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Thermal Power Measurements – yet another look

The construction proposal (1) for a thermal power-meter has evidently been an stimulus for many discussions and home-constractional projects. From the many demands and suggestions, I would like to place a few points forward for discussion.

The optimal design for a bolometer-head (transducer of HF power into DC) is a deciding factor in determining the stability and the attainable limiting frequency of the circuit. Experiments with 1.5 mm thick epoxy-glass PCBs arouse little enthusiasm since as well as the dielectric losses the transition from HF socket to the broad conductor strip signifies a reflection point at the joint. Even at 1.3 GHz, a return-loss of under 10 dB (SWR = 2:1) was recorded (in **Table 1** last line). A certain reduction in the transition losses of all types of PCB is attained by a ground coating of the conductor track side. Optimum results are achieved when the two surfaces at the PCB's end are soldered together via a U-formed strip of thin copper (**Fig. 1**).

Experiments with cylindrical resistors (metal film) proved to be fruitless because of skin-effects, current in the direction of the return (ground) conductor, led to the resistor's value increasing with frequency.

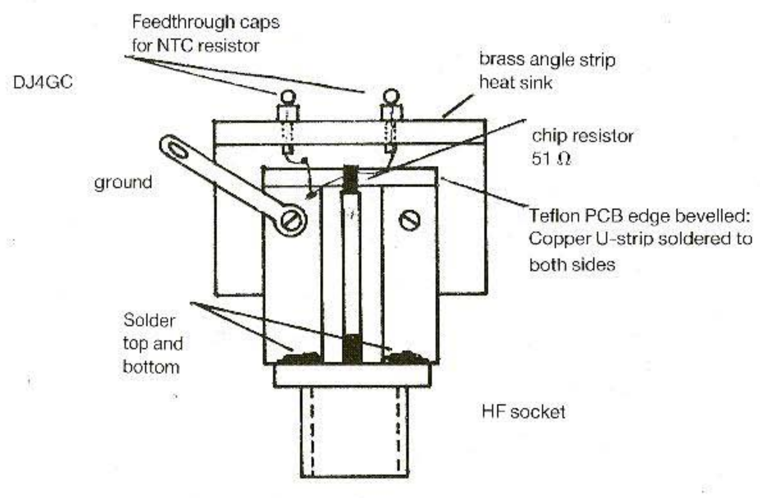

Fig. 1: Modification of a bolometer-head

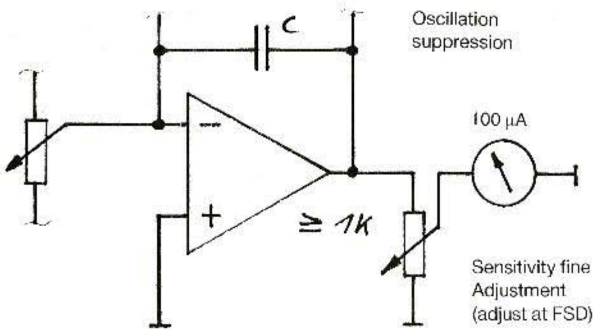

Fig. 2:
Modification of voltage amplifier

The connecting leads of NTC resistors can only be soldered reliably at high temperatures. At solder temperatures under 350°C, they are liable to "glue" together, thereby increasing the risk of developing a thermo-junction.

The bridge-supply voltage can be made potentially isolated with only a small loss of linearity (**Fig. 2**). The first operational amplifier, with its possible offset-drift problems, may then be dispensed with. This voltage must however, be perfectly stabilised. The drift of the IC 78L05 is very small and only influences the read-out information in a linear fashion but does not disturb the linearity of the bolometer bridge.

LED displays, as well as power-supplies, should never be placed anywhere near the bolometer, in order that heating effects may be avoided.

The display amplifier is most advantageously provided by the chopper-stabilised operational amplifier ICL 7650 by Intersil (2). Offset-drift and offset-voltage are practically absent. In the circuit of (1) however, two of these op. amps. were required. A point to watch is the very small output current of this C-MOS IC, which necessitates the use of a 100 µA FSD meter.

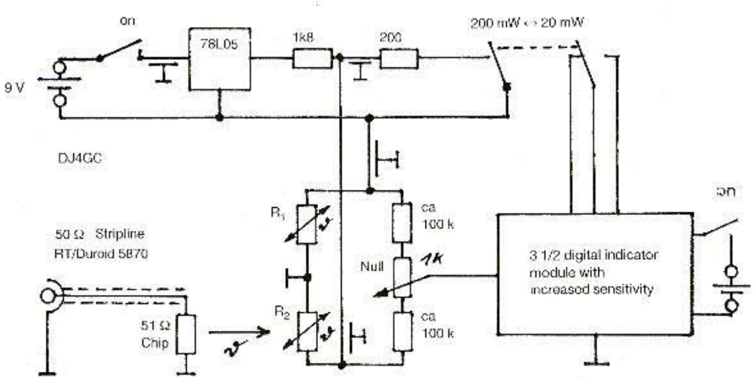

Fig. 3: Complete circuit diagram of a digital display thermal milli-wattmeter
R_1 = (temperature compensation): micro-NTC resistor ca. 1 MΩ
R_2 = (bolometer-probe): as R_1

A jumping around of the indicator null-point upon range-switching can usually be attributed to oscillation of the operational amplifier (check with an oscilloscope). One remedy is to bypass and block the supply lines to the IC as near as possible to the pins. Another method is to place a (1 nF – 0.1 μF) capacitor between the output and the inverted input of the op-amp. which reduces its AC amplification sufficiently to stop the oscillation.

The meter-movement is most advantageously provided with an additional dB-scale. The FSD of about 1 mW, corresponding to 0 dBm, with the graduations descending to a convenient −10 dBm. Upon range-switching in decades, 10 dB can be added to, or substracted from the indicated value. It is thereby possible to obtain a dBm-scale without having to calculate anything. Amplification or attenuation may be read directly in dB. For the optimal use of this scala a fine-adjustment of the indicator sensitivity is recommended.

A particularly interesting circuit on account of its amazing simplicity, was made by the author in large numbers. It was a thermal power-meter with a digital display which required no output amplifier. The bridge-voltage was simply fed to a 3½ digit LCD multi-meter module.

At a bridge voltage of 5 V the differential voltage was about 60 mV at 20 mW HF input power. The resolution (one digit) then being 10 μW. Range-switching of 200 mW was carried out simply by division of the bridge voltage supply. The instruments constructed in this manner, exhibited a loss of indicated linearity of only a few percent when measuring input powers of below 200 mW. Interestingly, the sensitivity of the dual-slope converter could be altered from 200 mV for maximum reading by compensating with the multi-turn potentiometer for the requisite HF input.

The employment of a digital display for tuning purposes takes a bit of getting used to, but this however, is the same problem with all digital multi-meters.

Literature

(1) Carsten Vieland, DJ4GC:
A Sensitive Thermal Power Meter
VHF COMMUNICATIONS Vol. 15, Winter Ed. 4/1983, Pages 225 – 231

(2) Dr. Hannes Fuchs:
Messen im Mikrovolt-Bereich (ICL 7650)
Funkschau, Heft 11/1984

	DJ4GC	30 MHz	144 MHz	440 MHz	1.3 GHz	Base material
BNC	Return loss SWR	35 dB 1.03	33 dB 1.04	27 dB 1.09	27 dB 1.09	RT-Duroid 5870
N	Return loss SWR	40 dB 1.02	39 dB 1.02	37 dB 1.03	23 dB 1.15	0,79 mm thick
SMA	Return loss SWR	40 dB 1.02	42 dB 1.02	55 dB 1.00	31 dB 1.06	
N	Return loss SWR	39 dB 1.02	31 dB 1.06	21 dB 1.2	10 dB 2	1,5 mm Epoxy

Table 1: Return loss measurements from bolometer-head Fig. 1