1 Introduction

This document describes the design and build of a temperature controlled head amplifier assembly for use in Radio Astronomy at 1420MHz. The design is compact so that the amplifier can be mounted closely coupled to the dish antenna feed. The feed is a 155mm (6 inch) diameter cylindrical waveguide with a coaxial output.

There are two key requirements for a useful telescope head amplifier. These are:

- Low noise
- High and stable gain

Both can be obtained by using the best modern components such as pHEMT[1] devices and keeping them cold and at a stable temperature.

The temperature control system uses a Peltier semiconductor cooling/ heating unit driven remotely from a temperature control electronics unit which takes real-time temperature readings from the cold plate on which the Peltier element and the head amplifiers are mounted.

The feed and the head amplifier are mounted close together to minimise coaxial cable losses and the whole is packaged in a radio transparent weatherproof container to minimise aperture blocking.

2 System concept

2.1 Outline design

The concept is to build the compact head amplifier unit onto an aluminium plate with significant thermal mass which can then be cooled using a commercial semiconductor Peltier component. By varying the current through the Peltier device the plate can be kept at a constant temperature irrespective of the ambient air temperature outside of the unit.

The current is varied automatically by control electronics connected to a temperature sensor mounted on the thermal plate. The control electronics are situated remotely from the head and connected by a multi-core cable. Readings of plate temperature, air temperature and Peltier drive current are taken regularly and recorded by a data logger connected to a PC.

By stabilizing the temperature of the amplifier electronics at a low value, typically 0^0 Centigrade, the gain and noise output of the device will be stable and will not introduce temperature related artefacts into the measured signal data.

2.2 Block diagram

The components of the system are shown in Figure 1.

They fall into two groups – the RF chain is shown above the cold plate in the diagram and consists of the Low Noise Amplifier (LNA) with 28dB gain designed by W5AGO available from http://www.radioastronomysupplies.com. A good quality commercial high pass filter above 1200MHz http://www.mincircuits.com is used - and a coaxial line driving amplifier based on a BGA616 MMIC gain block from Infineon Technologies www.infineon.com/. This has a gain of 15dB @ 1420MHz and is mounted on a silvered PCB inside a die cast aluminium enclosure fitted with SMA connectors.

The other group are components required for the temperature control of the thermal plate. The key item is the semiconductor Peltier element, for example Manufacturers Part No. ETH-127-14-11-S-RS available from RS Components www.rs-components.com .

Power requirements for each component can be seen in Figure 1.

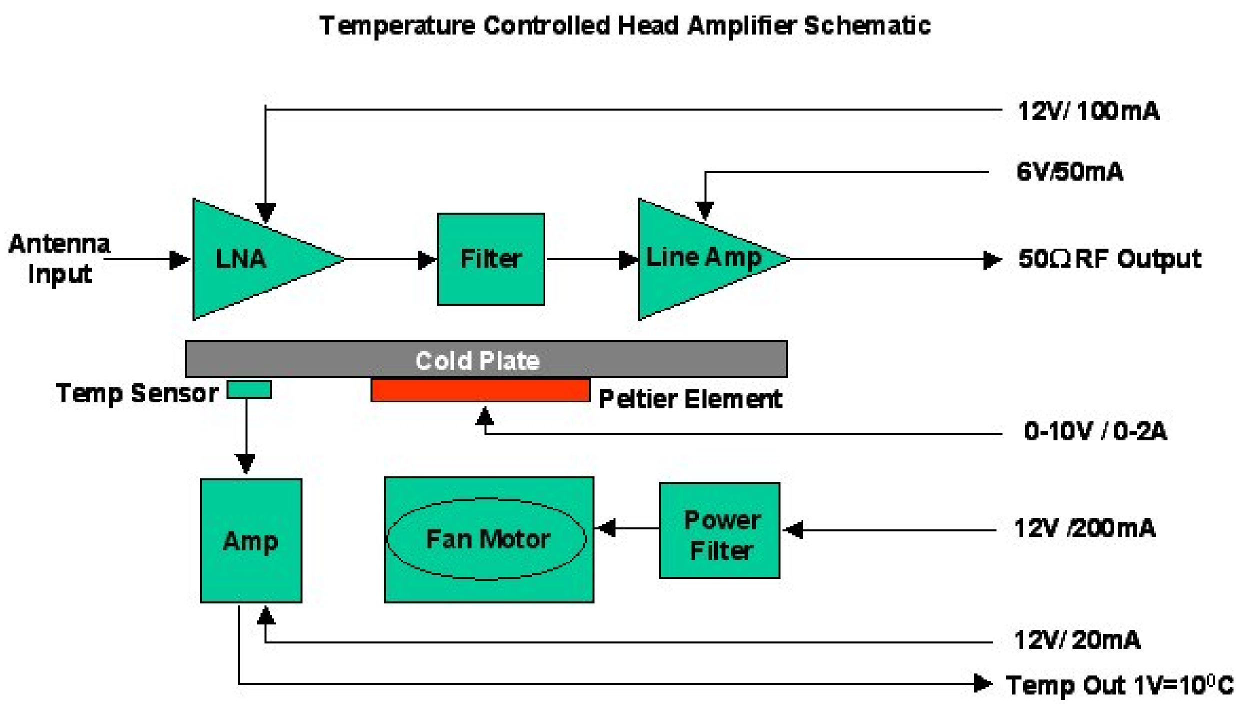


Figure 1 Head Unit block diagram

The gain of the combined amplifier / filter chain in the head @ 1420MHz is 43dB. The output is connected via a few metres of URM67 to a second 15dB gain BGA616 cable line drive amplifier. The signal level is then high enough to overcome the 4dB loss incurred in 20m of URM67 coaxial cable to the receiver.

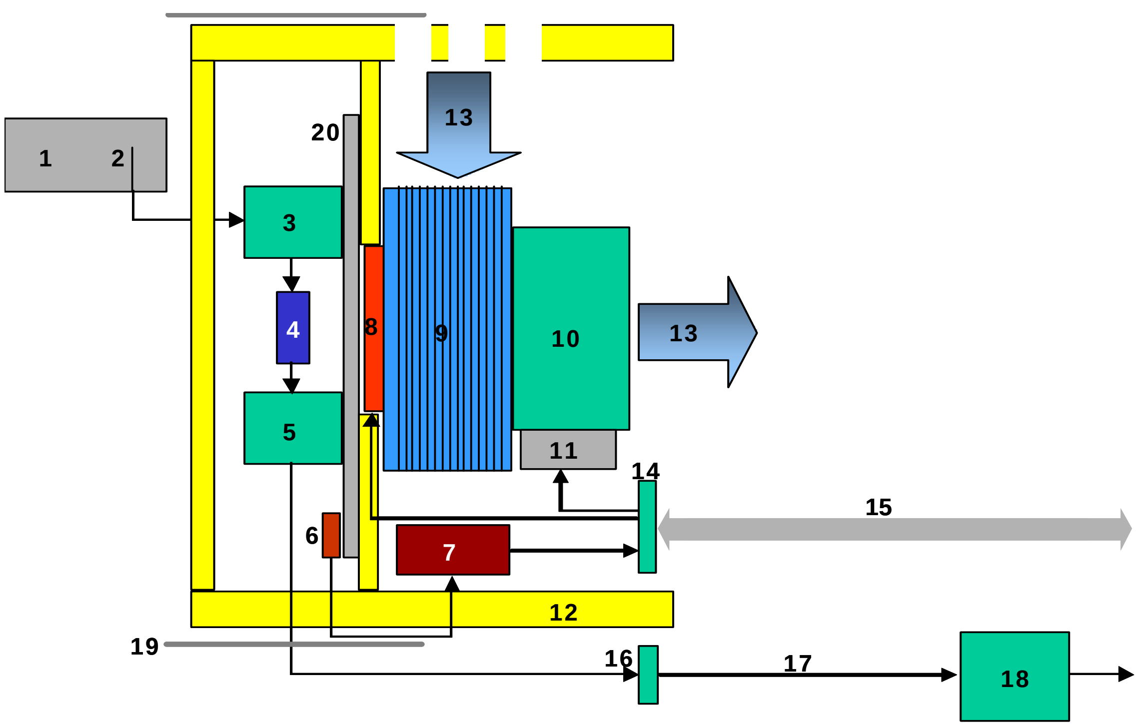
2.3 Temperature Control

The purpose of the temperature stabilisation is to maintain the 43dB gain figure to 0.1dB over long periods of time during observations. This requires that the closed loop temperature control is better than 1^{0}C for an outside temperature variation of 20^{0}C.

In order to achieve this, the amplifiers are well thermally bonded to a thick aluminium cold plate with significant thermal capacity. The Peltier cooling element is bonded to the other side of this plate and to the heat sink from which the fan draws waste heat. The amplifier unit on the cold side of the plate is surrounded with expanded polystyrene insulation and the whole is enclosed in bright aluminised Mylar foil to reflect heat from outside.

The temperature sensor is an LM35DZ IC connected to a CA3140EZ MosFET Operational Amplifier providing a gain of 10x and able to drive the 30m of twisted-pair cable to the control electronics.

Finally the entire assembly is fitted inside a white painted plastic rain cover. A block diagram is given in Figure 2.



1	6 inch diameter cylindrical waveguide	8	Peltier Cooling element	15	Power / signal cable
2	Probe element	9	Heat exchanger	16	N Type RF connector
3	Phemt LNA	10	Fan	17	URM 67 coax
4	1200MHz LP filter	11	Fan power filter	18	BGA616 Line amplifier
5	BGA616 MMIC amp chip	12	Insulation	19	Aluminised reflective layer
6	Temp sensor IC	13	Ventilation	20	Cold Plate
7	Temp sensor amplifier /driver	14	Power connector		

Figure 2 The head unit block diagram

The Radio Astronomy Supplies' LNA and the BGA616 line amplifier were mounted to the cold plate using heat sink compound to ensure good thermal conductivity and fast heat transfer to the active components. The temperature sensing IC is spring loaded onto the cold plate and also faced with heat sink compound. The Peltier cooling element cannot be seen in the picture in Figure 3 as it lies at the heart of the assembly between the cold plate and the multi-finned heat sink.

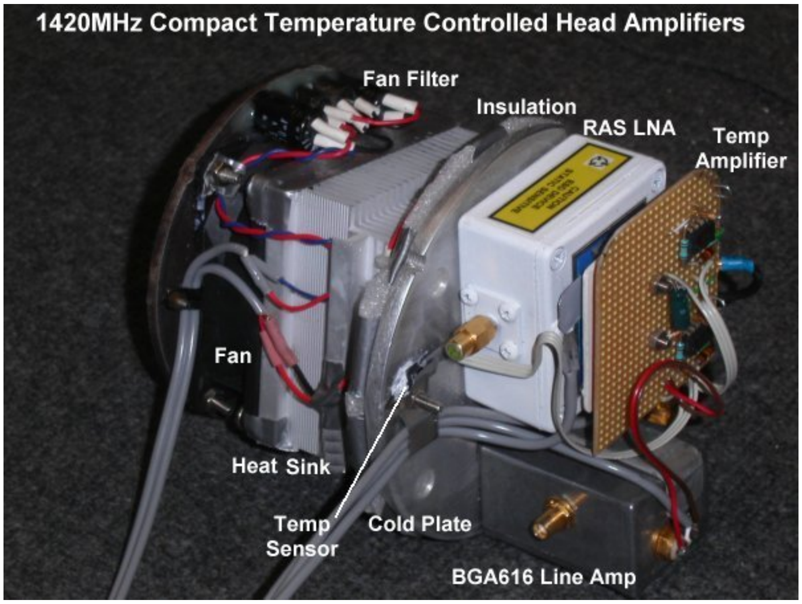


Figure 3 Assembled head amplifier unit

The whole assembly is ~ 100mm diameter and fits inside the plastic weatherproof container shown in Figure 4 below.

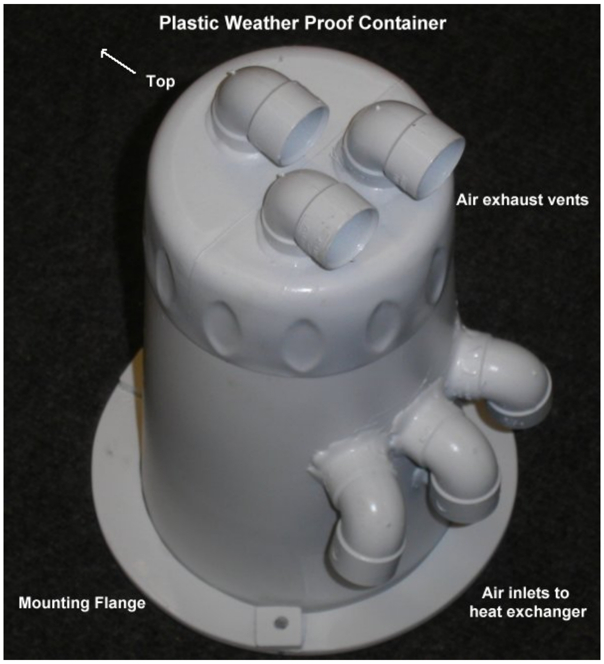


Figure 4 Weatherproof container

2.4 Integration with the feed

The thermo-electric temperature unit is fitted on the back of the 6 inch waveguide feed as shown below in Figure 5. Both units are enclosed in white painted light weight weather-proof plastic containers shown in Figure 6.

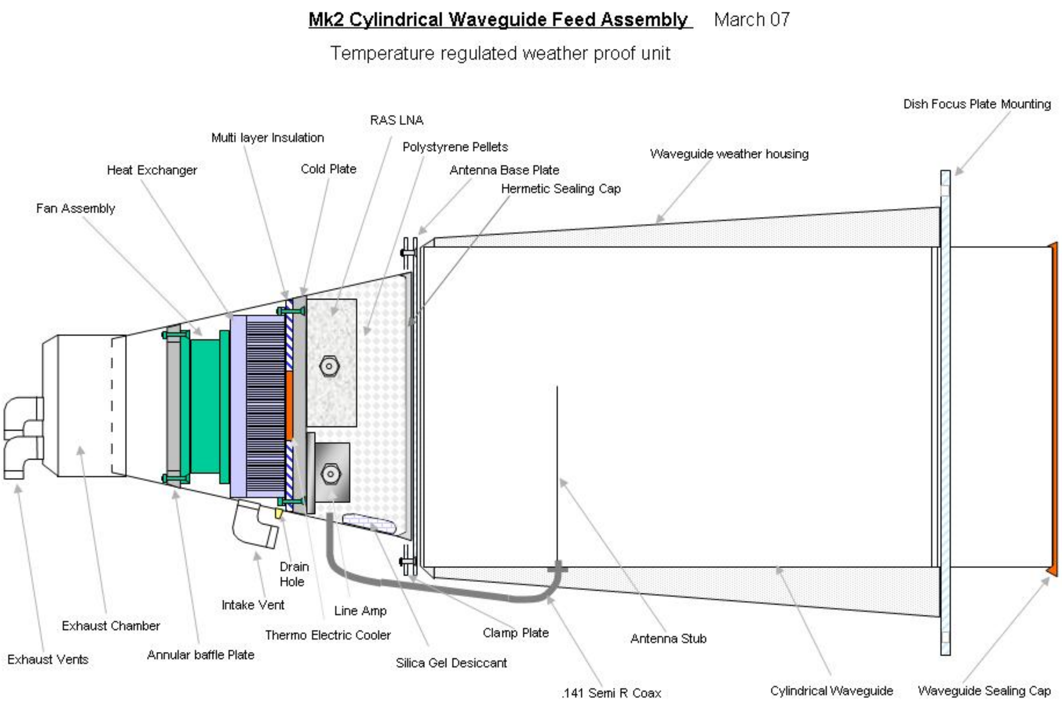


Figure 5 Integration of Head amplifiers with the Cylindrical Feed

Figure 6
Complete Head Amplifiers and cylindrical feed assembly

3 Performance

The graph in Figure 7 shows the operation of the temperature controlled head amplifier assembly. The light blue trace is the temperature of the cold plate as a function of time over a period of ~ 1 hour after switching on. The yellow trace is the temperature of the RAS LNA (which shows some thermal lag behind the cold plate).

The cooling is switched on at the start of the trace and reduces the temperature from 18^{0}C to 7^{0}C in a few minutes. Once the required control temperature is reached, the Peltier element drive current [dark blue trace] reduces from maximum drive and, following a short settling period, keeps the temperature stable. Twice during the hour long test a 1kW fan heater is used to heat up the outer skin of the head amplifier assembly (the second instance is marked on the graph).

The heating is much greater than would be experienced when mounted on the dish and represents extreme conditions.

The Peltier drive current [dark blue trace] responds by increasing and thus keeps the Amp and Plate temperatures constant to within 0.2^{0}C.

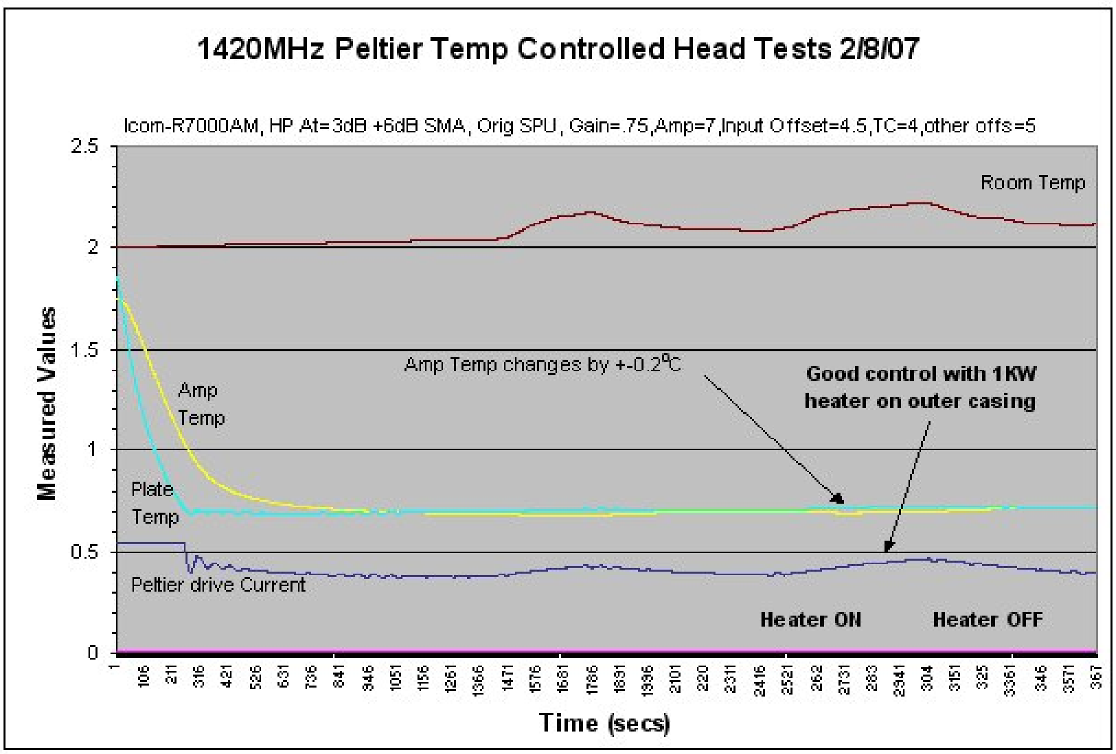


Figure 7 Performance of Temperature control system during a test

4 Control electronics

The temperature control unit is a straightforward OP Amp based analogue system where the actual sensed temperature of the head amplifier is compared with the required temperature (determined by a front panel setting). The difference signal is amplified with sufficient current (up to + - 3A to quickly drive the Peltier semiconductor element in the correct direction to reduce the temperature difference to zero.

Temperature control is better than 1^0C for air temperatures of $–5^0$C to $+25^0$C. Temperature control to this accuracy ensures that the noise level and gain of the head amplifier does not affect the stability of a measured astronomical signal over long periods of up to 24 hours.

A block schematic is given in Figure 8 and a circuit is presented in Appendix A.

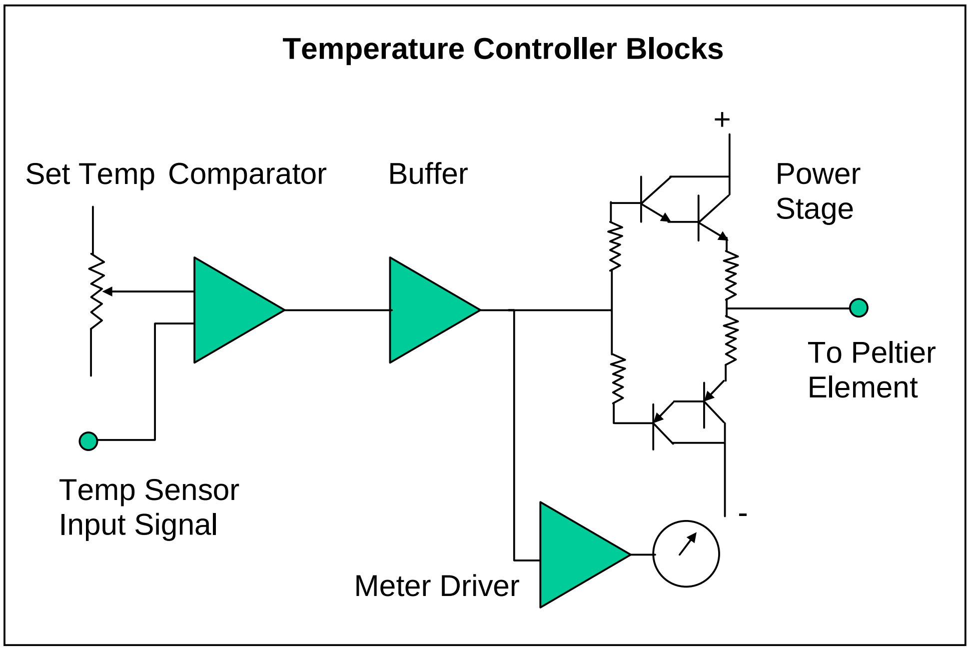
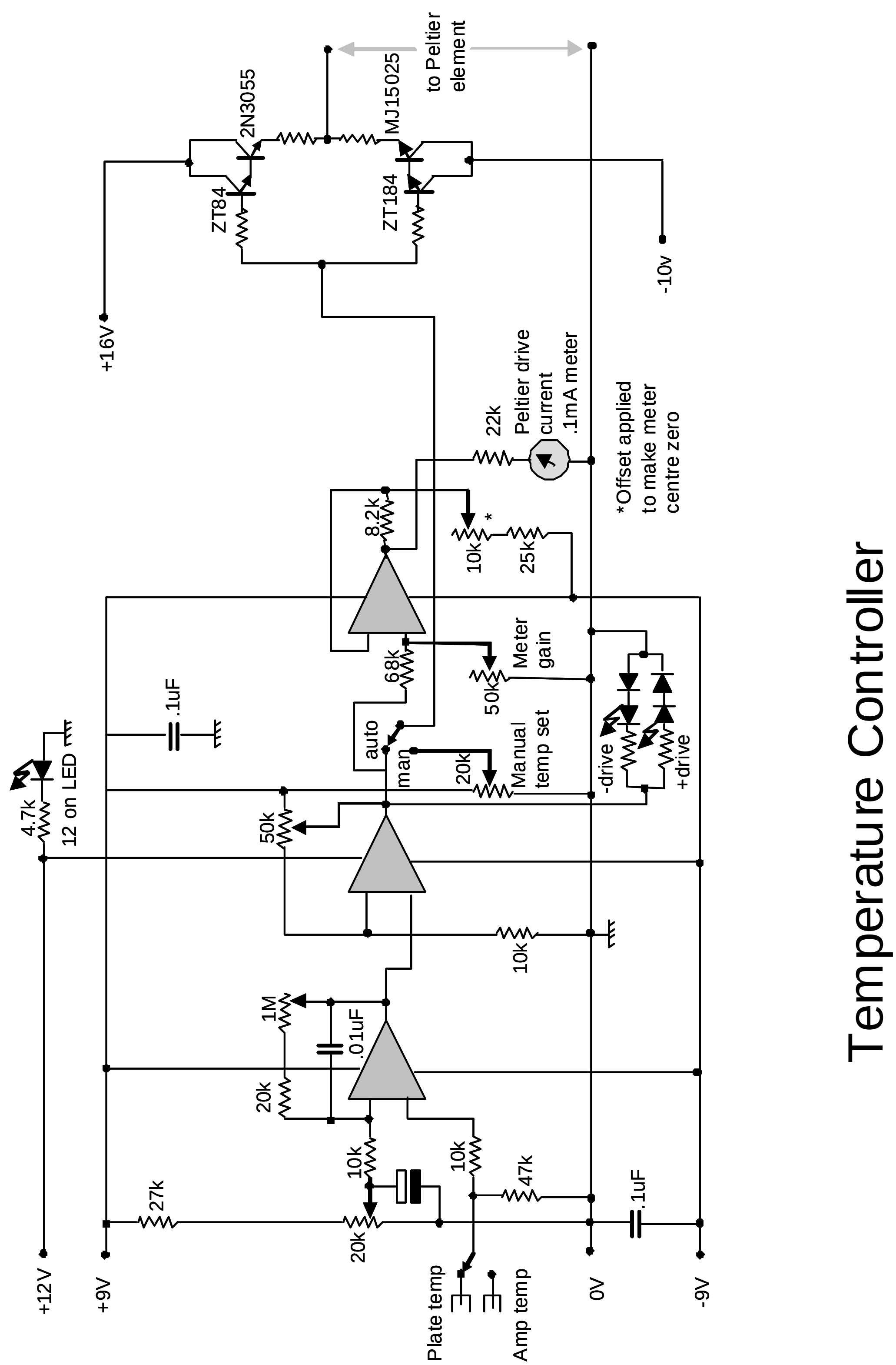
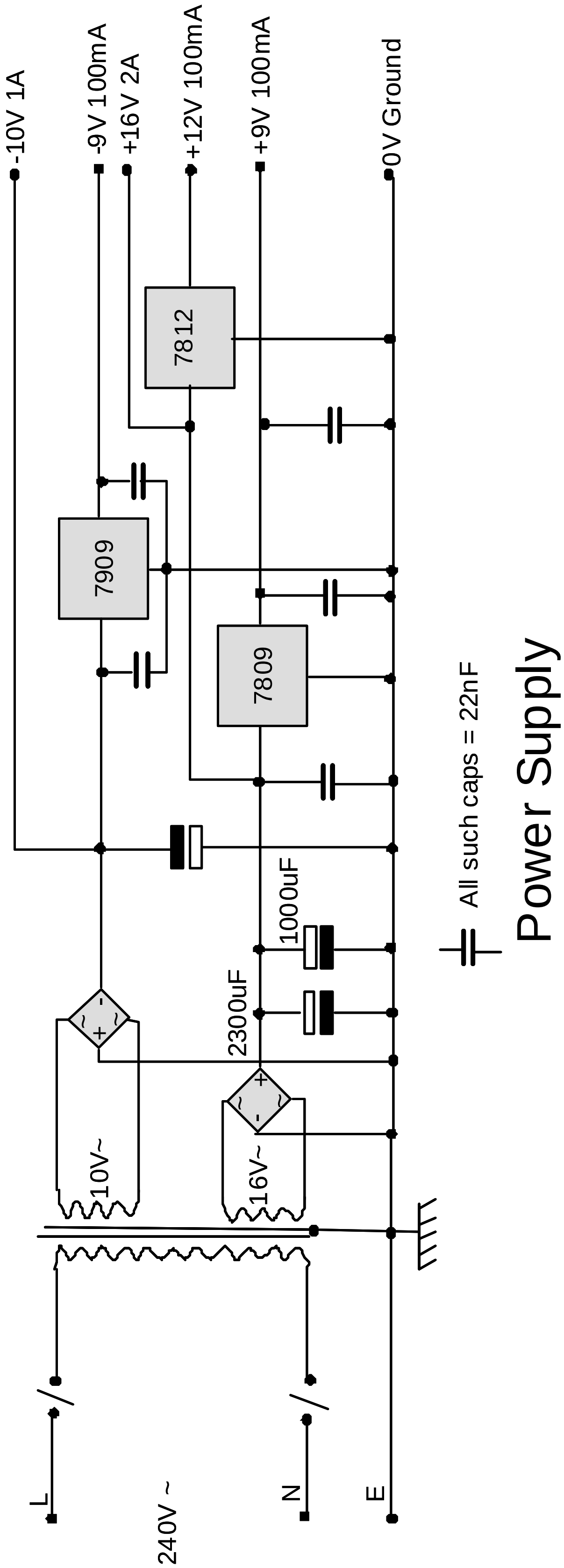


Figure 8 Temperature control Unit schematic

Appendix A Temperature Controller Circuit




-10V 1A
-9V 100mA
+16V 2A
+12V 100mA
+9V 100mA
0V Ground
7812
7909
7809
1000uF
2300uF
10V~
16V~
L
N
E
240V ~
All such caps = 22nF
Power Supply

References

1 pHEMT - pseudomorphic HEMT - high electron mobility transistor (HEMT), also known as heterostructure FET (HFET) or modulation-doped FET (MODFET), is a field effect transistor incorporating a junction between two materials with different band gaps (i.e., a heterojunction) as the channel, instead of a doped region, as is generally the case for MOSFET.

wikipedia.org/wiki/PHEMT