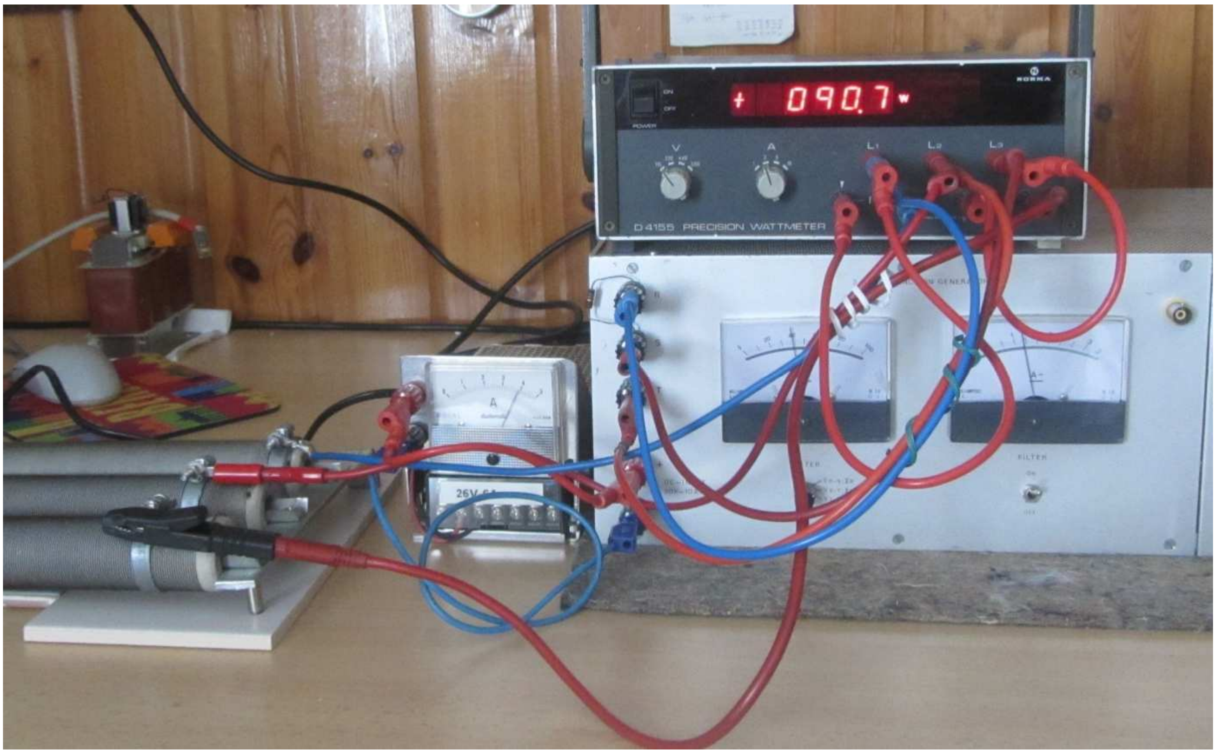
# NORMA  D4155 Precision 3-phase Wattmeter

21 mei 2022 / kb




This precision wattmeter has two single-phase Wattmeters in Aron connection,  intended for 3-phase systems ***without*** neutral.  A high sampling rate allows the use at frequency controlled motors.
The ( line to line) **voltage** ranges are 110 - 220 - 440 - 550V, and for **current** . 1 - 2 - 5 - 10 A .
It is advised to insert a 0.2A fuse  in the connection to terminal L2  as this terminal is hard connected to the common of all electronics including the power supply.

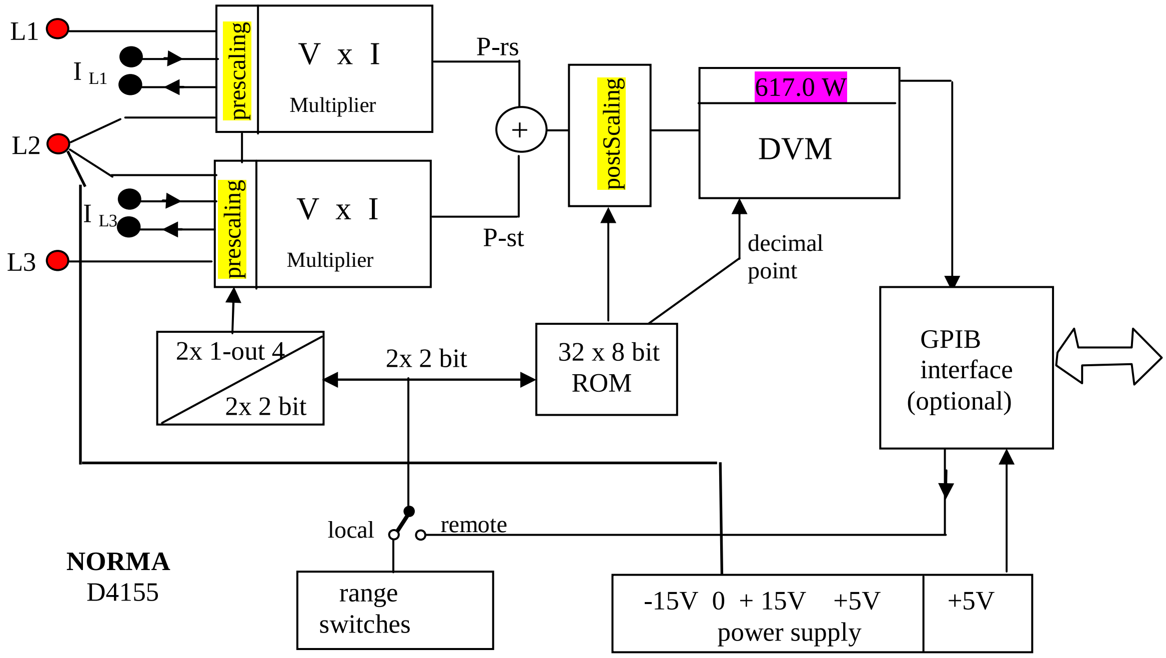
## Specifications

### NORMA   D 4155 precision Watt meter

| | |
|---|---|
| Use | Power measurement in 3-phase circuits without neutral |
| Input terminals | L1, L2, L3 for voltage  (L2 is the common )  Rin = 660kΩ |
| | I1^ - I1, and   I3^ - I3 for ac current   Rin = 25 mΩ |
| Principle | Aron circuit |
| Voltage ranges | 110, 220, 440, 550 V line-line |
| Current ranges | 1,  2,  5,  10A  (at 50Hz) |
| Overload led | up to  600Hz :  overcurrent lights above 110% of range current |
| | up to  1 kHz  :  overcurrent lights above  80% of range  current |
| | up to  4 kHz  :  overcurrent lights above  40% of range  current  *) |
| Frequency | 15Hz - 1000 Hz  with 0.5% accuracy |
| I * U  multiplier | pulse width / pulse height modulator |
| Sampling cycle | 20 µs |
| Accuracy | 0.2% at mains frequency (50Hz-60Hz)  0.5% at other frequencies |
| Self test | Lamp test, zero test, full scale test of the A/D converter at turn-on |
| Built | ca 1980 |
| Optional | GPIB interface, galvanic isolated, allows remote control and measurement. |
| | internal connections and a floating 5V power supply for options is standard. |

*) At 4kHz, a higher current range must be selected, otherwise the "overload"  lamp will burn.  As an example, in the 2A range, a  4kHz current gives "overload" above 0.8 A.

**Block diagram**
The heart of the Wattmeter are the two multipliers. The lowest range is 110V x 1A x √3 = 190.5 W, while the highest range is 50 times more:   550V x 10A x √3 = 9525 W.
The dynamic  range of the multipliers is not that high, so the input voltage and current are reduced to a standard level ( pre-scaling)   After multiplication (voltage x current) the resulting Watt signal level is post scaled to compensate for the pre-scaling factors. The result is fed to the 4,5 digit voltmeter. This post-scaling includes a shift of the decimal point where needed.




**Pre-scaling**   The position of the range selectors  ( 110-220-440-550V, resp. 1-2-5-10A) appears as a 2-bit code each, so in total 4 bits. Using pre-scaling, these 16 combinations bring the full scale level to 3.33Vrms resp.  2Vrms. Pre-scaling is done with high precision resistors, selected with reed relays.
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| **Range** | Vprescale | Iprescale | Postscale | Dec.point | Display full scale |
|---|---|---|---|---|---|
| 110V/ 1A | 1 | 1 | 1 | 1 | 190.52 W |
| 110V/ 2A | 1 | 2 | 0.2 | 0.1 | 381.1 |
| 110V/ 5A | 1 | 5 | 0.5 | 0.1 | 952.6 |
| 110V/ 10A | 1 | 10 | 1 | 0.1 | 1905.2 |
| 220V/ 1A | 2 | 1 | 0.2 | 0.1 | 381.1 |
| 220V/ 2A | 2 | 2 | 0.4 | 0.1 | 762.0 |
| 220V/ 5A | 2 | 5 | 1 | 0.1 | 1905.2 |
| 220V/ 10A | 2 | 10 | 0.2 | 0.01 | 3810 |
| 440V/ 1A | 4 | 1 | 0.4 | 0.1 | 762.0 |
| 440V/ 2A | 4 | 2 | 0.8 | 0.1 | 1524.2 |
| 440V/ 5A | 4 | 5 | 0.2 | 0.01 | 3810 |
| 440V/ 10A | 4 | 10 | 0.4 | 0.01 | 7621 |
| 550V/ 1A | 5 | 1 | 0.5 | 0.1 | 952.6 |
| 550V/ 2A | 5 | 2 | 1 | 0.1 | 1905.2 |
| 550V/ 5A | 5 | 5 | 0.25 | 0.01 | 4763 |
| 550V/ 10A | 5 | 10 | 0.5 | 0.01 | 9526 |

Dec.Point = Postscale /(Vprescale*Iprescale)
" 1 "  means 2 digits after the decimal point;
"0.1"  means 1 digit after the decimal point
"0.01" means no decimal point

## Prints

The power meter has **6 printed circuits:**

- The backplane
- Two front-ends with pre-scaling;
- A post-scaler that scales back the "watt" output of the multiplier;
- The ADC print with display; ( and prepared for an GPIB interface)
- The power supply making +/-15V and +5V;
- And optional an GPIB interface.

**Technology of 1979**

The Opamps are LM308 and OPA 725C, the digital logic is CMOS, a 4,5 digit DVM chip set, and a 32 x 8 bit fusible link PROM which provides the post-scaling for each of the 16 range combinations. Reed relays and manganine resistors wound on mica cards guarantee a high accuracy.

**Backplane**

The backplane provides the interconnection of the modules. The two 4-position range switches are also on this board, including the conversion form 2x 2 bit into 2 x 1-out-of-4 to drive the reed relays of the voltage and current pre- and postscalers

**Front end**

The **voltage measurement** is an LM308 opamp with 660k input resistor and a range dependant feedback resistor. In the 110V range, the conversion is 20k/660k, so 20/6 = 3.33Vrms, 4.7V top. There is some margin above this full scale level, up to 2x Vrange seems possible.
The voltage measurement is dc coupled.

The **current measurement** starts with a flux-compensated current transformer (CT) with a range dependant burden resistor . The CT allows current measurement from 15Hz to several kHz.

The **multiplier** is of the pulse height -pulse width type. The **voltage** sets the *height* of the pulses, the **current** sets the *width*. There is a 50kHz oscillator ( 10us high, 10us low without current) , the duty cycle is controlled by the ac current.
The oscillator is a fully balanced circuit. A current source is made with an opamp and a jfet, its current is then divided equally over two branches of the oscillator. One sets the "high" time, the other the "low" time. The current sources are jFets with 100Ω channel resistance at 0V gate voltage.
The resulting pulse width modulated (PWM) signal determines whether the voltage signal is applied to the positive or negative input of a differential amplifier. This amplifier has a low pass function, giving a dc level on its output, proportional to the active power. This dc level can be positive or negative with power either delivered or fed-back.

Two comparators control the leds on the front of the meter for over voltage or over current per channel. Above 600Hz 3-phase frequency, these leds turn on below the chosen current range.

**Scaler**

With 4 voltage ranges and 4 current ranges, there are 16 possible Watt ranges. These are scaled to an internal range that can be accomodated by the pulse height-pulse width multiplier.
The output of the multiplier is in Watts and should be scaled back for a correct display of the measured power. This is done in the (post) scaler.
The available post scale values are 0.2, 0.25, 0.4, 0.5, 0.8 of 1 x
Beyond these 6 values, the scaler has a 7th position for the self test, immediately after turn-on of the power meter. This sends 1.000V to the DVM , so 999.9 or 10000 should be displayed.

**ADC and Display print**
The analog Watt signal is fed to a standard **4½ digit voltmeter** which drives the LED digits. The A/D converter is a dual slope type, the up,- and down time are counted by an external clock signal. The clock frequency is always synchronized to 2048 x mains frequency using a PLL . The highest precision is reached when measuring power at the local mains frequency.

On the internet, much can be found of the LD120/ LD121 4½ digit DVM chipset. The chipset shows full-scale 19999 at ±1.9999V dc
Also on this board are connectors for the optional GPIB interface board. This allows remote setting of the range, and readout of the digits (in BCD code).
The optional GPIB board has opto couplers to provide a floating interface.

**Self test.** The ADC /Display board contains a few delay circuits to test the power meter immediately after turn-on. The following tests are performed:
- **Lamp test**: all segments, decimal points, and overload leds turn on, showing *.8.8.8.8.8
- **A/D test**: 10000. is displayed as full scale of the A/D converter;
- followed by 999.9 idem

After 2 seconds, the displayed value drops to zero, and the power meter is operational.

**Power supply**
Provides -15V, +15V and +5V to all modules.. The 5V has two output wires, one for the sensitive parts, the other for the display and reed relays.
These 3 supply voltages have the same common, connected to the L2 terminal on the front. .
The power supply has a second floating +5V output, intended for the output side of the optional GPIB interface.

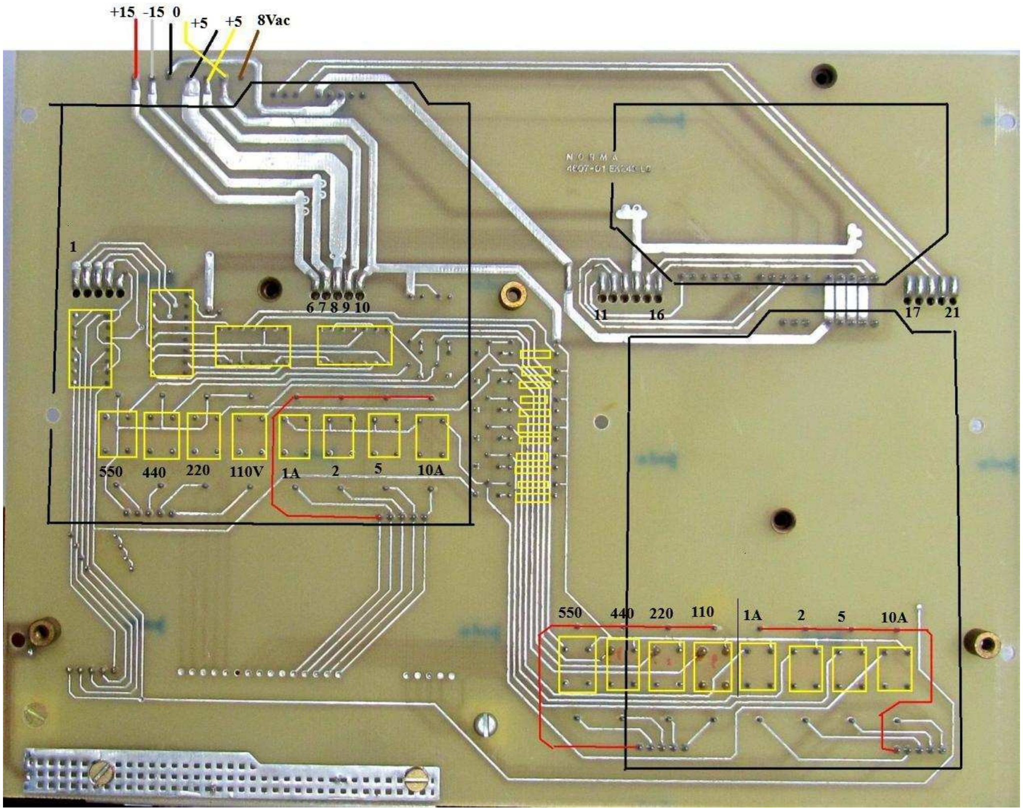
**NOTE**

As there is no documentation available of the **NORMA D4155 Precision Power Meter**, I wrote this document myself after reverse engineering. Some details are missing, hidden features are not found, and even pure errors may be present in this document. However, it gives an impression of its functioning, and can be a guide when you intend to use the power meter.

Koos Bouwknegt

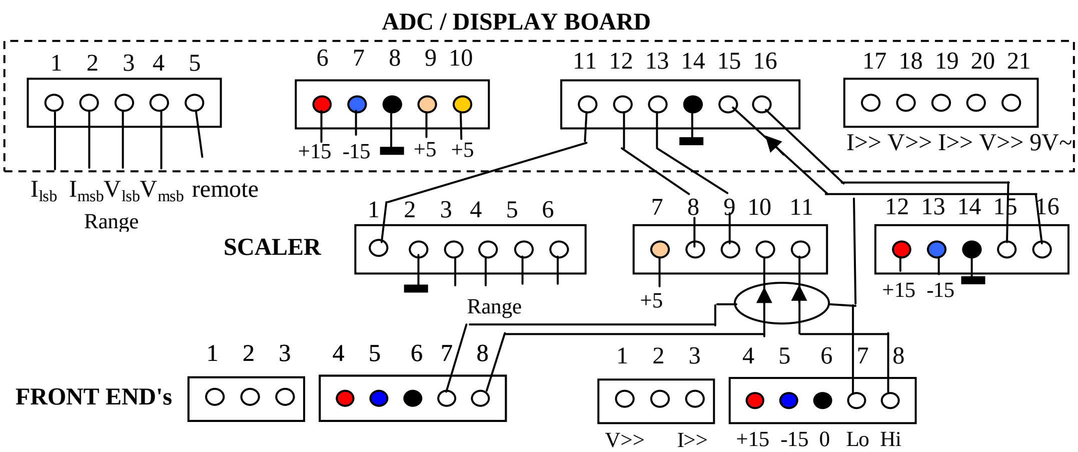
# Printed circuit boards description

## Norma D4155 Backplane

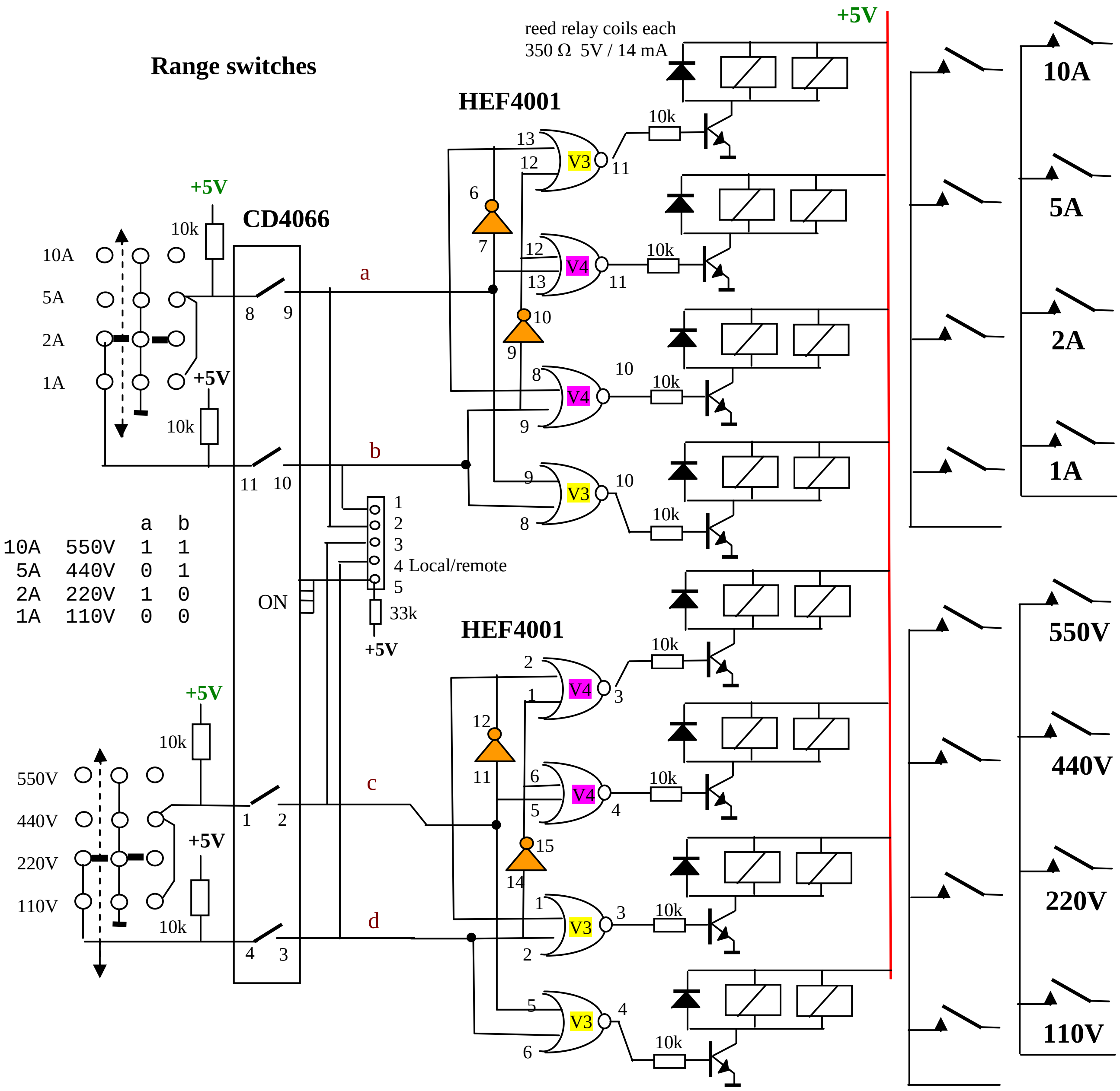


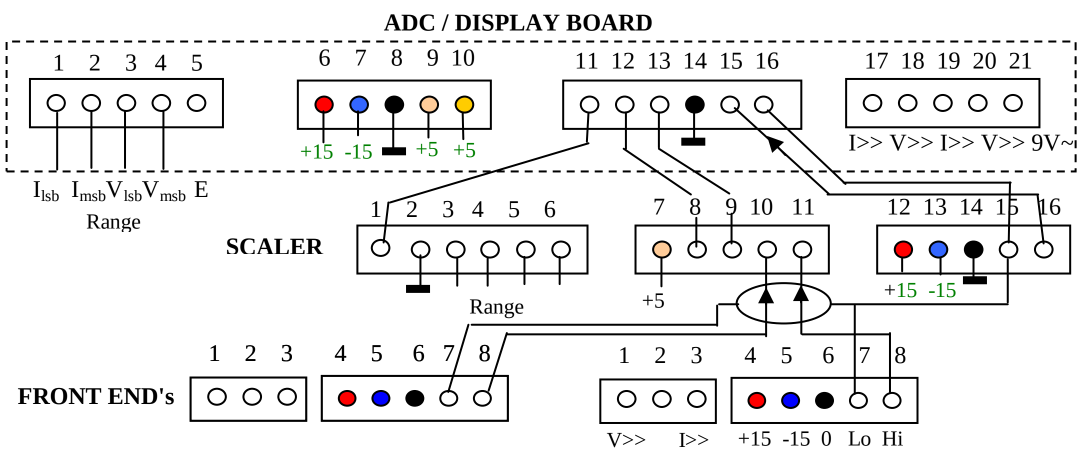

The backplane interconnects all modules, and contains the 16 reed relays selecting the input sensitivity for voltage and current for both Aron wattmeters . While the range selector switches produce a binary code, this is decoded here into two times 1-out-of-4 code to drive the reed relays.

Although the plug-in modules have many connector strips, the pin numbering is as if it was one long connector, numbered form left to right as in the picture above, and in the drawing shown below.



# Backplane: code conversion for prescalers



# Norma D4155 front end ( two equal circuits )

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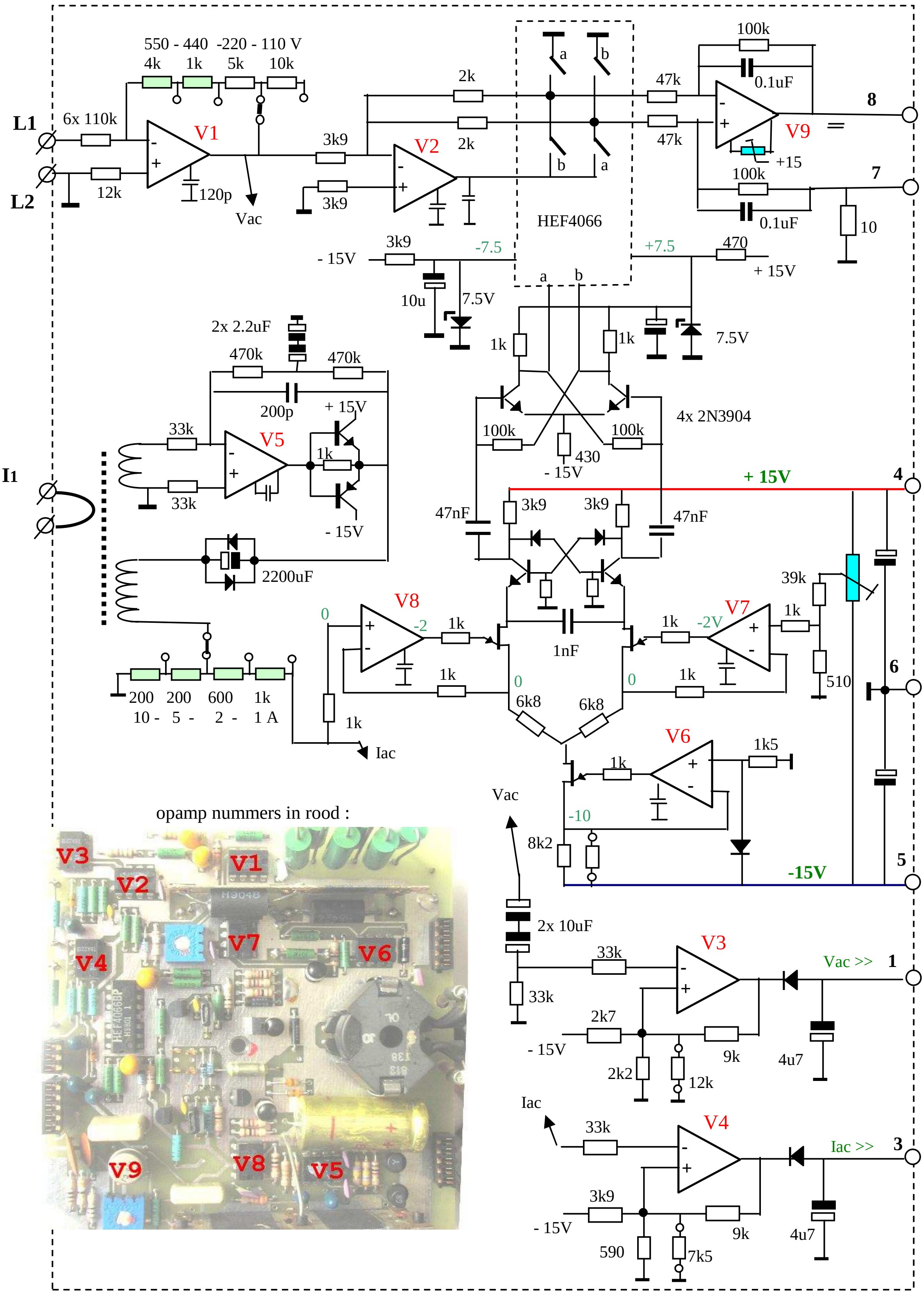
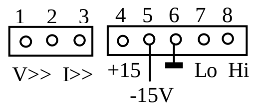


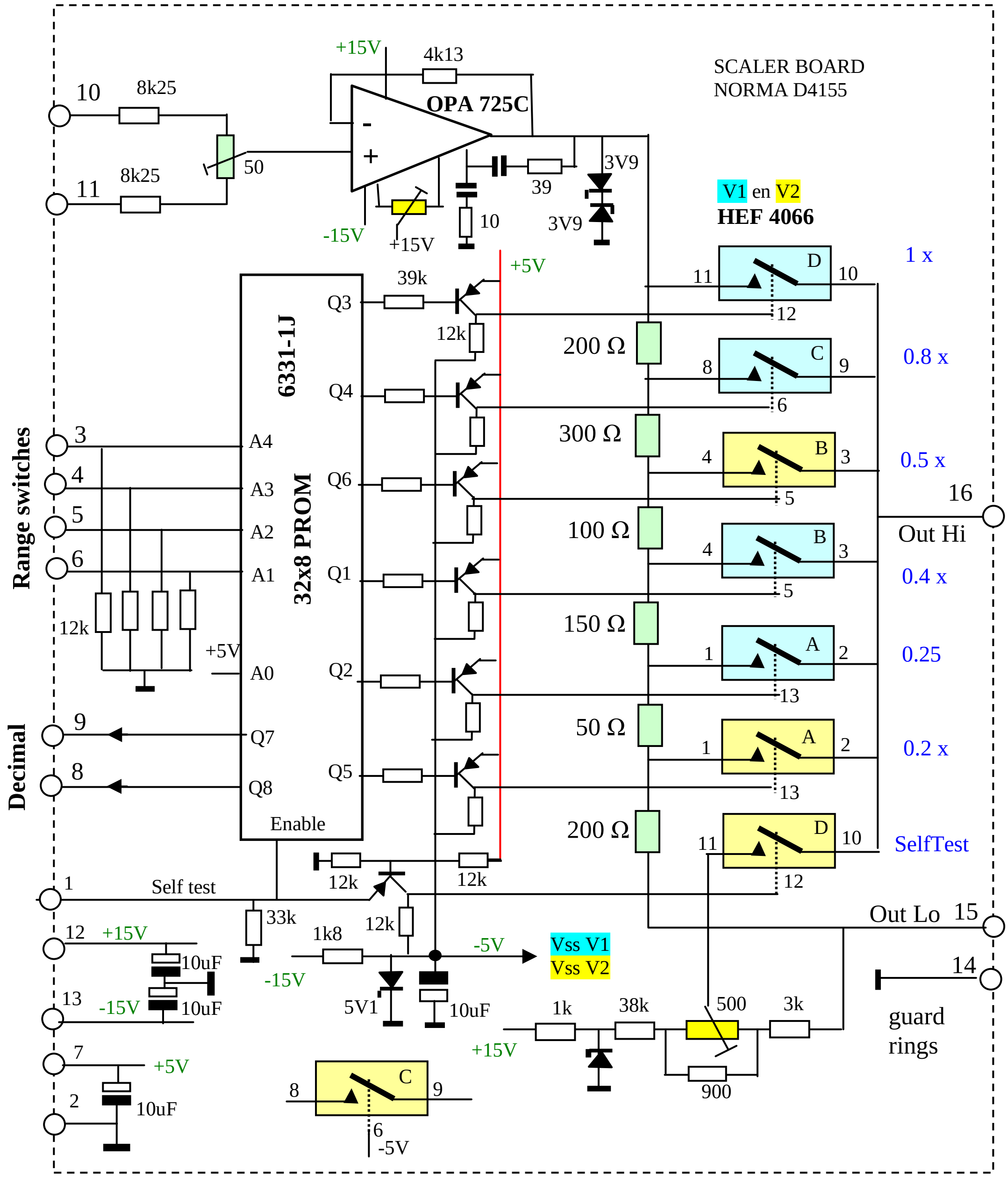

alle opamps V1…V8 LM308 N
Opamps V9 : OP47 ?
comparators V3 en V4 TBA221 B

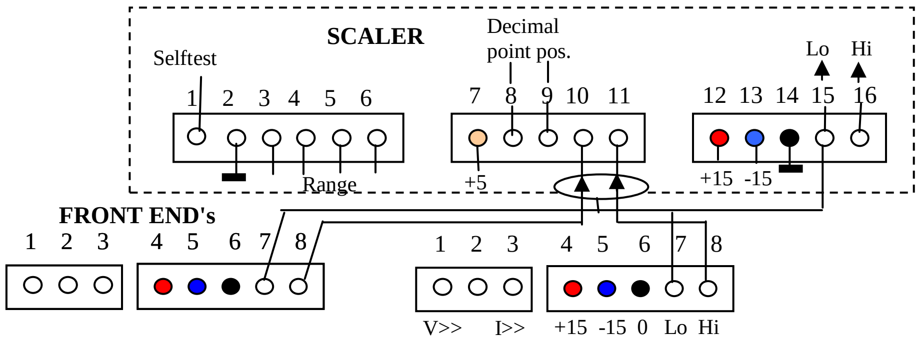
3 Jfet s
Rds=100Ω bij 0V gate
Werkpunt bij -2V gate



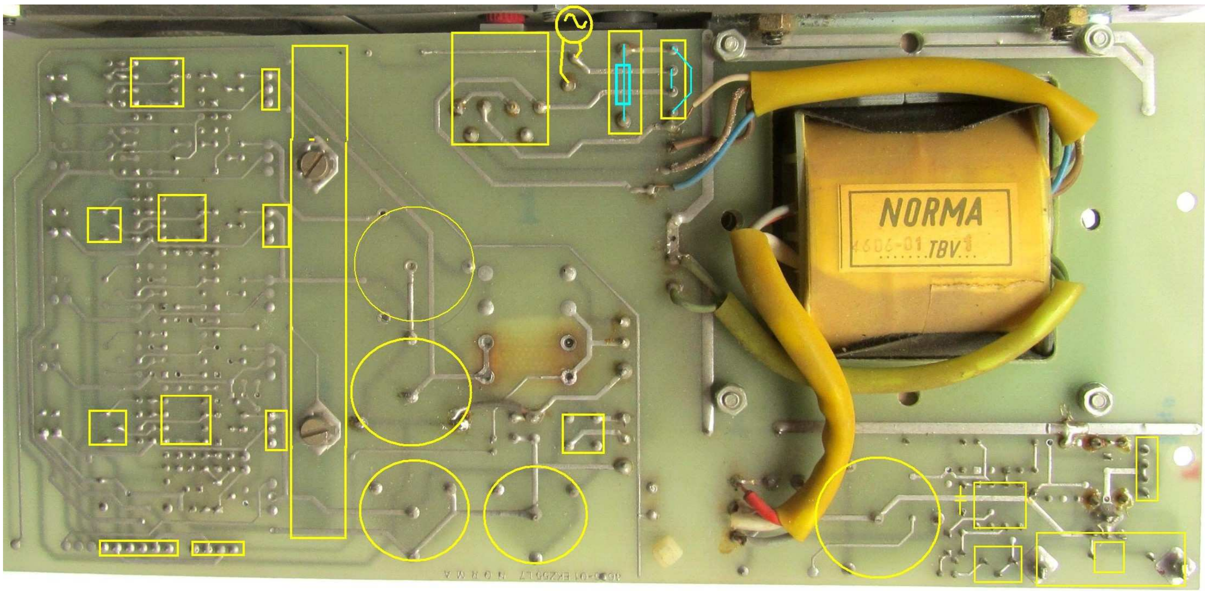
# Norma D4155 Scaling board

The dc output of the two front-end wattmeter boards are added, and post-scaling is applied for the correct result is display

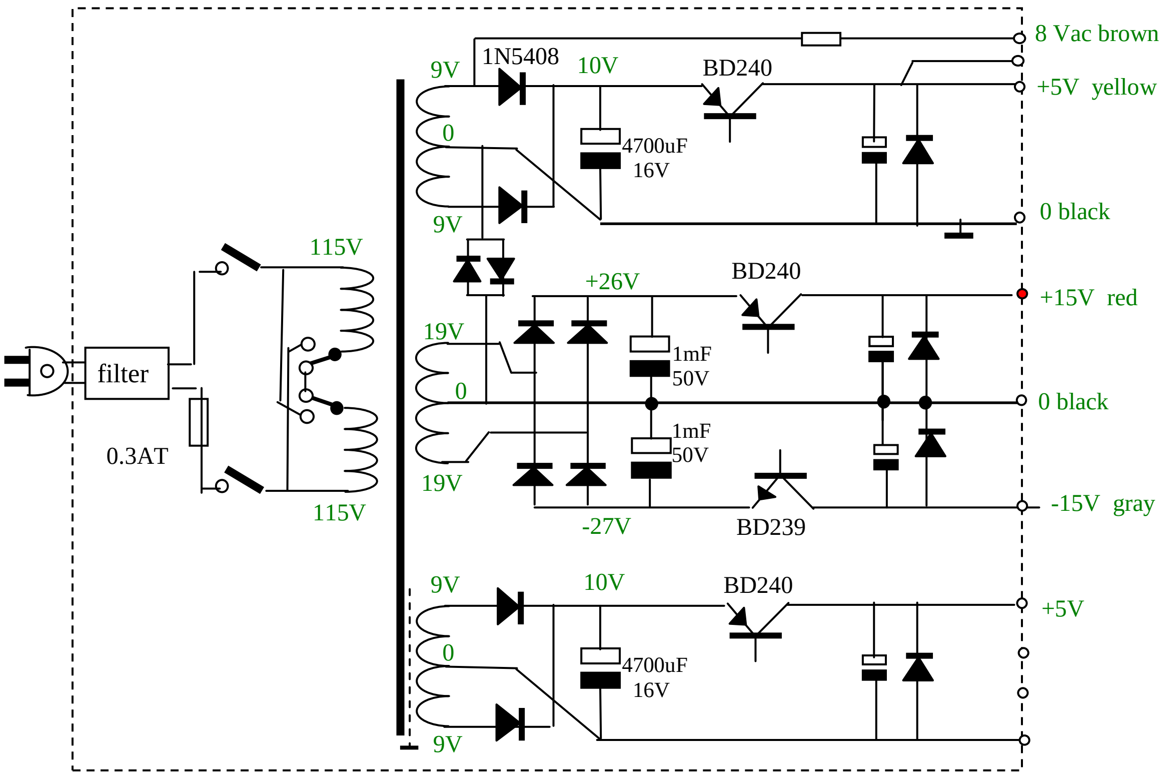


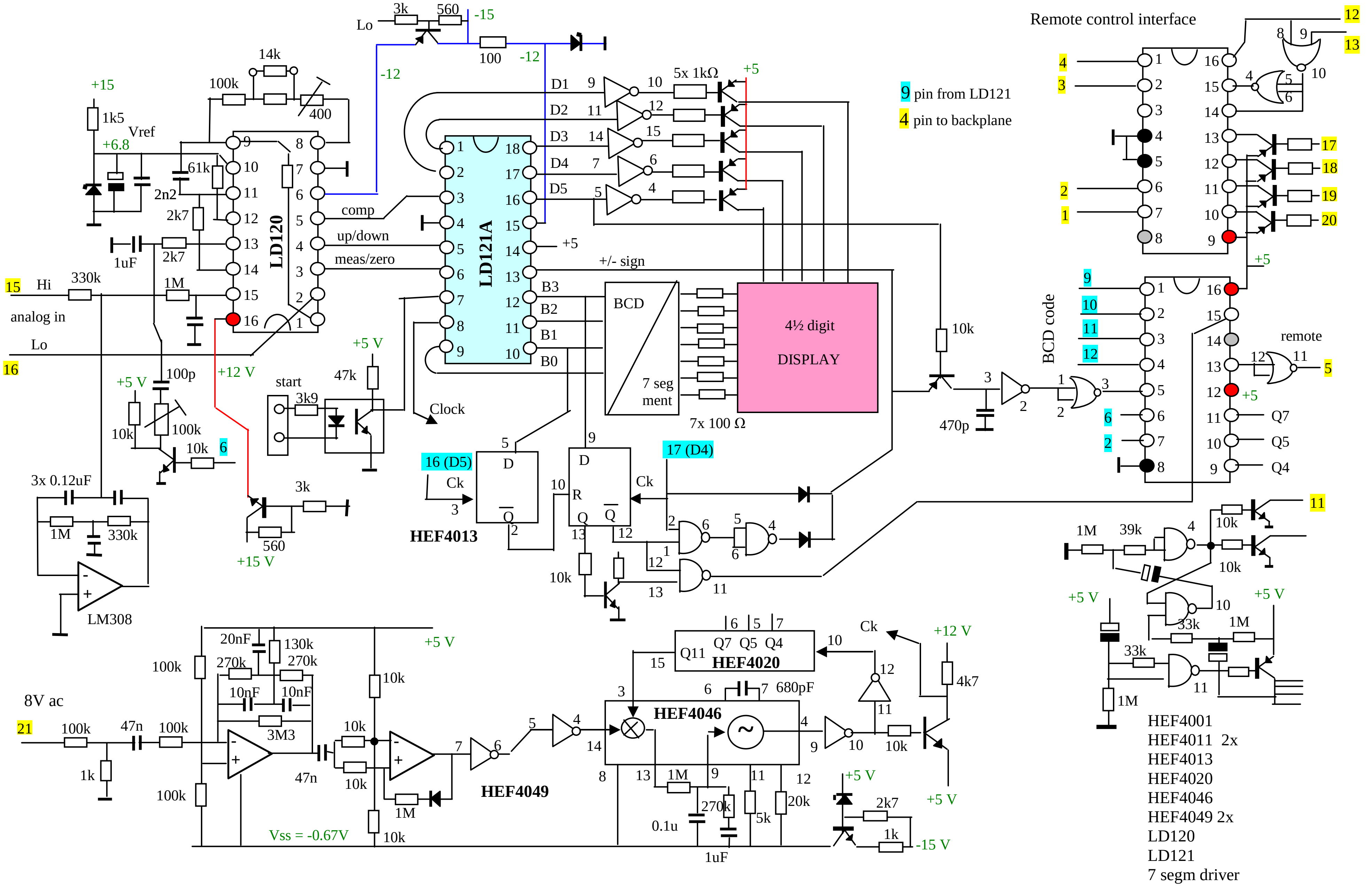
# Norma  D4155    Power Supply Module




Power consumption 40W. Left are the  +15V, -15V en 5V output, all three with respect to input connector L2.   Beware, this implies the complete electronics is live.
The second 5V output  is for the optional GPIB interface.



# ADC and display board



Notes