DIGITAL VOLT/AMPERE INDICATING INSTRUMENTS WITH LED DISPLAY VAD1/2

This project complements best a mains-operated DC adjustable-deck for electrical laboratory practical, but could in other context also be used as an ordinary volt or/and ampere instrument. Usually choose the most people an IC that is suitable for this purpose, such as CA3162, ICL7106 or ICL7107 but this variant is entirely based on standard logic. So if you have a lot of logic circuits as lying around can they be of use here.

VAD1/2 is intended for 4 pieces of 14 segment LED displays, 4 digits for both current and the voltage display. The LED display can either be of the type; common anode (CA) or common cathode (CC) - it goes either way. For adaptation to the intended variation it is necessary to carry out proper wiring through intended solder terminals. Nor is it excluded that it is possible to use an LCD display... flexibility? This requires that you connect a square wave to the PH terminal out from the 4543 (display driver).

It for this purpose the necessary A/D converter also is based on discrete components, which forms the link between the analog measurement section and the digital display section. The A/D converter works with the ramp conversion principle with an associated sweep generator. It is clocked by the versatile 4060-counter using a 12MHz quartz crystal.

The total cost for VAD is similar to those ICs. It becomes a little more soldering job here, but considers that this project is highly optimized for the task. VAD1/2 was originally designed for displaying voltage and current at the same time! Both voltage and current are presented in real time, without flicker through multiplexing. Shifting of the field/multiple unit and the "commas" is done automatically without sacrificing accuracy.

Shift is done - one time - by a factor of 10, from 8 - 10V and 800mA - 1A. The shift position is determined by the value of R16. The default position is 0-99.9V 0-9.990A but can be varied in many ways. Theoretically, one can measure from 0 to 999V and/or 0 to 999.0A!

Then this category of instrument usually consumes a lot of power is VAD designed to work with a low supply voltage (8VDC) but with ordinary CMOS circuits from the 4000 series. The LED display is pulsed quickly through the 4060 circuit. 100mA is quite affordable.

VAD need to be supplied through a free secondary terminal from the main transformer. It is preferred when a unit for measurement should be separated from the object it controlling. Later must the ground plane on VAD and the negative pole kept separate. From an interference point of view is the minus-potential connected via a capacitor (Cd) of approx 220nF. Observe that the OP in VAD1/2 fail if a galvanically coupled voltage higher than the supply voltage is registered. VAD is available in two variants; one with LED displays that is implemented on the same circuit board that houses the electronics, while the second only contains the electronics so it can be placed at the side of the display module. VAD is equivalent to a linear A/D converter for small signals. The subtitle could be: Linear A/D converter with display.

DIGITAL VOLT/AMPERE INDICATING INSTRUMENTS WITH LED DISPLAY VAD1/2

Like all other electronics projects that I have developed is also VAD based on SMD-tech, as much as possible. It is preferred when the size of the board becomes smaller and the drilling operations are reduced, but a certain number of holes must be drilled in all cases.

The power supply should be done via a free transformer winding, rectified and stabilized with an ISOWATT220 7808 regulator. The case on ISOWATT220 is isolated and can be directly attached to an arbitrary heat sink. The supply-wiring is then drawn and connected to VAD1/2, but the voltage regulator can be mounted directly on the circuit board with a separate heat sink. VAD is designed for a high ambient temperature (should be avoid). That is why R7 and R19 are coal based resistors. These actually offset that C3 and C4 deviate.

Before VAD can be used it must be calibrated with P0, P1 and Ri. It is best done when VAD is mounted and connected in the object it has to measure. Before this happens, you should test that the construction working fairly. The downside to energize a faulty electrical circuit is that in the same moment can break. This is from my own experience usually a mechanical failure. More specifically, it qualifies in this case of a solder-error. The PCB layout of VAD is relatively dense. <u>So I ask you to do the following</u>: Check for solder bridges between the insulated tracks and fix them. Especially between IC legs, where there may be unwanted bridges. The safest is to spray the etched PCB with protective coating before soldering begins, or you can scrape between IC legs with a narrow pointed object after soldering.

Now to the function test: Connect 8VDC to 8V+ input. Both displays will now show 000, however one screw at P0 and when you touch the input terminals M1, M2 and M3 with a finger, they begin to flutter. The power consumption will be approximately 100mA. Thus it can be concluded that the unit is serviceable. To test the device's measurement capability and numerical presentation recommended a full-scale experiment with the L-circuit plus an external voltage source. In this case can a calibration be carried out (this is described later). It may happen that the system not can "zero" itself entirely, which is completely normal. <u>It varies with your copy of the operation amplifier LM224N. Some copy goes down to zero and others are not</u>. This can easy be fixed. Change R12 to a next higher resistance value. As a rule, you can start with 3.3k and then gradually increase until the display reads zero when there is zero volts in. A small R12 is however preferable from the linearity point of view. VAD has a built-in offset error (jump) at the beginning. This means that smaller current values than 50mA is misleading.

A little about R4: As you may understand is it R4 that determines the gain of the two operational amplifiers. The gain F between them must also be exactly the same, otherwise it will be wrong in the system. The size of F is thus dependent on the value of Ri. It is the small voltage across Ri that will be amplified, i.e. at the current measurement, but the signal for measuring the voltage must pass through the same amplifier and be amplified as much as the current measurement signal too. This is only positive when the measurement only in a minor way affects the object. So the larger the F is, the smaller the impact on the object is.

When R4 is equal to 1.0Mohm will Ri be around 0.01ohm. It is an appropriate value when measuring currents from 0-10A. At 10A will the voltage drop across Ri be 0.1V - it is negligible. The voltage drop on the measuring cables is likely to affect more. Ri may consist of an approximately 150mm long wire of diameter 0.5mm. The calibration for an accurate current display is made by cutting the thread until the correct value is present. For higher currents than 10A can Ri be reduced further.

You can also choose to not going backwards, i.e. determine F for a given value of Ri - it's complicated. First, it can be difficult to get hold of a resistor with the value 0.01ohm, and second must R4 be determined mathematically. It may happen that R4 will be 983kohm, which can be difficult to realize. Enough about that - then VAD of design reasons, measures the voltage before Ri, becomes this "invisible" voltage drop not registered. Therefore shall Ri be as small as possible.

When R4 = 1.0M is F = 454ggr. (~ 45ggr. after the 10-selector is activated). The condition of the resistances so that any different-error can occur between the 10-selector is:
R1/10 = R1//(R2 + R3 + 80). If it turns out that the measurements between the low and high range differ from each other, will it depends on the difference between R1 and R2 + R3). Try then with another value for R3 and test. This operation is unusual and shall not have to be done, but it may be necessary if a high voltage is to be measured - then the small error between 1/10-field makes itself visible. 2200ohm plus 160ohm may not be sufficient for the requirements it shall hold? However, make sure all of the three R1, R2 and R3 - is equal!

Regarding the measurement of the voltage, also this (by structural reasons) is passes through the amplifiers. The voltage thus amplified considerably and should therefore be divided down before it reaches M3. The figures on the subsequent pages show how this is arranged. It also shows that the voltage and current are measured in close connection with each other in a three-point L-circuit.

If one choose to measure a current between 0-9A and Ri to 0.01ohm, becomes R4 about 1 Mohm. If one simultaneously want to measure the voltage between 0-40V shall the voltage been taken from a potentiometer in series with a 100kohm resistor via the L-circuit in the DC unit / measurement object. First calibrated the voltage alternating with P0 and P1, the current is finally calibrated with Ri. The input impedance is not very large (~2200ohm), so for measurement of various high impedance sources must VAD be provided with some kind of buffer at the input - this are not described here. There is a circuit that controls if MSD (Most Significant Digit) is zero, if so - turns the display off (goes blank). Exceeded the measurement range will not the display show "overload" but MSD remains a nine (9), while the other numbers starting at zero. It is therefore possible to record measured values above the upper measurable limit, however, only marginally.

Negative inputs are not supported by VAD, i.e. negative values can not be displayed.

VAD uses two dual 7-segment displays for each digit window. Actually, one could use a quad 7-segment... for each display-component but then I guess the chances are greater that you'll find dual displays in the electronics box, it had to be so. As the circuit diagram show is the voltage on the left and the current to the right. The voltage is shown in green and the current with red color, but this can be chosen arbitrarily. The current can for example be green, yellow, orange... and lie in the left display screen. If it were so shall M3 measure current and M2 voltage. The displays are of the type; one pin for each segment. It would require additional logic to control displays that share pins for several digits. The digit along the right side of the voltage displays are not used in normal cases. This can be changed through 0u1-0u3. It is required if you want to measure mill volts (or mill amperes).

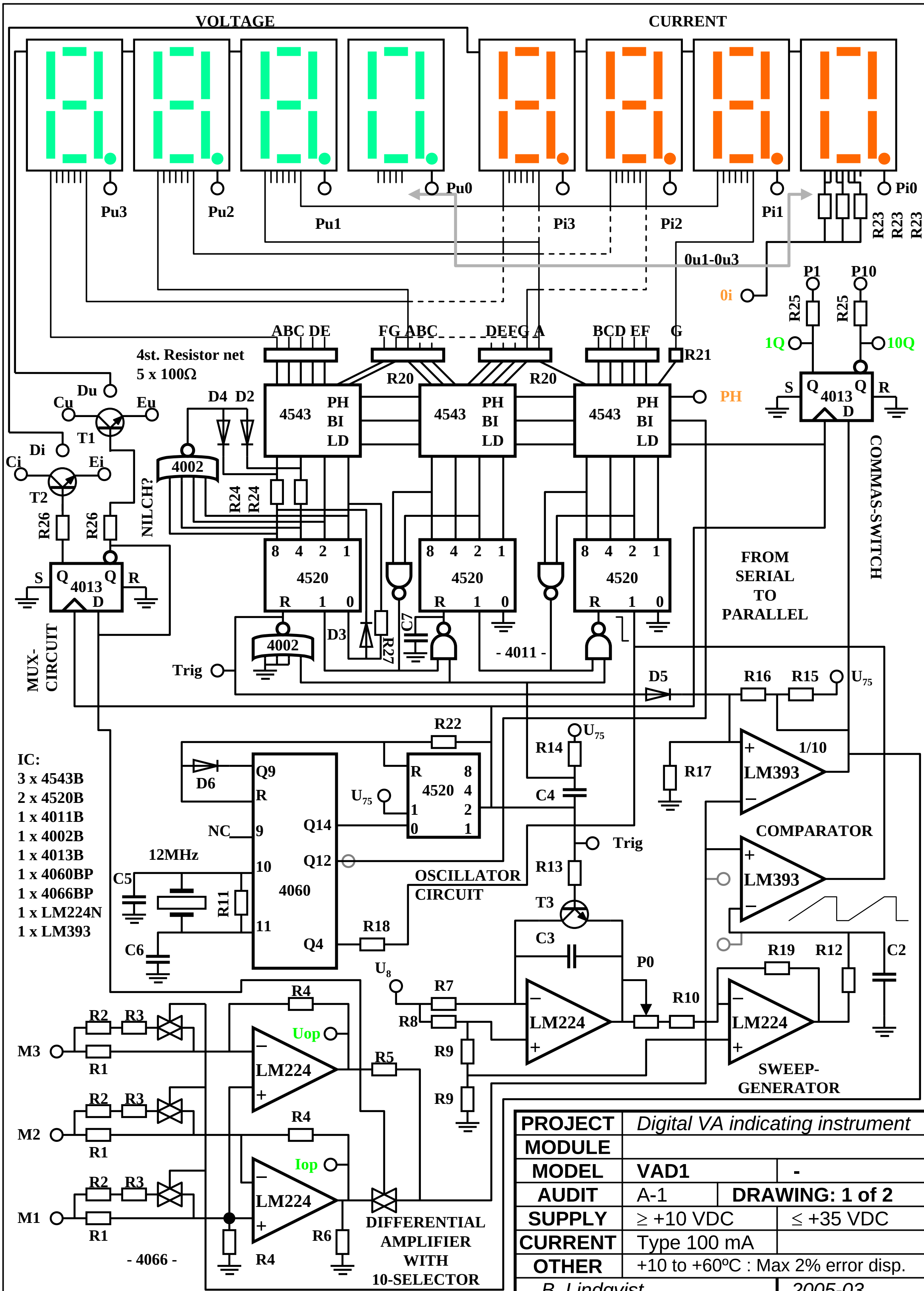
The PCB layout for VAD1 have a standard dimension; 100x150mm. This requirement has led to that the tracks are quite close (to being an amateur project). The safest way is to use the UV method before etching, otherwise it may be tricky? Then VAD2 is divided into two units to be able to put the electronics unit next to the display unit. Maybe you want to have various panel components just below the display unit?

A double-board PCB is needed. When space is critical is one side only for the power supply, dc-capacitors, ground plane and for segment-links. The ground plane makes a distinction between analog and digital signals - in order to keep the noise low on the analog side. The other side is known as the place for the main circuit constructions. Mounting and soldering should go pretty fast, as no jumpers or zero-ohm resistors exist.

The number of holes that has to be drilled is greatly reduced; it will speed up the construction. For this reason shall ALL legs of ICs be cut, except the plus and minus legs! Holes need only to be drilled for plus pin and minus pin. It is pin no.1 and no.14 alt. no.16, for the logic circuits. 1&8 for LM393 and 4&11 for LM224. The plus and the minus legs are soldered on both sides. This also applies to C1, D1 and the display unit. The top of the display unit can be difficult to solder if they are pressed fully against the board. Therefore; try to place a temporary distance (approximately 2.5mm), between the display unit and the PCB when these are to be soldered.

IC chips are of the type hole-mounted but are mounted like other SMD components (except the plus and minus legs). Any holes for the hole-mounted resistors shall not be drilled! They shall be soldered on the component side, like a surface-mounted resistor. The same applies for the resistor-net. It is essential that the level of all vertical components is below the top of the display module - because these shall lie against the display window. It should not be a problem if the mounting is done correctly. One can use transparent plastic of various paper collectors, plastic boxes, etc. - as a display window. VAD records signals faster than an eye can perceive. It may therefore be difficult to measure the current through a load that varies rapidly. The only way to avoid this is to connect a filter capacitor at the output of the DC power supply (i.e. the measurement object).

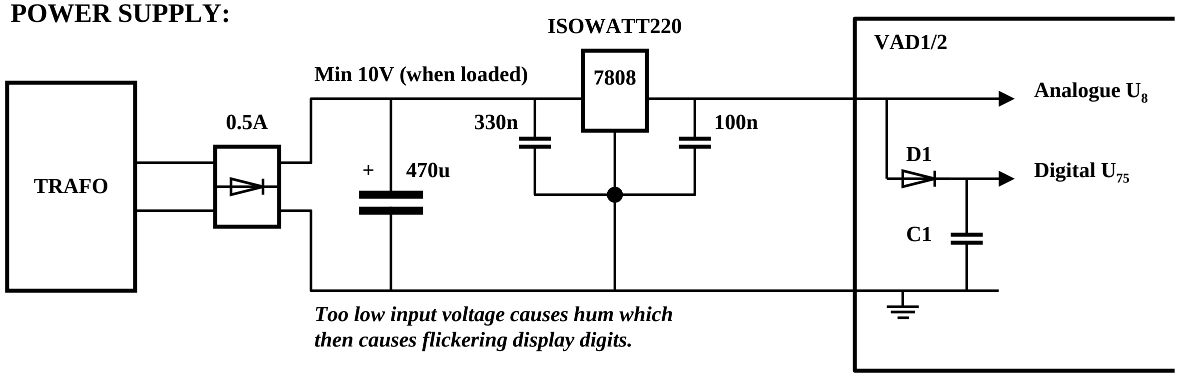
CIRCUIT DIAGRAM



PROJECT	*Digital VA indicating instrument*	
MODULE		
MODEL	VAD1	-
AUDIT	A-1	DRAWING: 1 of 2
SUPPLY	≥ +10 VDC	≤ +35 VDC
CURRENT	Type 100 mA	
OTHER	+10 to +60ºC : Max 2% error disp.	
B. Lindqvist	*2005-03*	

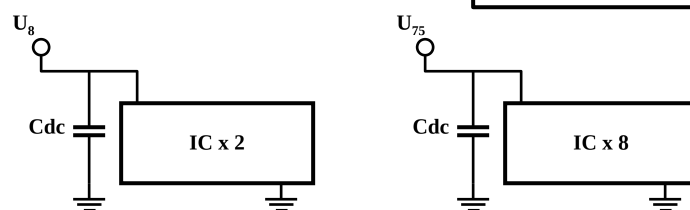
CIRCUIT DIAGRAM

POWER SUPPLY:



Too low input voltage causes hum which then causes flickering display digits.

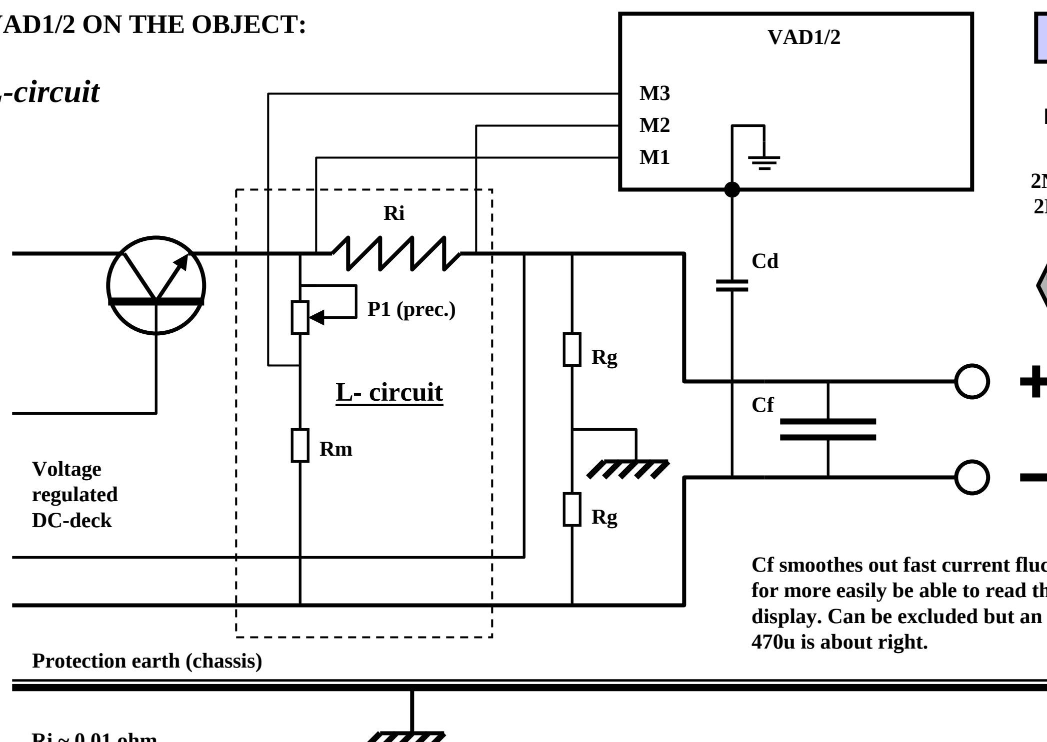
DECOUPLING FOR ALL IC:
(not LM224)

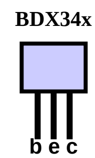


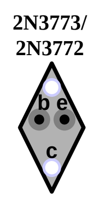
Cdc = 10n, SMC-1206

VAD1/2 ON THE OBJECT:

L-circuit







Cf smoothes out fast current fluctuations for more easily be able to read the current display. Can be excluded but an e-lytic at 470u is about right.

Ri ~ 0.01 ohm

P1 ≤ 220 ohm

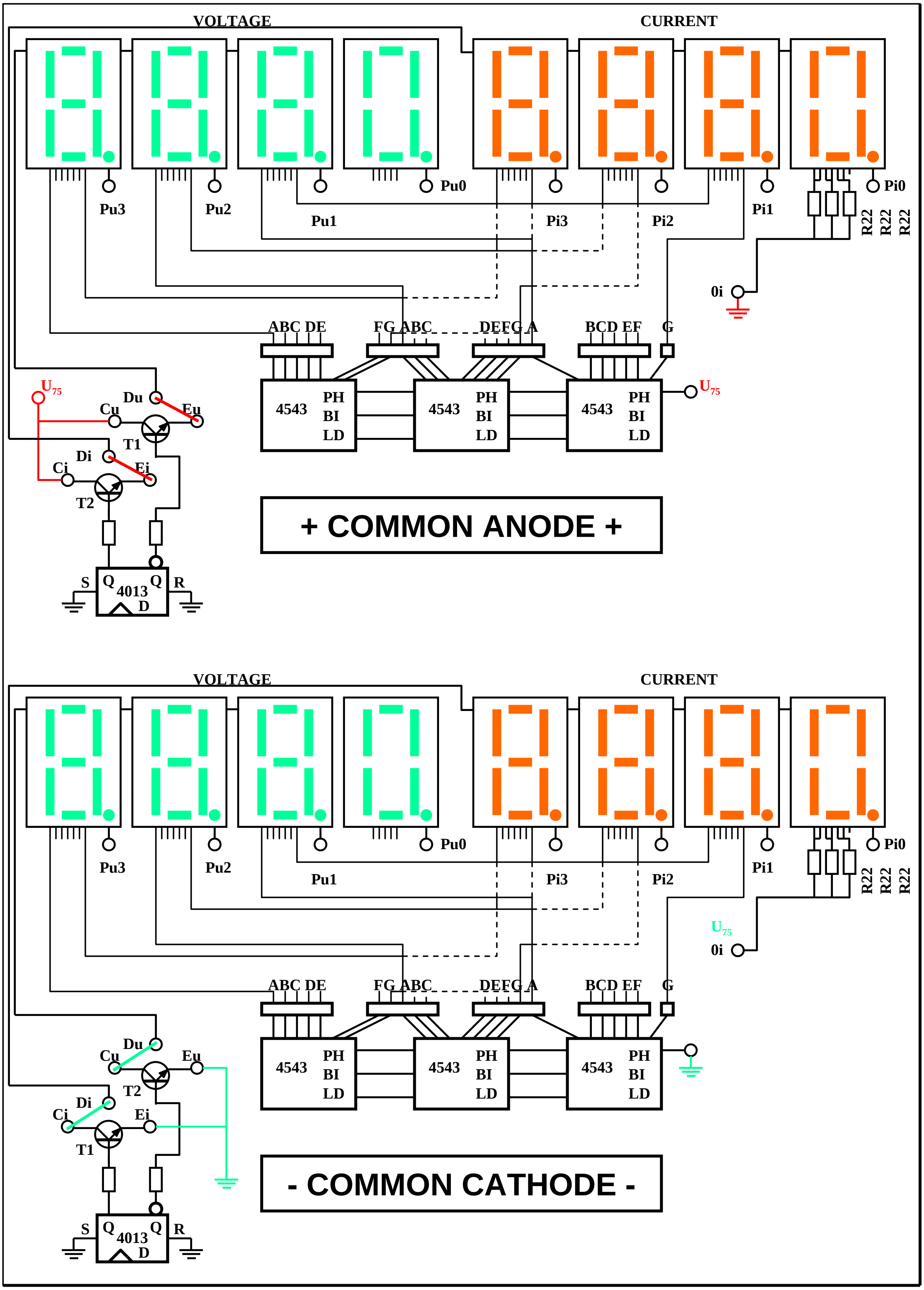
Rm ~ Fmax • P1 (if P1=220ohm becomes Rm~100k)

Rg ≥ 10M (prefer to not choose SMD)

Cd = 220n (bigger Cd creates display interferences at rapid in-variations)

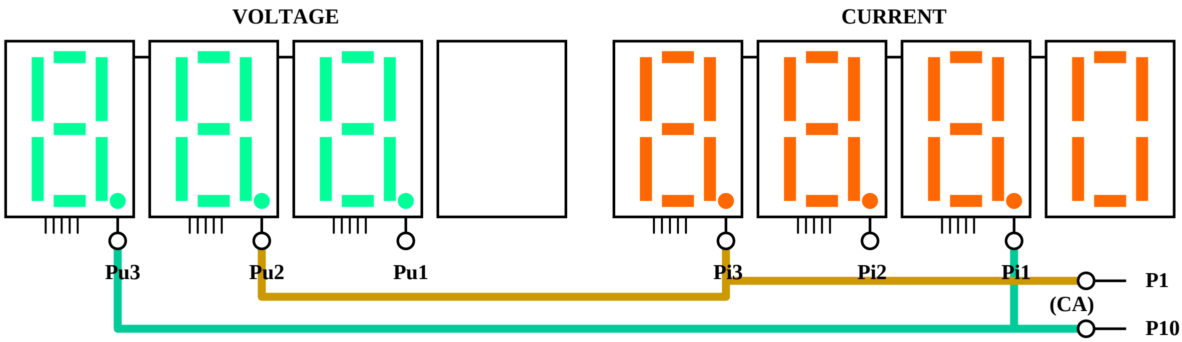
PROJECT	*Digital VA indicating instrument*	
MODULE	*L-circuit etc.*	
MODEL	**VAD1/2**	**-**
AUDIT	A-1	**DRAWING: 2 of 2**
SUPPLY		
CURRENT		
OTHER		
B. Lindqvist		*2005-03*

CONNECTING OF DISPLAY ELEMENT



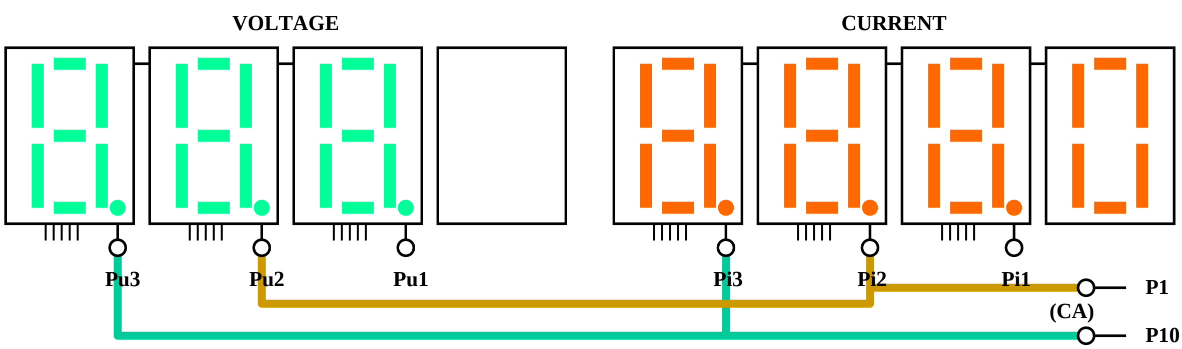
WIRING FOR SELECTED MEASURING RANGE

0-99.9V / 0-999mA - 9.990A :



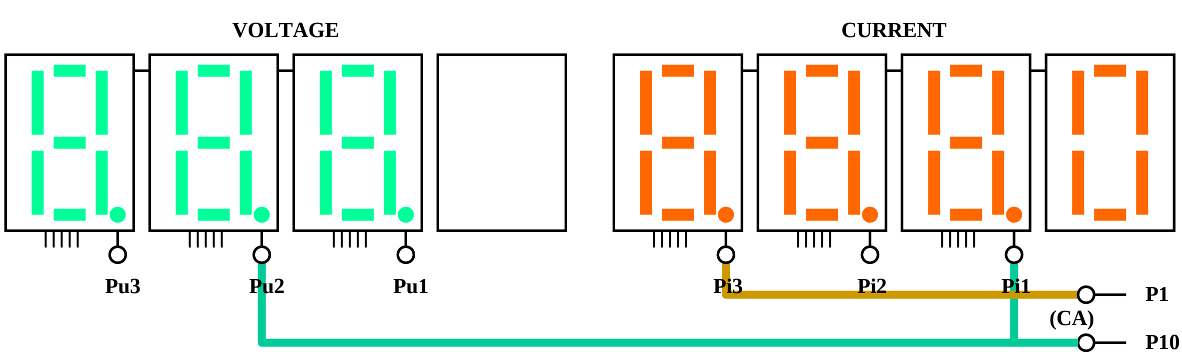

```
Ex:    .2 7  V*        Ex:      0 3.0 mA*
      7.3 8  V                  8 8.0 mA
      1 5.6  V                4 7 9.0 mA
      4 1.3  V                7.6 3 0  A
```

0-99.9V / 0-99.90A :




```
Ex:   .7 1 0  A
     7.5 5 0  A
     1 5.9 0  A
     8 2.6 0  A
```

0-999V / 0-999mA - 9.990A :

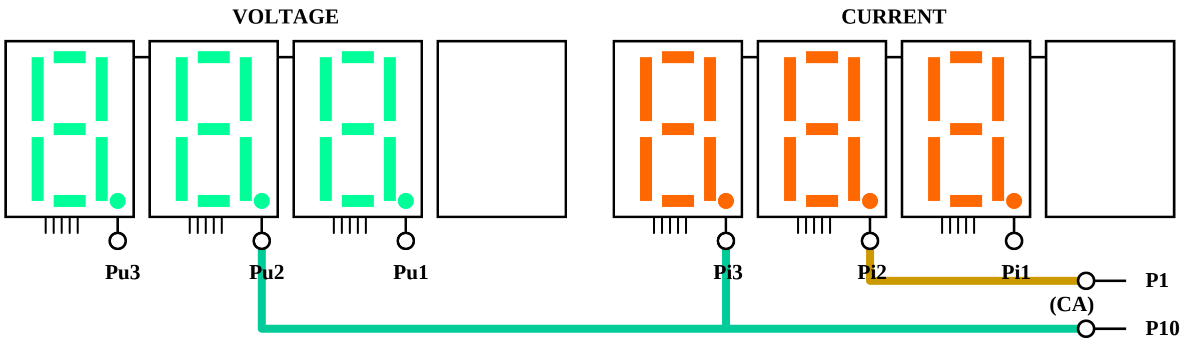



```
Ex:     4.2  V*
      2 9.8  V
      1 4 1  V
      9 9 6  V
```

* unreliable value

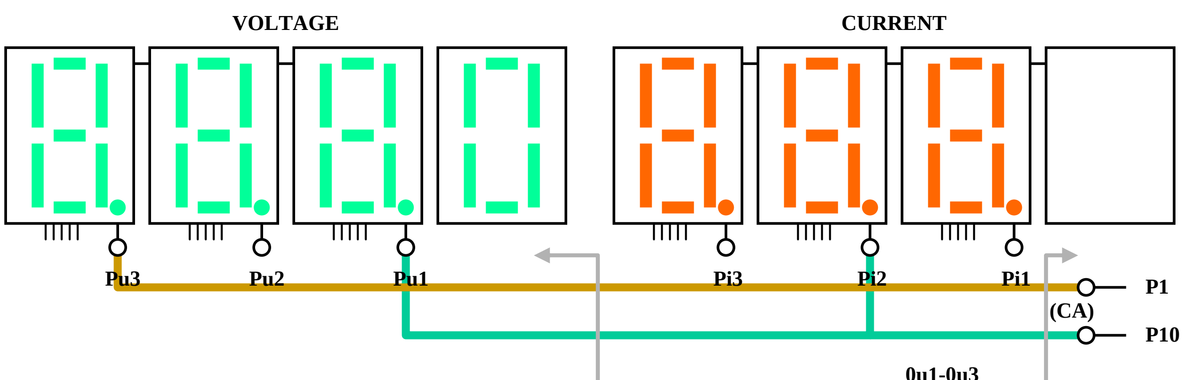
WIRING FOR SELECTED MEASURING RANGE

0-999V / 0-99.9A:




```
Ex:   .8 8  A
     8.3 3  A
     3 7.4  A
     9 8.1  A
```

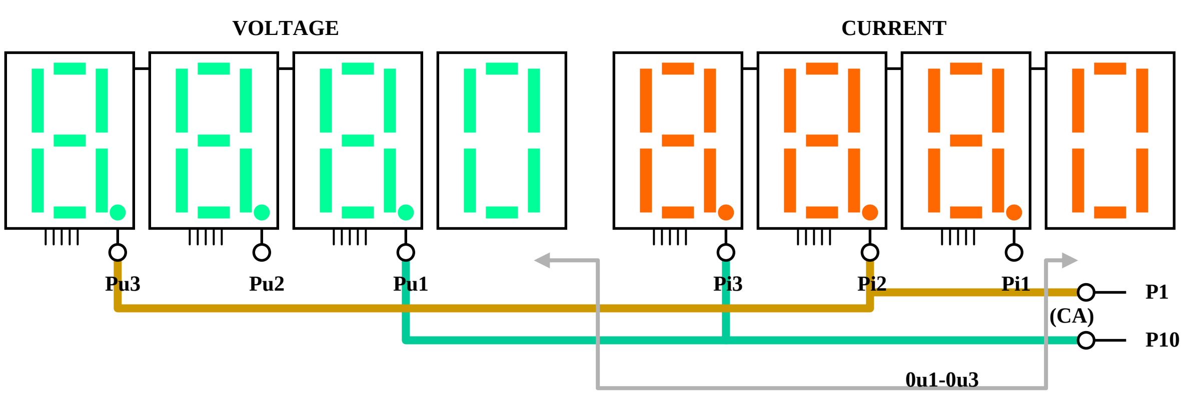
0-999mV - 9.990V / 0-999A:




```
Ex:     1 0.0 mV*
        8 4.0 mV
      7 1 5.0 mV
      8.7 2 0  V
```

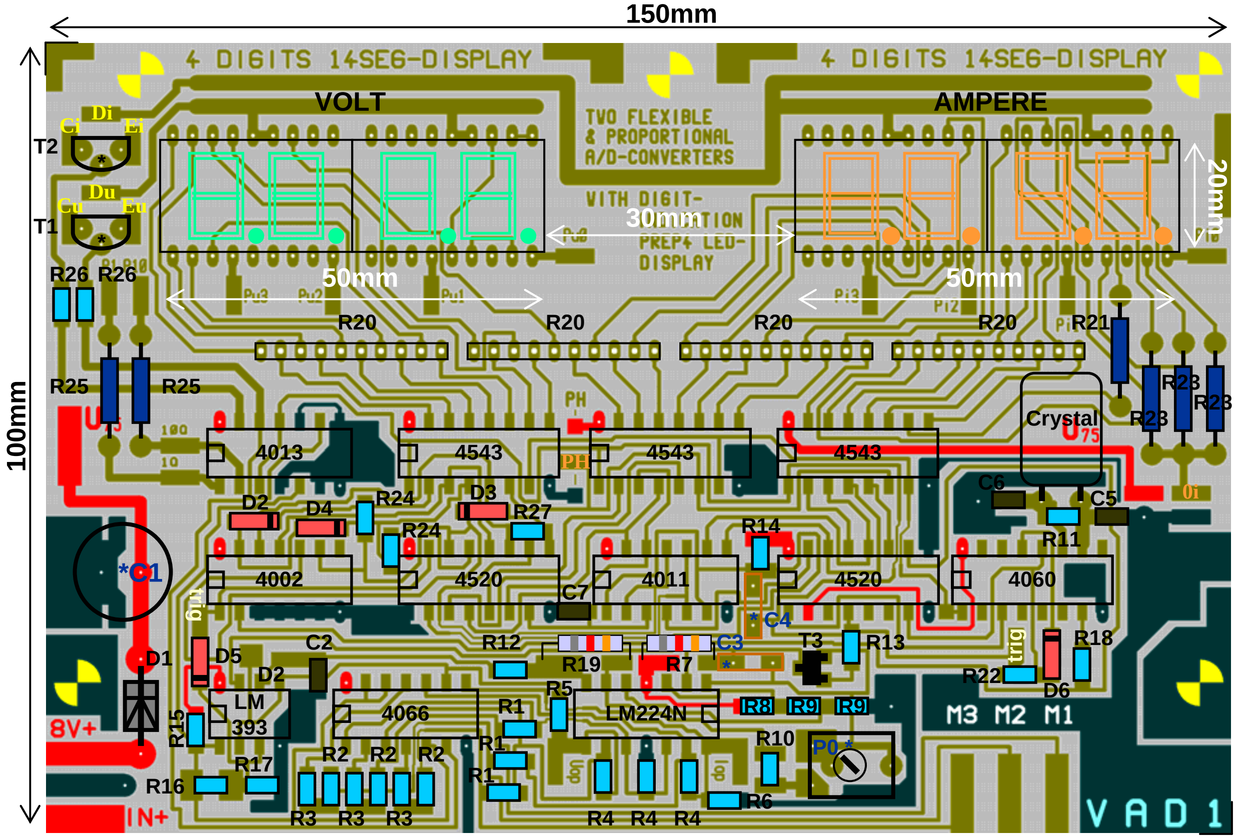
```
Ex:     0.4  A*
        5.7  A
      2 2.1  A
      9 1 8  A
```

0-999mV - 9.990V / 0-99.90A :



* unreliable value

PLACING OF COMPONENTS



SMR1206:
- R1 = 22k x 3
- R2 = 2k2 x 3
- R3 = 160Ω x 3
- R4 = 1M x 3
- R5 = 100k
- R6 = 1k
- R8 = 330Ω
- R9 = 1k x 2
- R10 = 47k
- R11 = 100k
- R12 = 4k7
- R13 = 47k
- R14 = 220k
- R15 = 4k7
- R16 = 22k
- R17 = 100k
- R18 = 4k7
- R22 = 4k7
- R24 = 47k x 2
- R26 = 1k x 2
- R27 = 22k

SMC1206:
- C2 = 10n
- C3 = 4n7 (NP0)
- C4 = 4n7 (NP0)
- C5 = 100p
- C6 = 33p
- C7 = 10n
- Cdc = 10n x 10

LOGIK:
- 4543B x 3
- 4520B x 2
- 4013B x 1
- 4002B x 1
- 4011B x 1
- 4060BP x 1
- 4066BP x 1

Other components:
- R20 = SIL resistor net x 4, $R_{1\text{-}5}$=100Ω
- R21 = 100Ω , Hole mount
- R23 & R25 = 330Ω x 5 , Hole mount
- R7 & R19 = 82k , Coal based , h-mount - Shall lie against the board!
- C1 = 1000u , 10V , E-lytic , Hole mount
- D1 = 1N4004 , Hole mount
- D2 - D6 = BAS32 x 5 , SMD
- T1 & T2 = BC337/25 , Hole mount
- T3 = BC847B , SMD
- P0 = 10k , PTC-10 , Cermet (L or S)
- 4OP = LM224N , Hole mount & turned! (LM324N is an alt. but less good)
- Dual comparator = LM393 , Hole mount
- CPU crystal 12MHz , Hole mount
- Stab. 8V = 7808 ISOWATT220
- LED-DISPLAYER 4pc. 14 segment

**** = Mount it on the ground plane side***

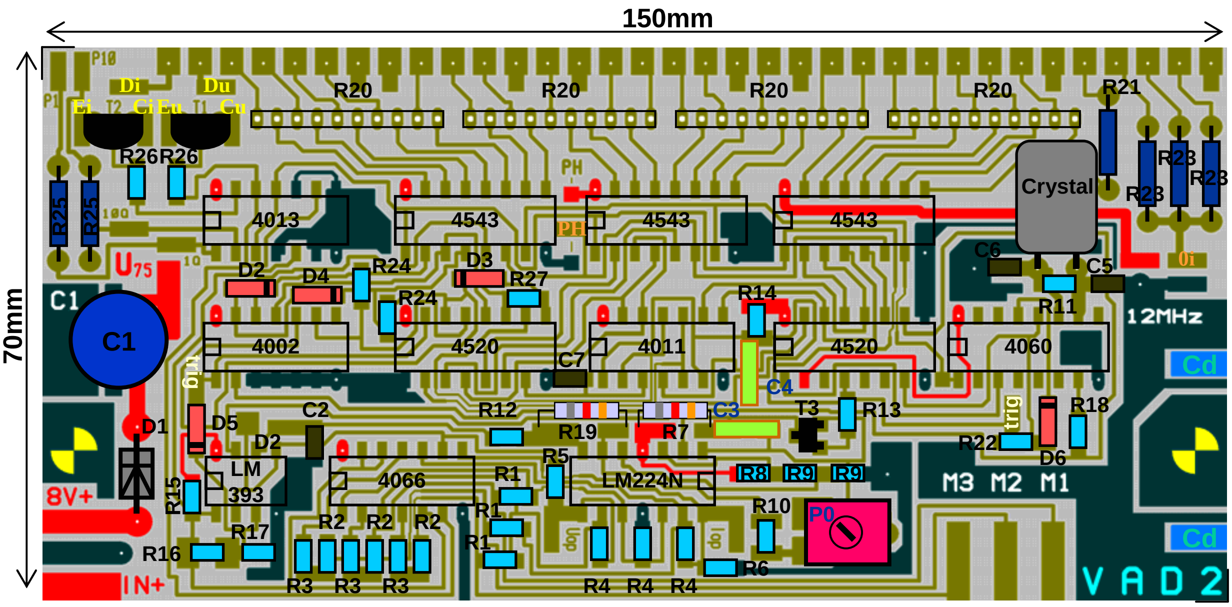
NOTE. Don't drill any unnecessary holes. E.g. should no holes be drilled for the resistor networks. See the ground plane layout.

C3 and C4 shall be SMC with NP0-dielectric, or a fancy plastic capacitor. Both should be of the same sort! This is crucial for a stable numerical displaying and for the temperature stability.

As VAD is constructed can it be linked with current-limitation. Use the soldering terminals to achieve this; IOP, UOP, 1Q and 10Q.

PROJECT	*Digital VA indicating instrument*	
MODULE		
MODEL	**VAD1**	
AUDIT	A-1	**DRAWING: 1 of 3**
OTHER	*Component side*	
B. Lindqvist		*2005-03*

PLACING OF COMPONENTS



SMR1206:

R1 = 22k x 3
R2 = 2k2 x 3
R3 = 160Ω x 3
R4 = 1M x 3
R5 = 100k
R6 = 1k
R8 = 330Ω
R9 = 1k x 2
R10 = 47k
R11 = 100k
R12 = 4k7
R13 = 47k
R14 = 220k
R15 = 4k7
R16 = 22k
R17 = 100k
R18 = 4k7
R22 = 4k7
R24 = 47k x 2
R26 = 1k x 2
R27 = 22k

SMC1206:

C2 = 10n
C3 = 4n7 (NP0)
C4 = 4n7 (NP0)
C5 = 100p
C6 = 33p
C7 = 10n
Cdc = 10n x 10

LOGIK:

4543B x 3
4520B x 2
4013B x 1
4002B x 1
4011B x 1
4060BP x 1
4066BP x 1

Other components:

R20 = SIL resistor net x 4, R_{1-5}=100Ω
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R7 & R19 = 82k , Coal based , h-mount - Shall lie against the board!
C1 = 1000u , 10V , E-lytic , Hole mount
D1 = 1N4004 , Hole mount
D2 - D6 = BAS32 x 5 , SMD
T1 & T2 = BC337/25 , Hole mount
T3 = BC847B , SMD
P0 = 10k , PTC-10 , Cermet (L or S)
4OP = LM224N , Hole mount & turned! (LM324N is an alt. but less good)
Dual comparator = LM393 , Hole mount
CPU crystal 12MHz , Hole mounted
Stab. 8V = 7808 ISOWATT220

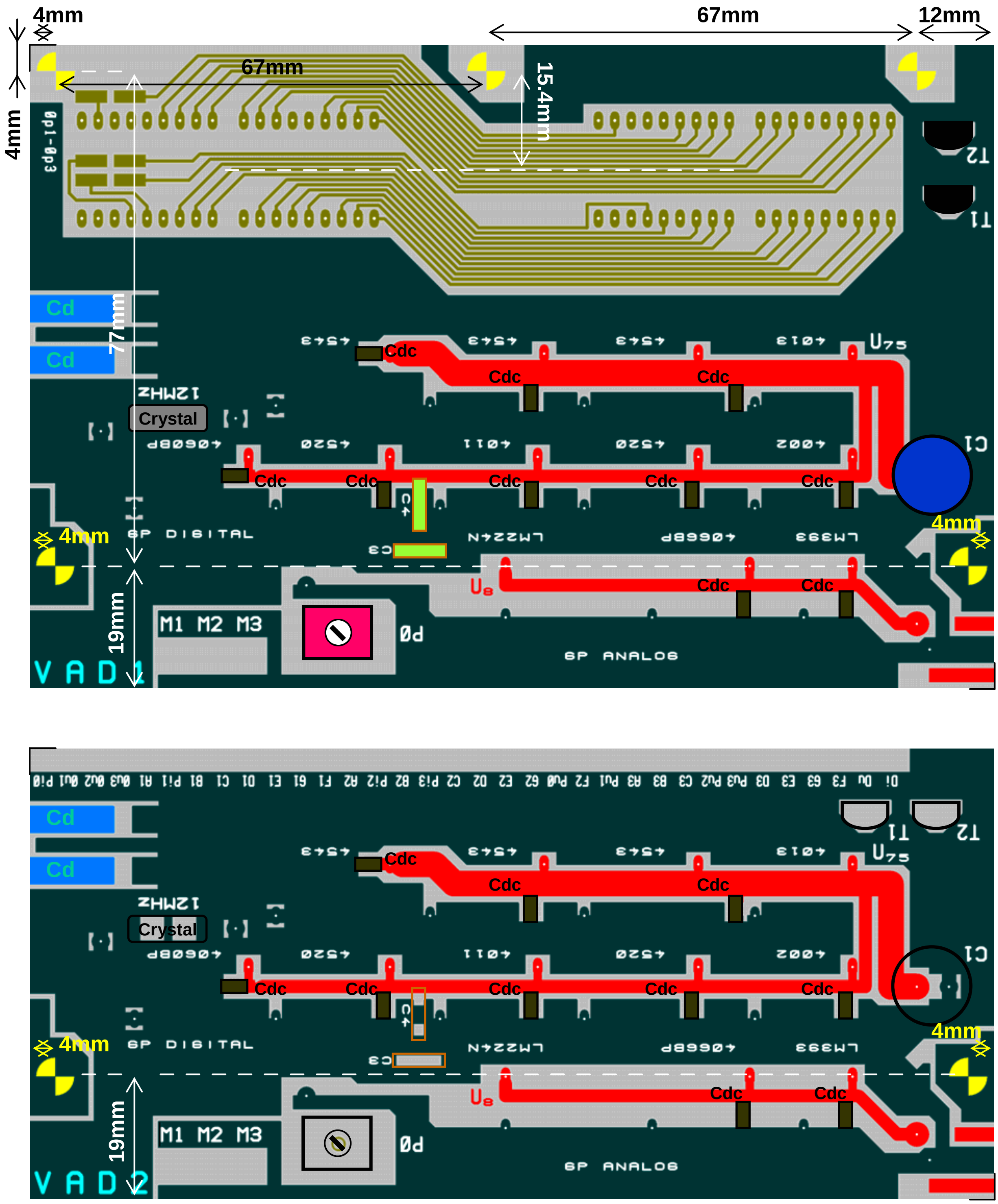
NOTE. Don't drill any unnecessary holes. E.g. should no holes be drilled for the resistor networks. See the ground plane layout.

C3 and C4 shall be SMC with NP0-dielectric, or a fancy plastic capacitor. Both should be of the same sort! This is crucial for a stable numerical displaying and for the temperature stability.

As VAD is constructed can it be linked with current-limitation. Use the soldering terminals to achieve this; IOP, UOP, 1Q and 10Q.

PROJECT	*Digital VA indicating instrument*		
MODULE			
MODEL	**VAD2**		
AUDIT	A-1	**DRAWING: 2 of 3**	
OTHER	*Component side*		
B. Lindqvist		*2005-03*	

PLACING OF COMPONENTS



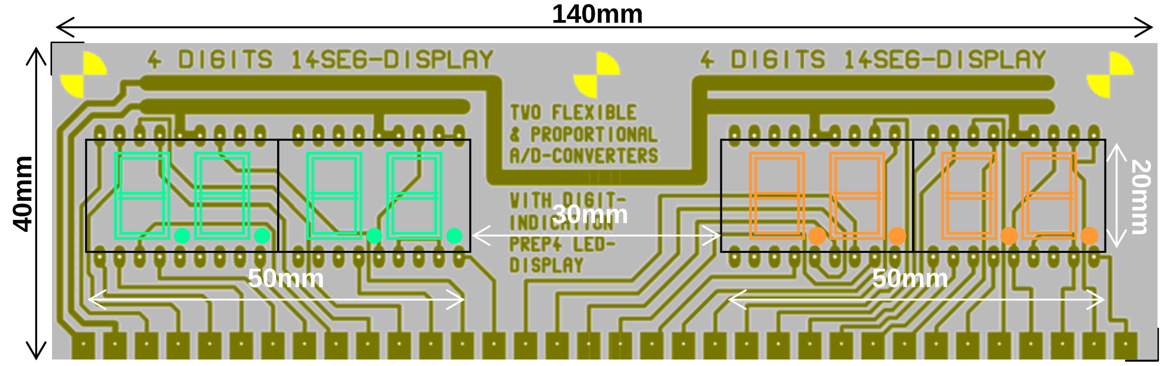
Length dimension refer to one decimal (if no decimal is exposed) according to the example:

4mm is equal to 4.0mm,
22mm is equal to 22mm ±0.2mm and
2.4mm is equal to 2.4mm.

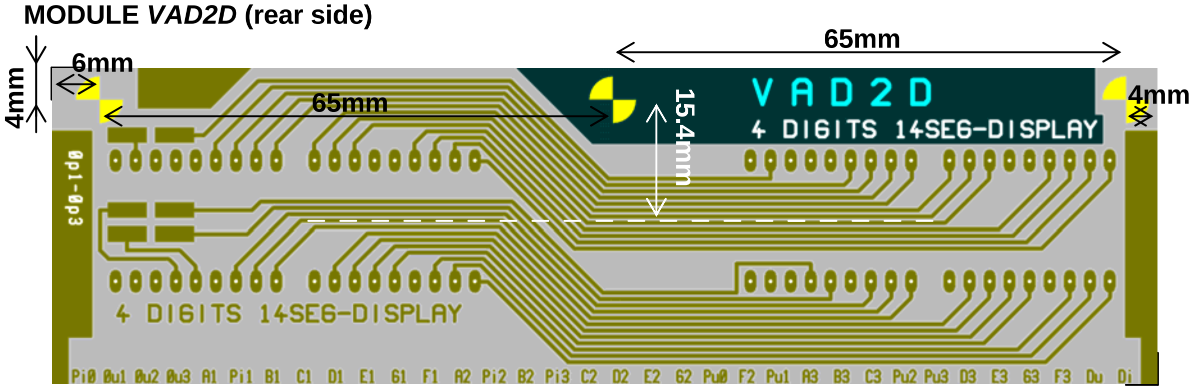
PROJECT	*Digital VA indicating instrument*		
MODULE			
MODEL	**VAD1/2**		
AUDIT	A-1	**DRAWING: 3 of 3**	
OTHER	*Ground plane side*		
B. Lindqvist		*2005-03*	

PLACING OF COMPONENTS

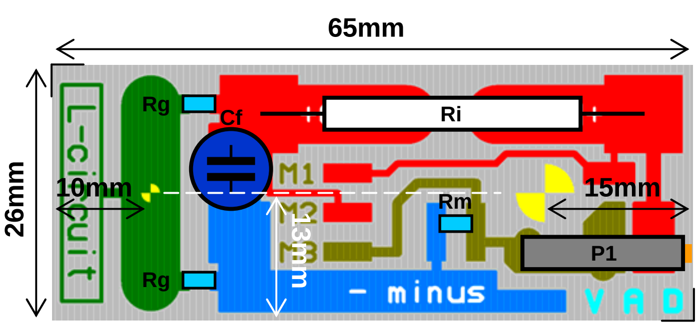
MODULE *VAD2D* (component side)



MODULE *VAD2D* (rear side)



MODULE *L-circuit* (component side)

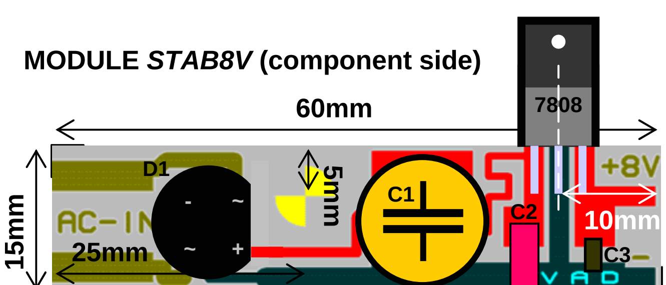


SINGLE-SIDED BOARD - NO HOLES

P1: A hole mount precision pot…
ELFA: Type 89P BI Technologies
164-72-146 (100ohm)
164-72-161 (200ohm)

Single-sided board, in which all components should be mounted on top. The board should be grounded on chassis (protective earth), via the left screw hole.

MODULE *STAB8V* (component side)

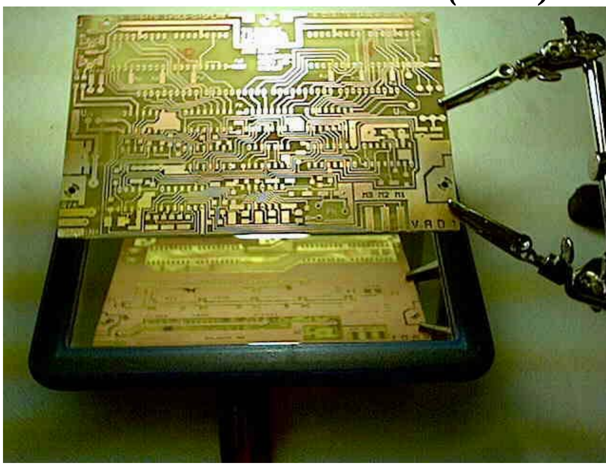


7808 = Voltage stab 8V , ISOWATT220
D1 = DC bridge , hole mount
C1 = 470u , E-lytic , hole mount
C2 = 330n , plastic capacitor , hole mount
C3 = 100n , SMC

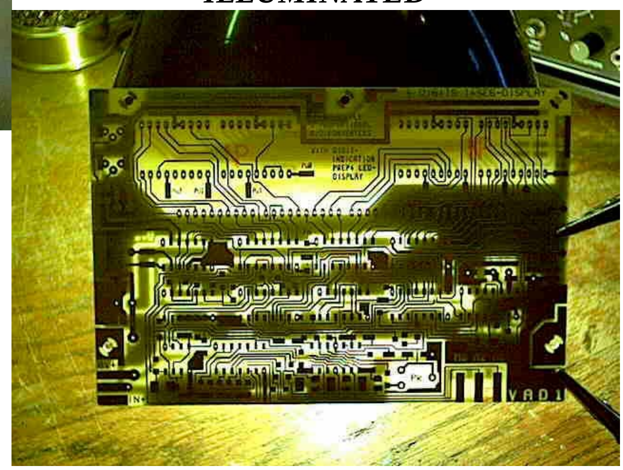
Single-sided board, in which all components should be mounted on top. Considerate if only one screw hole via 7808 is enough?

PHOTOS

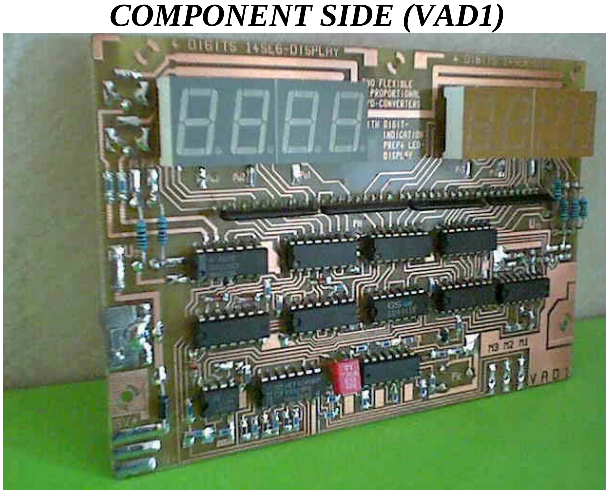
ETCHED WIRING BOARD (VAD1)



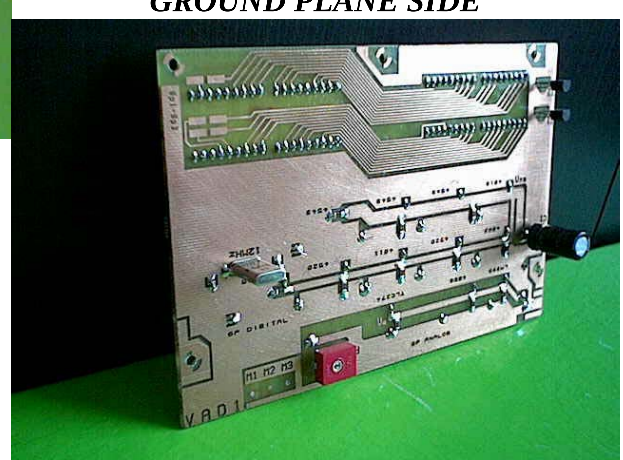
ILLUMINATED



COMPONENT SIDE (VAD1)



GROUND PLANE SIDE



The pictures show an earlier prototype that has minor differences in the pattern layout. Otherwise is it identical to the latest version.