QUT RoBoTiCs CLUB

Robot Power Systems

The “Common Sense” Approach

SAFETY FIRST – ENERGY KILLS [Robots]

- **Never** just plug batteries into things – make sure it's not a short circuit (with a multi-meter) and that the device can handle that voltage level!
- **Never** plug batteries into things "backwards" for reverse polarity – some devices have protection, but inevitably they will fail (explosively) while protecting their parent circuits.
- **Never** leave batteries charging unattended for long periods of time, unless accounted for (thermal shutdown, timed charge sequences).
- **Always** charge batteries with their appropriate chargers.
- **Always** use fuses.
- **Always** check voltage levels, or your may over-drain a battery or over-volt your device

MOBILE ROBOTS NEED MOBILE ENERGY…

- Batteries – cheap(?), very high energy storage
  - But they are heavy – to carry more weight you need larger motors – larger motors use more energy! Positive feedback loop here
- Solar/Other forms of renewable power generation on-board
  - Low/no capacity – more of a generator
  - Usually very low ‘power’ output. A high power device will eventually fail under load.

VOLTAGE

- Match as close as possible to what your system needs examples below:
- 5V microcontroller and sensors, 5-6V servo, 6V motors
  - Perfect match for a 7.4V Nominal (2 Cell) Lithium Polymer battery pack. Capacities will be discussed later.
- 3.3V-5V microcontroller, 3.3V Communication device (Bluetooth, Radio, etc), hardly used small servo which can run off 5V
  - This system is basically "low power" and will be fine with a combination of AA batteries [x4], or maybe a 9V battery.
  - Is a good match for something like a solar panel to assist

REGULATION OF VOLTAGE

- Two types of regulation
  - Linear
  - Switching
- Linear has high power loss if voltage difference is anything more than a few V.
- Switching can drop huge differences in V and remain above 80%+ efficient!

WHEN/WHAT TO REGULATE?

- In the scenario where you have a **6V motor**, and the **rest of the circuit is 3.3V logic and communications** – only regulate the 3.3V rail. The 6V for the motor can come from unregulated battery (probably a 7.4V Li-Po) and using a simple voltage sense the microcontroller can make sure the motor isn't constantly over-volted. Allows for "software" regulation for the motor.
- In the scenario where you have a **6-12V motor**, **5V micro controller, and a 3.3V wireless communication device** you should examine where the power losses will occur, and observe "Drop out" voltages. Select a 11.1V (3 Cell) Li-Po to power the system, unregulated to the motor and then use a switching regulator to get 5V, followed by a linear "Low Dropout Regulator" (LDO) for 3.3V from the 5V rail. This gives you efficient step-down from possibly as high as 12.6V to 5V, and then a low-current, low power 3.3V rail for circuit usage.
- **AS YOU CAN SEE, AVOID REGULATING MOTOR POWER! NOTHING GOOD WILL COME FROM IT!** You could regulate it to some extent, by having things such as over-current protection circuitry - but voltage is not really an issue for motors where software can be used to help reduce effects of higher than rated voltages. If motors are kept "all on" for long times at higher than rated voltages, then it may be wise for the life-expectancy of the motors to do some form of regulation with as little *pass-elements* as possible.

MYTHS ABOUT CURRENT

- Common misconception that giving a device a power supply with X amps output, even though the device only 'uses' X amps, will not damage it.
  - You cannot force more water into a pipe that can't take it. A device only uses as much current as it needs for whatever purpose – this can change during transients like motor start-up and changing directions but for the most part, it's fine.
  - Short circuits are the exception to this, they will pull as much current as possible and blow things up!
- For example, a 1.5A Phone charger will NOT damage your phone which normally charges with 0.5-1A. New USB standards will allow quite high charge currents.
- **RELEVANT TO BATTERY CHARGING CURRENTS – DO NOT CHARGE BATTERIES AT MORE THAN THEIR RATED "C". For example Don't charge a 250mAh battery at more than 250 mA.**

CURRENT OUTPUT AND HEAT

- Current supplied by a battery is based on the internal chemistry
  - high current batteries such as Li-Po ones can provide extremely high ampere output in comparison to something like AA alkaline ones
  - A 9V battery short circuited will not be very exciting.
- Less current in your circuits the better – heat is generated (power lost) by current, not voltage.
  - Equation of power: $P_{lost} = I^2 * R \ [Watts]$
  - If you have a power MOSFET as a switch with 1 Ohm resistance, and you have 3 Amps running through it (to motors, perhaps), you will burn 9*1 Watts of power! If it's Thermal resistance is $30°C/Watt$ then your MOSFET will heat up to $(25°C + (30 * 9))°C, or\ almost\ 300°C$! This will melt, of course.

CAPACITY

- Capacity of batteries is given by the unit “Amp-hour” (Ah) or more usually with the scales we use, “Milli-amp-hour” (mAH).
- Specify the capacity of your batteries by looking at the average power consumption during normal activity of your device, and then if it’s a functional requirement of the project, how long should it operate for? Or what is a reasonable and useful length of time for it to operate, if that happens to be infrequent.
- Choosing a very high capacity battery is not always the best solution – weight, cost, and time to charge can be frustrating or negatively impact your project.
- If you draw on average 500mA with normal speed constant movement and operation of onboard sensors and processors, and you want 2 hours of operation, select a battery capacity which is AT LEAST 1 Amp-hour, or “1000mAh”, but upsize by about 30% to allow for voltage drop over time and loading, and for the fact your power systems will most likely be wasting 20-30% of input power due to level conversions.

HOW TO PROTECT AGAINST SHORT CIRCUITS AND STALLING MOTORS?

- If you had a motor stall through a switch-mode regulator (despite me telling you not to regulate motor power) It may draw 3-5 Amps continuouslu as long as the stall condition remains. Similar situations (much worse though especially from a LiPo pack) can happen if you short circuit this motor power rail. How do you protect against this?

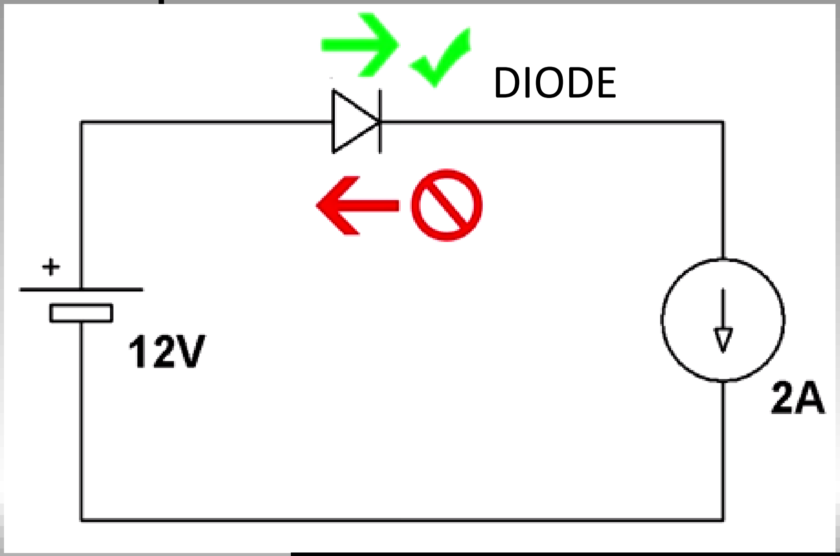
- ***USE A DAMN FUSE!*** ***See next slide!***

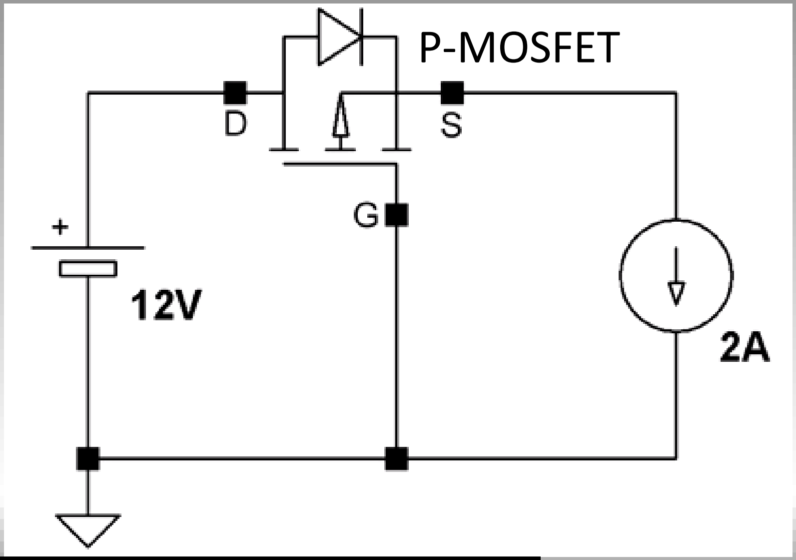
FUSES AND SWITCHES

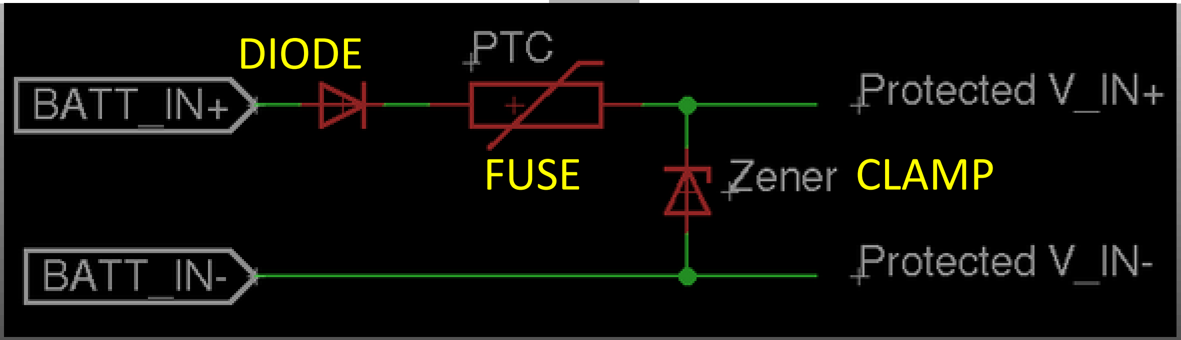
- In the power system management of your robot, consider (read: Do It Or Else!) placing at least one fuse with appropriate current rating at the battery connections, and perhaps even more throughout the system where necessary/expected shorts might occur for prolonged periods (not a motor starting up!).
- Consider placing an On/Off physical toggle switch close to the battery terminals for turning on your robot. More physical switches may be located that provide power path to your regulator circuits and microcontrollers etc.
- Cunning use of power sequencing and digital control/monitoring of power in your robot with MOSFET or Darlington driver Transistors as “digital switches” can allow better safety and operation of your robot. If the motors are stalling a lot, why not cut power with your microcontroller? Might save blowing a fuse and other circuitry.

REVERSE POLARITY PROTECTION

- Want to idiot-proof your robot, and put lots of cunning protection circuitry in it rather than just good labels and polarized connectors? OKAY!







Top two Images from Afrotechmods' awesome youtube videos. Bottom from Kit Scuzz on EE.SE

CIRCUIT POWER CONSIDERATIONS

- “Single supply” is easiest. Don’t use opamps for dual supply unless you desperately have to.
- Use decoupling “filter” capacitors for every IC, as close as possible.
- Place “bulk” capacitors at the output of each regulator stage, and near motor power pins (these should be as huge as possible! ~10mF!)

SENSORS ARE SENSITIVE! WHAT!?

- Sensors give back a voltage which tells you about the world – temperature, distance to something, ambient sound levels etc.
- **The return voltage signal can pick up electrical noise**, and come back as fake signal information!
- Capacitors everywhere and a clean, ripple-free power supply system avoid these issues. Use Ferrite beads, series inductors with capacitors nearby for "LC filters", varying sizes of capacitors and also material – 0.01, 0.1, 1, 10, 100uF all on the same power rail gives pretty damn good noise suppression!
- Try to use Tantalum and ceramic capacitors, as well as aluminium electrolytic and polymer electrolytic (cheap and nasty) for high capacitance values.
- PCB layout considerations such as placing nearby high speed communication lines should be away from sensitive analog signal return paths. Switching power supplies and high power return current paths should be as far away as possible!