Resistance of Hardboard Revisited & Use in Crystal Sets

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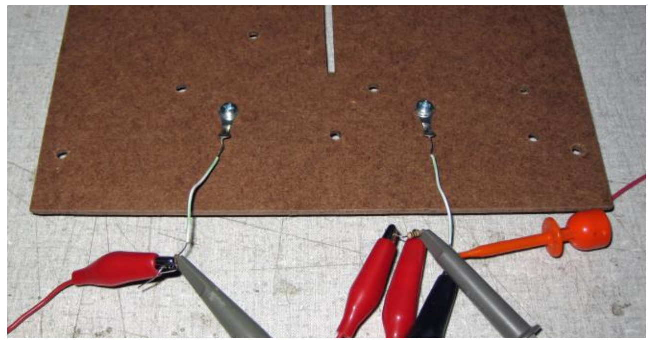
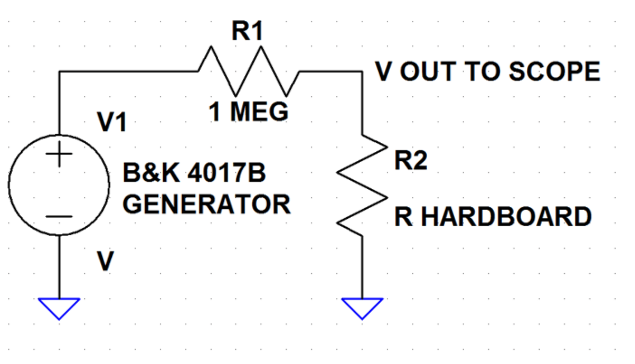
Many of us have constructed the front panel and chassis for crystal radio sets using 1/8th-inch hardboard, purchased at Lowes, Ace, or Home Depot. This board is inexpensive, easy to saw, drill, and punch, and the resulting sets have worked satisfactorily. At the same time, many are aware, starting with the DX contesters, that using low-loss sheet plastic can boost performance when working with high impedance sets. The resistive losses in hardboard are hinted at in the experiments outlined below.



Two measurements schemes were taken, using an 8″ by 7″ by 1/8th inch piece of hardboard, shown in Figure 1. The solder lug terminals were – arbitrarily - spaced 3 inches apart.

While the first scheme used was found to be incorrect, I’ll described it anyway, as an example of how one can go astray when



“assuming” a circuit model and ignoring part of the data obtained. Figure 2 denotes this first test circuit, consisting of a B&K signal generator, a 1 Meg ohm resistor, the resistance of the hardboard between terminals, and a two-channel scope (not shown).

Assuming the circuit model was correct, the generator output was attached to channel 1 of the scope and the output of the voltage divider – between R1 and the hardboard resistor – was attached to channel 2. Knowing the generator voltage, V1, Vout, and R1, R of the hardboard connections could be calculated:

$$R_{board} = \frac{V_{out} R_1}{V_1 - V_{out}}.$$

Data were gathered for 1, 10, 100, and 1,000 kHz. It was interesting to note, a bit of a surprise to me at the time – which should have been a hint, that the resistivity of the hardboard varies with frequency. At 100 kHz Rboard computed to be 160k. Within the AM band at 1 MHz, it was a measly 127K!

I summarized the results on RAPNTAP, our crystal radio forum (ref 1); and, several comments were posted. "Cymoscope's" comments and suggestions were helpful.

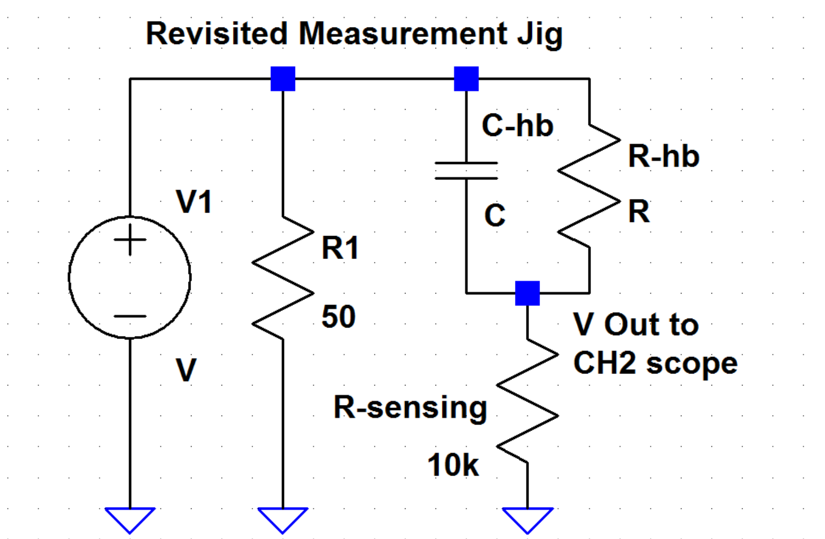
"The parallel losses of all dielectrics are frequency sensitive. This is often a linear (inverse) function of the frequency so that the parallel resistance drops as the frequency rises. This is because the resistance is realized through the capacity (reactance) between the two connection points on the hardboard. The dielectric constant for hardboard may vary significantly with frequency."

Ops! I'd forgotten to include capacitance in my measurement model of the hardboard in Figure 2. I located Kraus's "standard" text on Electromagnetics on my bookshelf (ref 2), read several chapters, and found the following relevant text on page 318:

"As a final step, suppose that instead of having two separate elements in parallel, one of which acts like a pure resistance and the other like a pure capacitance, we have only one, which has both capacitance and resistance."

This text was underlined and notes referencing the dielectric pages were penciled in the margin. Gosh! I'd been there before. Guess I can excuse myself, since I took that course in, gulp, 1963! Age is marching on brothers.

Anyway, that leads us to measurement circuit two, shown in Figure 3 to the right. The hardboard "element" is shown to contain both polarizing capacitance and resistance in parallel, i.e. a poor dielectric. The top lug attaches to the generator and the bottom lug connects to the sensing resistor and channel two of the scope.



Once the circuit was wired up on the bench, the phase of the voltage across Rsense relative to the phase of the generator voltage was evident, measured at 52 degrees at 1 MHz. Yup folks, we have an RC circuit with a classic phase shift.

Figure 4 below, lists the assumptions made with this circuit, the voltages obtained at the generator and sensing resistor at 1 MHz, and the resistance and reactance of the hardboard calculated. With Xhb known, the capacitance at 1 MHz calculated to be 0.4 pf and its parallel resistance having a healthy value of 528K.

Revisited Calculations:

Assuming Rsense << Rhd or X of hb,

$$Isense(@\text{ phase } \theta) = Vgen(@\text{ phase } 0)\,Y(@\text{ phase } \theta),$$

where Y=G + jB, G is the conductance of the hardboard, and B is the susceptance of the hardboard.

Given the measurements taken at 1 MHz,

$$Y = \left|\frac{I(@\ \theta)}{Vgen}\right| = \left|\frac{.302/10k\,(@52\,\deg)}{9.75}\right| \text{, hence,}$$

$G = 3.1e^{-6}\cos(52)$, and $B = 3.1e^{-6}\sin(52)$, thus

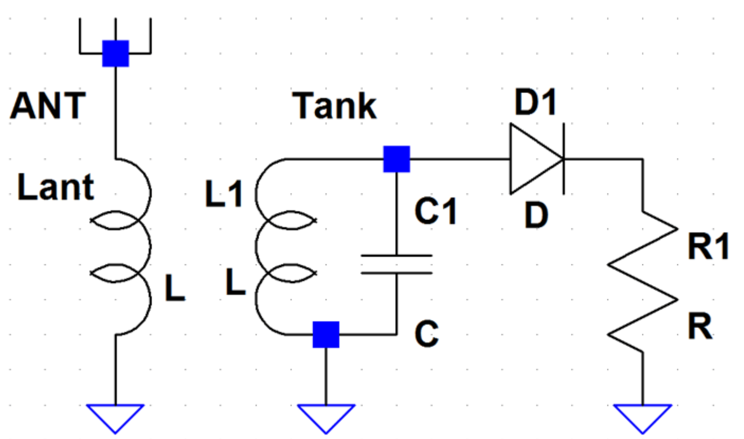
Rhb = 1/G = 528k

Xhb = 1/B = 413k.

Depending upon how a crystal set is wired and its components positioned, this mid-range resistance could have an impact on set performance, and particularly Hi-Z DX sets.

Take for example the simple set noted in Figure 4. If one uses a solder lug on the chassis for wiring the top of the tank and detector diode and another solder lug is used somewhere else on the chassis, then chassis resistance and more will be placed in parallel with the tuning tank!

One way to bypass the board resistance is to make the wiring point to point and not let connections drop to the chassis. Second, nylon or plastic washers, nuts, and screws can be used to mount the lugs on the chassis, thereby isolating the lug from the potential resistive paths of the board. We can imagine additional scenarios for more complicated circuits.



References:

(1) "Resistance of Hardboard " post on RAPNTAP, a crystal radio forum at www.midnightscience.com/rapntap.

(2) Kraus, Electromagnetics, McGraw Hill, 1953, "dielectrics," pp 4, 48, 308.