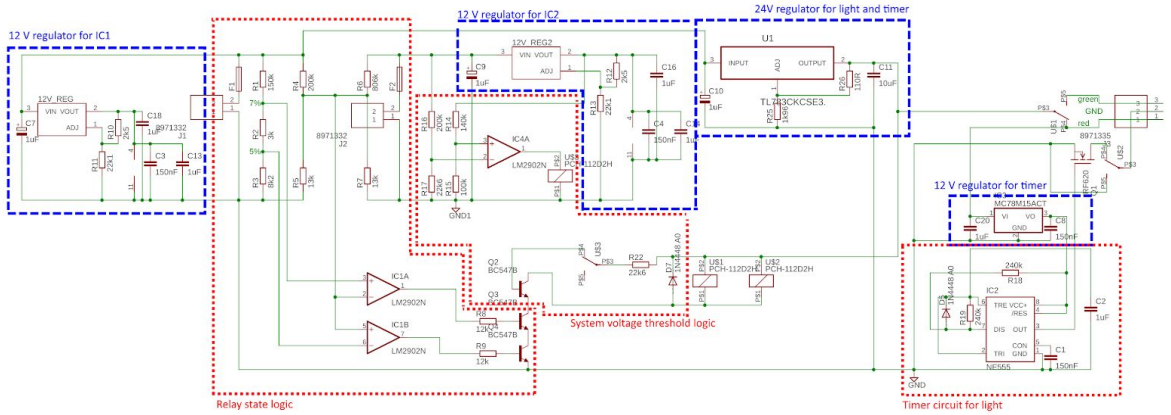
Documentation and calculations

Overview

The Tractive System Active Light (TSAL) is an external system which will monitor and indicate the battery activity status. The battery is active if any of the two main relays (AIRs) are closed or if the outside system voltage is above 60 VDC. The TSAL will have to measure the relays physical state, so it's not permitted to measure the control signal to the relays.

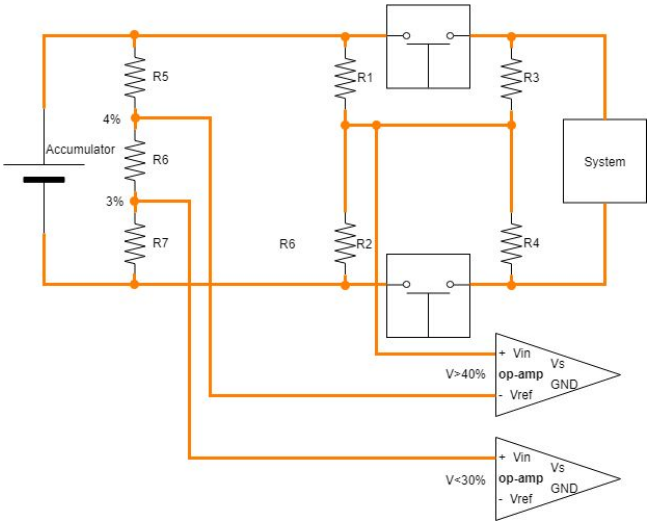
A circuit digram can be seen below. The circuit consist of three main parts; the *relay state logic,* the *system voltage threshold logic*, and the *timer circuit for light*. These parts can be seen marked in a red box. The blue boxes marks the voltage regulators used to step down the full battery voltage.

The circuit will have a default state that indicate an active battery. The red lamp will blink continuously using the timer circuit. To indicate a safe state, all three op-amps will have to be active so the current can run through transistors Q2, Q3 and Q4 and connect the relays U1 and U2.



Relay state detection

A resistor network is used to determine the state of the two main relays. A diagram of the system can be seen below



The resistors R1 to R4 is creating the network to detect the relay states. The relay values chosen are:

R1: 200k

R2: 13k

R3: 806k

R4: 13k

Depending on the relay positions, the measured voltage will be different. There are four possible states the relays can have. The states and measured voltage can be seen in the table below

State	Relay 1	Relay 2	Measured voltage (% of acc voltage)
1 (inactive)	open	open	6.10 %
2 (active)	closed	closed	3.90 %
3 (active)	open	closed	3.15 %
4 (active)	closed	open	7.50%

A safe state is chosen to be between 5% and 7%. Anything outside those boundaries will be considered active. Three resistors R7 to R9 is used to set a reference voltage of 5% and 7%, and two op-amps are used to compare the reference signal to the measured signal. The resistor values are

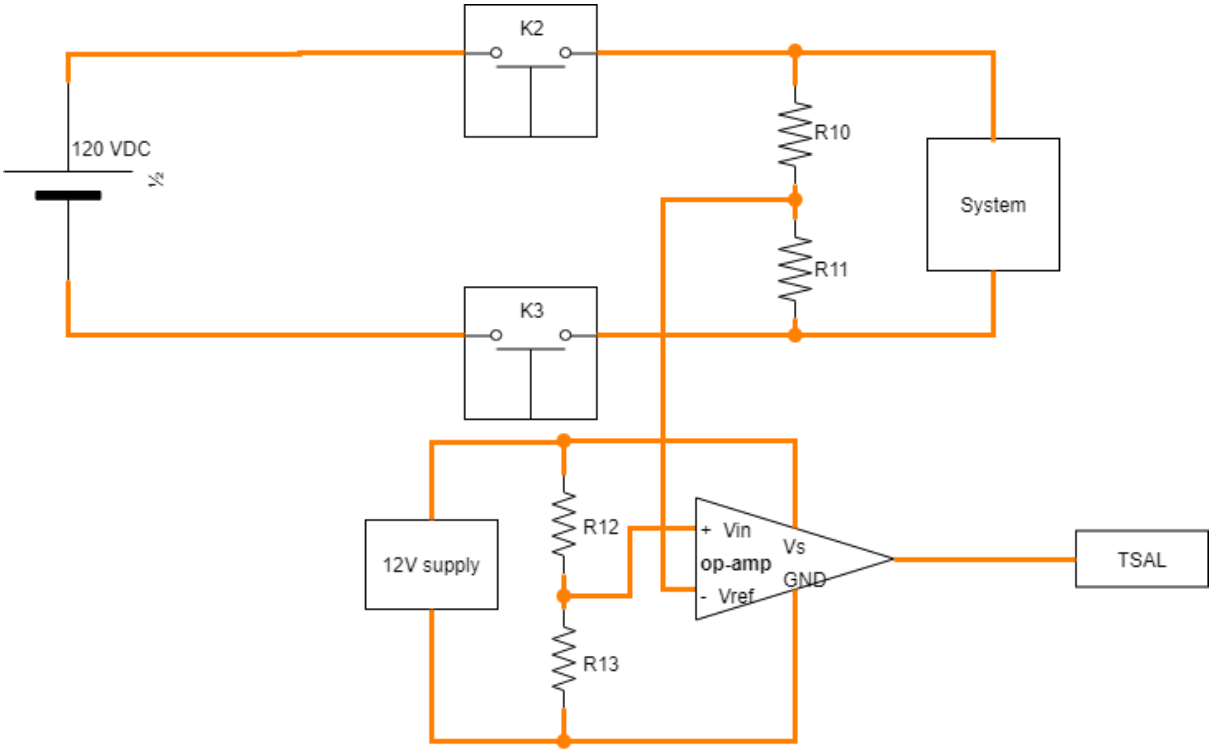
R5: 150k

R6: 3k

R7: 8k2

System voltage detection

The system voltage is detected using the following circuit



The two resistors R10 and R11 creates a voltage divider and have the values

R10 = 9N

R11 = 1N

The resistors R12 and R13 will divide the 12V regulator voltage to a 5V reference. If the system voltage exceed 50V, the op-amp will trigger the TSAL. The resistor values chosen are:

R10: 200k

R11: 22k6

R12: 140k

R13: 100k

Detection circuit regulators

Two separate 12-volt regulators are used for the two parts of the detection circuit. They are mainly used for powering the op-amps. The output voltage is set with two resistors as:

V_out = 1.20V (1+R_2/R_1)+I_ADJ*R_2

Where

I_ADJ = 10 µA

Good resistor values would be

R_1 = 2k5

R_2 =22k1

Which would give a output voltage of

V_out = 12.03 V

Which is acceptable

Timer circuit for red light
A 555 timer is used to blink the red light at 3 Hz. The circuit is designed so the timer only recieve power when the TSAL is active.
Red/green light
A red/green signal tower will be used for the light.
Decoupling
150nF and 1uF low ESR ceramic capacitors is used for decoupling. The 555 timer, voltage regulators and op-amps have been decoupled. As the circuit is operating at a low frequency, there have not been made calculations to find the best capacitor values for each component. Instead, two capacitor values have been chosen which should stabilize the circuit and remove most noise. The datasheets for the timer and regulators have been checked for typical capacitor values. If no value have been set, a 150nF and 1uF capacitor have been added to stabilize the circuit as much as possible.

Parts list

Part	Quantity	Price per unit	RS/Farnell partnumber
Quad op-amp LM2902KNE4	2	1.67 kr	732-0982
Linear voltage regulator LR8N3-G	2	3.702 kr	829-3266
IRF620PBF N-type MOSFET	1	7.13 kr	543-0052
Diode 1N4448 A0	3	0.059 kr	687-2763
555 timer SE555P	1	2.266 kr	806-2835
MC78M12ABTG 12V regulator	1	5.20 kr	625-6366
TL783 regulator	1	16,144 kr	661-6232
BC547BTA NPN transistor	3	1,552 kr	671-1113
PCH-124D2H 1-polet skifte	3	21.18 kr	533-0845
Werma rød/grønt lystårn	1	745.45 kr	849-5392
2k5 modstand +-0.1%	2	10.31 kr	849-8979
22k1 modstand +-0.1%	2	3.204 kr	754-8843
133k modstand +-0.1%	1	2.338 kr	755-0858
1k37 modstand +-0.1%	1	8.066 kr	487-6233

4k12 modstand +-0.1%	1	1.906 kr	754-5856
100k modstand +-1%	3	0.128 kr	171-1691
200k modstand +-1%	3	0.66 kr	149-054
1M2 modstand +-1%	1	0.836 kr	506-5721
10M modstand +-1%	1	1.239 kr	683-2945
806k modstand +-0.1%	1	2.508 kr	754-6957
22k6 modstand +-1%	4	0.53 kr	683-3332
140k modstand +-1%	1	0.874 kr	683-3023
2k2 modstand +-5%	2	0.155 kr	125-1135
1k96 modstand ±1%	1	0.806 kr	683-3241
3k resistor ±1%	1	0.23 kr	9342990
150k resistor ±1%	1	0,23 kr	9342648
8k2 resistor ±1%	1	0,23 kr	9343571
12k resistor ±1%	2	0,24 kr	2401783
13k resistor ±1%	2	0,24 kr	2401784
110R modstand ±1%	1	0,237 kr	137-2758
150nF 25V ceramic capacitor	4	2.993 kr	136-5575
1uF 25V ceramic capacitor	6	2.993 kr	136-5583
150nF 160V polyfilm capacitor	2	1,681 kr	712-3800
1 uF 450V aluminum capacitor	3	0,544 kr	711-2103
10 uF 35V tantalum capacitor	1	8,56 kr	134-9828
TO-92 køleplade	2	4,298 kr	712-4320
TO-220 køleplade	1	5,04 kr	712-4257
RS Pro 2-pole connector	2	kr 3,11	897-1332
RS Pro 3-pole connector	1	kr 4,67	897-1335
Littlefuse fuse holder	2	3,001 kr	787-4164
SIBA 5x20mm 1A fuse	2	kr 2,59	783-3220

Future improvements

The voltage regulators should be tested long-term with a high voltage to make sure they don’t overheat. If overheating occur, a cooling regulator should be added. A flyback diode should be added to relay U3.
The parts list is not complete. New resistors have been added and some of the old have been removed.