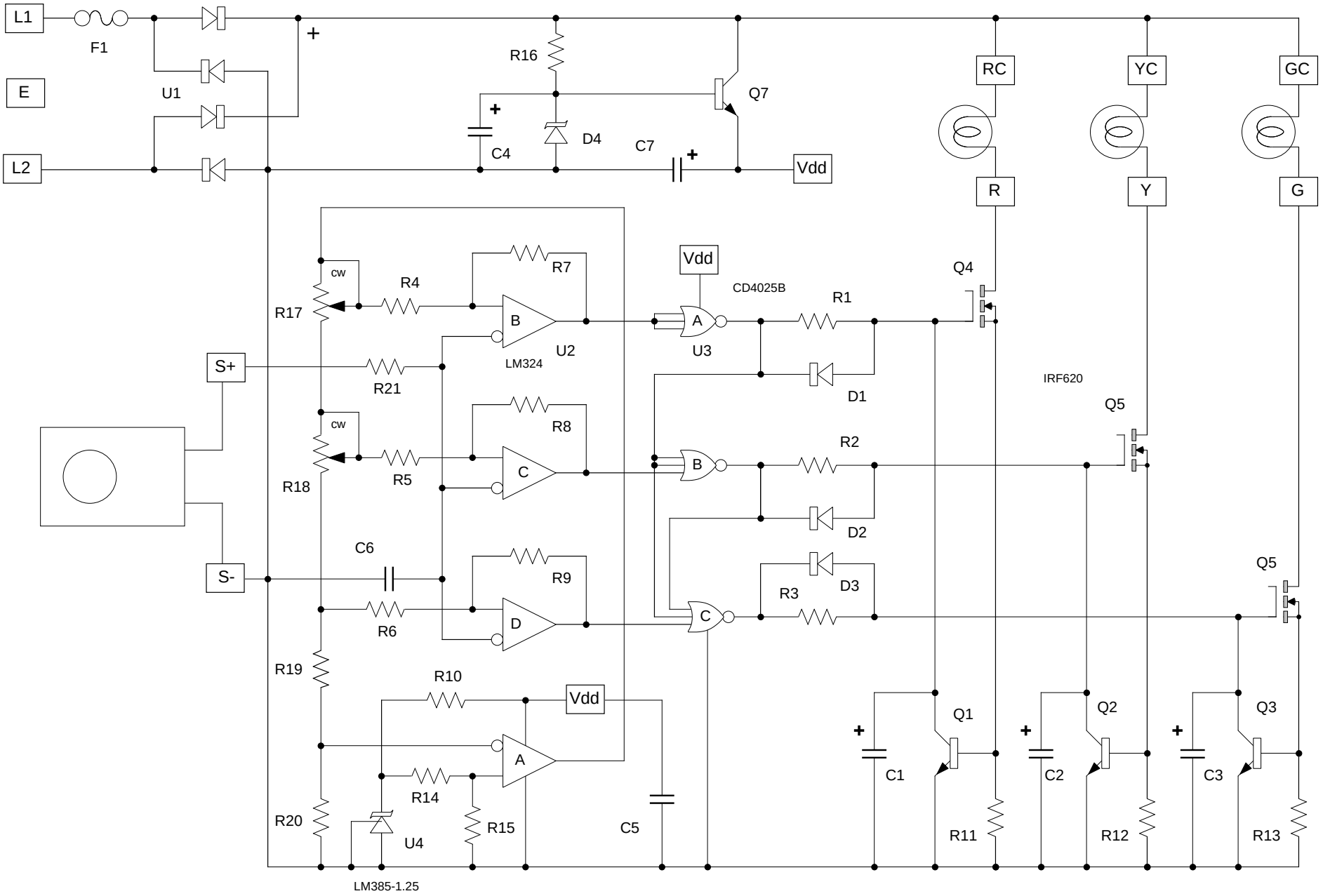


Next available ID's

C8 R22

D5 U5 Q8



# Three lamp driver

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Inductive AC voltage and current sensors

Using an SRT sensor to operate a three lamp indicator.

This application was proposed to us for use with a power tool for which is was necessary to provide visual feedback to an operator who was feeding work manually. It might also be useful for determining when a tool bit requires sharpening.

Input from the SRT DC output current sensor is delivered to the inverting inputs of U2B, U2C, and U2D by way of R21 and R6 which serve to protect the op-amps from unanticipated external influence such as radio frequency fields. The high input impedance of the op-amp is a good idea especially when using the more sensitive 0-5 volt sensors such as the CQ45 which can sense as low as 5 amps rms full scale.

U2B, U2C, and U2D are used in comparator mode and they could be implemented with true integrated circuit comparators save for U2A which needs to be a linear op-amp. Choosing a quad op-amp which allows large differential input without lock-up reduces the parts count.

Reference voltages for the comparators is derived from a constant current in a reference chain consisting of R17, R18, R19, and R20. U2A compares the current sensed by R20 to a standard voltage set by reference U4 and divided down by R14 and R15. Feedback guarantees a constant current in the reference chain regardless of the settings of R17 and R18. R19 could also be a variable if desired. The rheostat connection on R17 at the top of the chain is not required but is shown because it would allow extension to more lamps and it reduces the wire count if the variable resistors are mounted remotely.

R4 and R7 provide hysteresis for U2B which is required to prevent chattering and possible overheating of the output MOSFET's should they remain in a partially-on state for too long. The actual amount of hysteresis needed is installation dependent. Five percent is a good starting point for experimentation. R4 is chosen so that the load on the reference chain can be ignored and R7 is 20 times that. The input offset current of the op-amp must not load R7 too much. Hysteresis for the other comparators is similar.

Outputs from the 3 comparators could in principle have 8 logic states but the reference chain guarantees that only a few states are actually possible. With that constraint a triple 3-input NOR gate is sufficient for decoding. B series standard (not HC or AC) CMOS logic allows use of 12 volts on the drains which is enough to drive MOSFET's without further amplification. The current drive seems low if you're accustomed to switching MOSFET's at hundreds of kHz but it is adequate for light bulbs.

Q4, Q5, and Q6 are N-channel enhancement mode MOSFET's selected to support the desired lamp current. Low resistance FETs do not require a heat sink but are expensive. Heat sinking can support surprisingly large lamps with inexpensive FETs and may be required anyway to allow for moderated starting current in tungsten lamps.

Cold tungsten has a very low resistance and starting current can be 20 times running current in an incandescent lamp. The schematic shows two possible techniques for holding down starting current. Only one should be used.

D1, R1, and C1 can be used to slow down charging of the gate of Q4. Q1 and R11 should not be installed. As the output of U3A goes positive the R-C time constant controls the charging of Q4 to set a chosen startup time for the lamp. During startup Q4 will dissipate heat because it is only partially turned on. Its ratings must be observed! D1 will assure immediate discharge of Q4 as the lamp is shut down. That guarantees that no more than one lamp is drawing current ant any one time. This controlled-time method is probably better for the lamps but is harder on the MOSFETs than the next suggestion.

R11 and Q1 can be installed to provide current-limited startup of lamps. D1 and C1 are not installed. When the output of U3A rises the lamp attempts to draw a large current which is sensed by R11. When the voltage across R11 reaches the thermal base-emitter voltage of Q1 collector current holds the gate of Q4 down. As the lamp heats up the current falls and Q1 ceases to conduct. This will turn on the lamp more quickly than the time-limited procedure above and will thus dissipate less energy in the FET. It is also harder on the lamp and requires continuous dissipation in R11 which must be sized so that Q1 will not conduct at peaks of the normal operating current of the lamp. (Note that the power to the lamp is unfiltered!) Use of germanium transistors in the Q1 position is an interesting power-saving option.

Yet another option is to leak some current through all lamps, enough to keep the filaments warm but not glowing. This is not shown on the schematic because it requires considerable power dissipation in the leak resistor.

Operating power is taken directly from a 120 volt AC line through bridge rectifier U1. Pulsating DC is used to power the lamps. Circuit ground is displaced from earth ground and safety from shock is a design imperative. In particular the variable resistors in the reference chain must be selected to provide isolation for the user. Plastic shafts or grounding of metal shafts is required. The SRT current sensor is self isolating but the signal leads as installed in this circuit are not at ground. They must be insulated is if they were at line voltage. A fuse is highly recommended to protect against failure modes which could occur during changing of lamps. Oversizing of U1 is recommended for the same reason.

A small amount of filtered DC at about 12 volts is generated by R16, D4, C4, Q7, and C7. The circuit is a simple emitter follower using a high voltage NPN power transistor. It would be possible to use power devices for D4 and R16 in order to eliminate Q7 and C7 with an attendant increase in overall heating.

| part | usage | time limited | current limited | rating | |
|---|---|---|---|---|---|
| C 1 | Slow down Q4 | 4.7 µF | do not install | 20 V Ta | |
| C 2 | Slow down Q5 | 4.7 µF | do not install | 20 V Ta | |
| C 3 | Slow down Q6 | 4.7 µF | do not install | 20 V Ta | |
| C 4 | filter 120 Hz ripple | 10 µF | 10 µF | 20 V Al | |
| C 5 | bypass U2 for RF | 0.1 µF | 0.1 µF | 20 V cer | |
| C 6 | filter RF on hi-Z input | 0.01 µF | 0.01 µF | 20 V cer | |
| C 7 | filter 120 Hz ripple | 200 µF | 200 µF | 20 V Al | |
| C 8 | unassigned | | | | |
| D 1 | speedy discharge Q4 | GP Si | do not install | GP | 1N914 zB |
| D 2 | speedy discharge Q5 | GP Si | do not install | GP | 1N914 zB |
| D 3 | speedy discharge Q6 | GP Si | do not install | GP | 1N914 zB |
| D 4 | Reference for regulator | 13 V | 13 V | 1/4 W | 1N5243B |
| D 5 | unassigned | | | | |
| F 1 | Main power fuse | 1 A | 1 A | 200 V | |
| F 2 | Fuse holder | * * | * * | | |
| H 1 | insulator for Q4 | * * | * * | mica | |
| H 2 | insulator for Q5 | * * | * * | mica | |
| H 3 | insulator for Q6 | * * | * * | mica | |
| H 4 | insulator for Q7 | * * | * * | mica | |
| H 5 | Backup plate | * * | * * | | |
| H 6 | Lable for connections | * * | * * | | |
| H 7 | Overall lable | * * | * * | | |
| H 8 | Overall housing | * * | * * | | NEMA-xx |
| H 9 | Printed wire board | * * | * * | | |
| H 10 | unassigned | | | | |
| J 1 | Terminal strip 1 | * * | * * | 6 pins | |
| J 2 | Terminal strip 2 | * * | * * | 6 pins | |
| J 3 | Terminal strip jumpers | * * | * * | | |
| Q 1 | current limit for Q4 | do not install | NPN Si | GP | 2N3904 zB |
| Q 2 | current limit for Q5 | do not install | NPN Si | GP | 2N3904 zB |
| Q 3 | current limit for Q6 | do not install | NPN Si | GP | 2N3904 zB |
| Q 4 | MOSFET switch for red | * * | * * | 200 V | IRF620 |

| part | usage | time limited | current limited | rating | |
|---|---|---|---|---|---|
| Q 5 | MOSFET switch for yellow | * * | * * | 200 V | IRF620 |
| Q 6 | MOSFET switch for green | * * | * * | 200 V | IRF620 |
| Q 7 | High voltage regulator | NPN Si | NPN Si | 200 V, 1 W | TIP49 zB |
| Q 8 | unassigned | | | | |
| R 1 | Limit charging of Q4 | 100 kΩ | 10 kΩ | 1/10 W | |
| R 2 | Limit charging of Q5 | 100 kΩ | 10 kΩ | 1/10 W | |
| R 3 | Limit charging of Q6 | 100 kΩ | 10 kΩ | 1/10 W | |
| R 4 | Input hysteresis | 10 kΩ | 10 kΩ | 1/10 W | |
| R 5 | Input hysteresis | 10 kΩ | 10 kΩ | 1/10 W | |
| R 6 | Input hysteresis | 10 kΩ | 10 kΩ | 1/10 W | |
| R 7 | Output hysteresis | 470 kΩ | 470 kΩ | 1/10 W | |
| R 8 | Output hysteresis | 470 kΩ | 470 kΩ | 1/10 W | |
| R 9 | Output hysteresis | 470 kΩ | 470 kΩ | 1/10 W | |
| R 10 | Bias U4 | 33 kΩ | 33 kΩ | 1/10 W | |
| R 11 | Current sense in Q4 | 0 Ω | 1 Ω | 1 W | |
| R 12 | Current sense in Q5 | 0 Ω | 1 Ω | 1 W | |
| R 13 | Current sense in Q6 | 0 Ω | 1 Ω | 1 W | |
| R 14 | Divide reference voltage | 9.1 kΩ | 9.1 kΩ | 1/10 W | |
| R 15 | Divide reference voltage | 1 kΩ | 1 kΩ | 1/10 W | |
| R 16 | Drop voltage for D4 | 100 kΩ | 100 kΩ | 1/2 W | |
| R 17 | Set red threshold | 2.5 kΩ | 2.5 kΩ | 1/10 W | |
| R 18 | Set yellow threshold | 2 kΩ | 2 kΩ | 1/10 W | |
| R 19 | Set green threshold | 0 Ω | 0 Ω | | |
| R 20 | Sense current in reference chain | 50 Ω | 50 Ω | 1/10 W | |
| R 21 | Protection for hi-Z input | 10 kΩ | 10 kΩ | 1/10 W | |
| R 22 | unassigned | | | | |
| S 1 | Current sensor | * * | * * | | CQxx-5VDC |
| U 1 | Diode bridge | 200 V | 200 V | 1.5 A | |
| U 2 | Quad op-amp | * * | * * | | LM324 |
| U 3 | Triple 3 input NOR | * * | * * | 15 V | CD4025B |
| U 4 | Voltage reference | 1.25 V | 1.25 V | | LM385-1.25 |
| U 5 | unassigned | | | | |