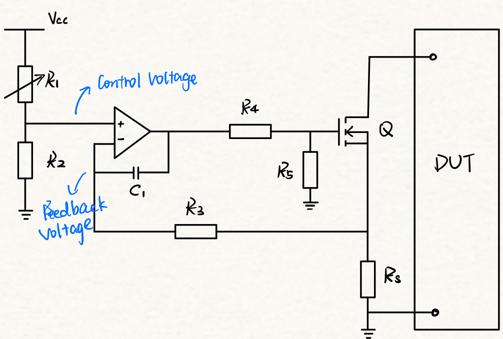
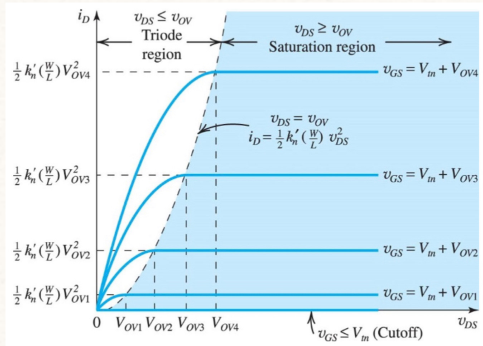
Electronic Load:





The main idea of an electronic load is to use MOSFET as a variable resistive load for the device under test (Buck converter in this case).
From the right figure for MOSFET, at the saturation region, drain current can be controlled by the gate voltage. The drain source voltage, which is the load voltage in this case, can be ignored. Since with respect to the load, the voltage across it can not predict. Therefore, by controlling the drain current of the MOSFET, this circuit can imitate a resistive load for the buck converter.

The circuit above shows a simple circuit for an electronic load, which is basically a closed loop for gate voltage control of the MOSFET.
There is an op-amp compares voltage difference at input terminals. The positive terminal is connect to a voltage divider as control voltage, this voltage can be controlled by the potentiometer (need to be replaced by digital potentiometer at the end for all-electronic control).The negative terminal is connected to feedback voltage from Rs. When the MOSFET is conducting and current flow through Q and Rs, the voltage across Rs is Id*Rs, current times resistance. As we all know, there is no current at op-amp terminals, no current through R3, thus the voltage at negative terminal is Id*Rs.
V+ = Vcc*R2/(R1+R2); V- = Id*Rs
The op-amp here will measure the difference between input voltages and produce output depending on the difference. For example, if the difference between V+ - V- increases, this means the feedback voltage is getting smaller than the control voltage, means the current is going lower than expected. In consequence, the output form the op-amp produce higher voltage since the difference become bigger, and gate voltage increasing causes higher drain current at MOSFET. An equilibrium will be reached at the end, and the drain current will stay at a certain value.

The RC network consists of C1 and R3 for dampening the crate of change of the feedback, in order to reduce the oscillation of the op-amp, causing MOSFET fast switch. - the value of C1 and R3 should be set carefully.

Q and Rs are the only two components consume power from DUT. Q is the main component that act as a resistive load (consume most power - heat sink or fan - thermal analysis needed), but Rs is for feedback control by sensing the current at load. The power that dissipated from Rs is I^2*Rs, resistance is the factor that determine how much power is consumed at Rs. In addition, Rs is also a part in total resistance at load. The buck converter needs 0.8Ω load resistance for reaching 4A when Vout is 3.3V (Extreme case, 3.9A at 1.75V -> 0.45Ω minimum RL). However, if we select a very small value for Rs, this means the feedback voltage will be extremely close to ground. Op-amp cannot operate properly when input voltage is close to ground, and noise will be easily corrupt the signal.

In order to obtain big feedback voltage without dissipating too much power on Rs, a current sense amplifier is needed.
A current sense amplifier is a differential amplifier to amplify the voltage across a small resistance (called shunt resistance) at load branch. Usually shunt resistance can be very small, 1~10 mΩ is suitable here. (Normally 0.25 W power rating for most of the resistor, this buck converter can support 5A output current, therefore 0.25W & 5A -> 0.01Ω at most)

current sense amplifier
NCS211RSQT2G as an example to show the circuits below (out of stock). INA212BIDCKR current sense amplifier has plenty stock on mouser.com.
The right circuit shows the differential amplifier to amplify the voltage across Rshunt, and the right circuit indicates a filter placed at the inputs.

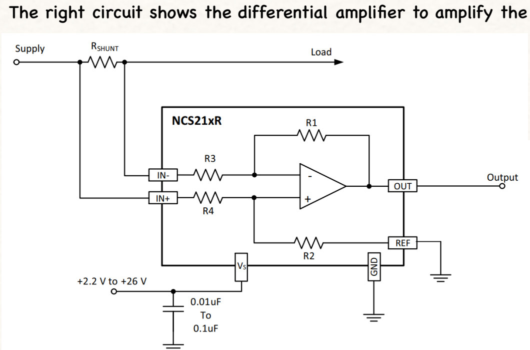


Figure 31. Basic Unidirectional Connection

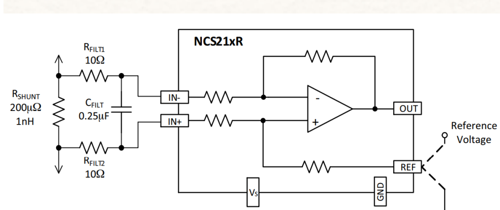


Figure 33. Input filtering compensates for shunt inductance on shunts less than 1 mΩ, as well as high frequency noise in any application

High power metal plate shunt resistor: ROHM semiconductor GMR50HJAAFD5L00 5mΩ & 4W

This circuit might not be able to test in bread board: 1) LTspice to simulate the performance 2) Build one with high ohmic shunt resistance and check the control principle of the electronic load.