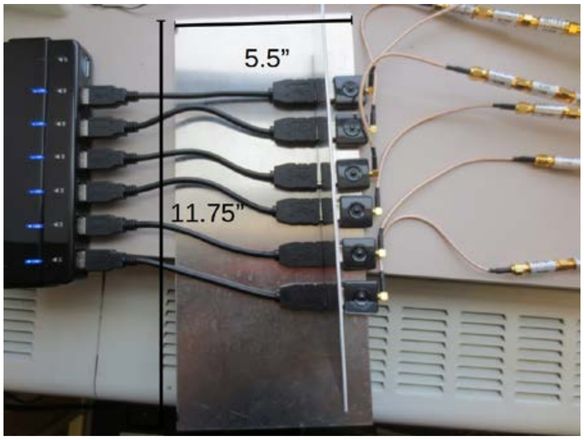
Subject: Cooling USB Dongles

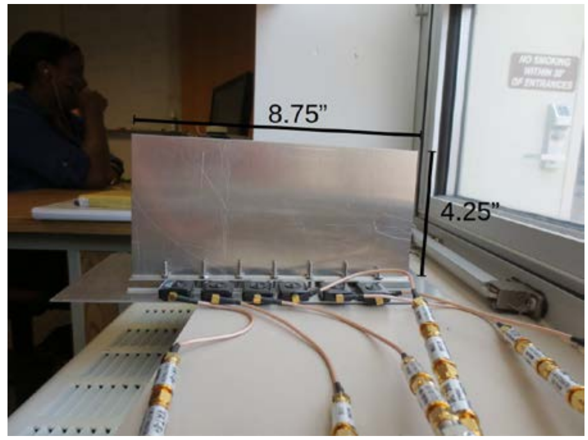
USB TV SDR dongles are low cost receivers which have found many applications outside their original purpose of TV reception via computer. One such application which uses six dongles is a multichannel ozone spectrometer. In order to collect and correlate the data from the LNBFs we needed to transfer it to the computer. Thus, the LNBFs were connected to the computer via a 7 port USB 3.0 HUB with a 12 V external power supply.



However under this configuration, the USB digital TV tuner RTL-SDR dongles were overheating to a temperature of 55°C as measured at the RF input connector. At a temperature around 55°C and above the local oscillator synthesizer fails.

In order to address this problem we created a heat sink to dissipate the power. The heat sink consisted of a 11.75 in by 5.5 in metal plate. We extended the dongles out away from the USB hub and fastened them to the plate by screwing a metal piece over them. The top metal piece was 8.75 in in length and extended up by 4.25 in.





Since the current drawn by the Hub was 840 mA supplied from a 12 V source about 10 W was dissipated in the circuit. Assuming that the majority of the power dissipated was in the dongles, we can assume that about 10 W will need to be dissipated by the heat sink. To find the power dissipated due to radiative transfer we can use the equation.

$$P = 2A\sigma\left(T_{metal}^4 - T_{atm}^4\right) \qquad (1)$$

Given:

P = Power
A = area
T_{metal} = Temperature of the metal
T_{atm} = Temperature of the atmosphere
σ = Stefan-Boltzman Constant
ε = emissivity of the heat sink material

Since

$$T_{metal} = T_{atm} + \delta \qquad (2)$$

Then equation (1) becomes

$$P = 2A\sigma\left(\left(T_{atm} + \delta\right)^4 - T_{atm}^4\right) \qquad (3)$$

By using the approximation for $b << a$

$$\left(a + b\right)^4 = a^4 + 4b\left(a^3\right) \qquad (4)$$

then equation (4) simplifies to

$$P = 2A\sigma\left(4\delta\right)T_{atm}^3 \qquad (5)$$

Solving with δ = 28 which was approximately the measured value of 55°C which is approximately 28°C above the room temperature of 27°C, ε = 0.1 for aluminum and A = .0417 m^2 for the bottom plate. The power dissipated on the bottom plate = 1.43 W. The area of the vertical piece is .0240 m^2 so the power dissipated on the vertical piece is .823 W. Total Power dissipated due radiation is 2.253 W

The heat sink was also erected in an upright position, so additional cooling occurs due to convection. The heat transfer due to convection can be calculated by solving the equation:

$$P = hA\left(T_{metal} - T_{atm}\right) \tag{6}$$

Where h is a constant depending on the material and orientation of the heat sink. For a vertical planes

$$h = \frac{k}{L}\left(0.825 + \frac{.387 Ra_L^{1/6}}{\left(1 + \left(.492/Pr\right)^{9/16}\right)^{8/27}}\right)^2 \tag{7}$$

Given:

k = Thermal conductivity of the material
L = height of plane
Ra_L = Rayleigh Number with respect to height of plane
Pr = Prandtl Number

For L = 0.10795 m and $Ra = 3.42\times10^6$ and $Pr = 4.94\times10^6$, h = 5.76 and the power dissipated from convection is 6.73 W. This brings the total heat dissipated to about 9.26 W. Since this value is lower than the needed value of 10 W, we considered painting the heat sink black to increase the rate of heat dissipation. Painting the heat sink black would result in an increase in emissivity and, as a result, the heat dissipated due to radiation. Using ε = 0.8 then the power dissipated on the lower plate would be 11.44 W and on the vertical piece it would be 6.58 W. As a result additional margin could be gained to keep the dongles well below 55°C.

Further tests of TV dongles

The TV SDR dongles currently available are the large black NooElec R820T SRR 8 DVB-T and the small DVB-T sticks like the Vantech RTL283UR820T DVB-T SDR DAB FM GSM GPS which comes in many colors.

1] DC power consumption
Both types draw 0.1 amp when not initialized (first plugs into USB port on hub) which then increases to 0.27 amp when running in an ozone spectrometer.

2] L.O. synthesizer temperature limit
The small dongles fail when the temperature measured at the USB connector reaches about 55 degC and recover when cooled to about 50 degC. The failure is loss of phase

lock presumably in the analog circuitry. The large dongles fail at about 65 degC and recovers at about 60 degC.

3] Plastic covers
The small dongle needs to be cooled by conducting heat away from the USB connector. The large dongle runs about 34 degC in a 25 degC room and about 2 degC cooler with covers removed.