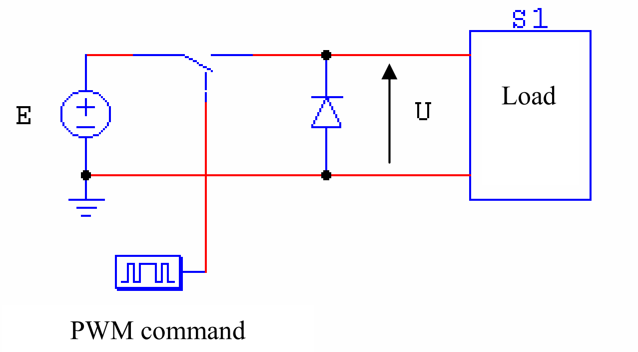
ELECTRICAL ENGINEERING

MODELLING A DC CHOPPER

Basic structure:



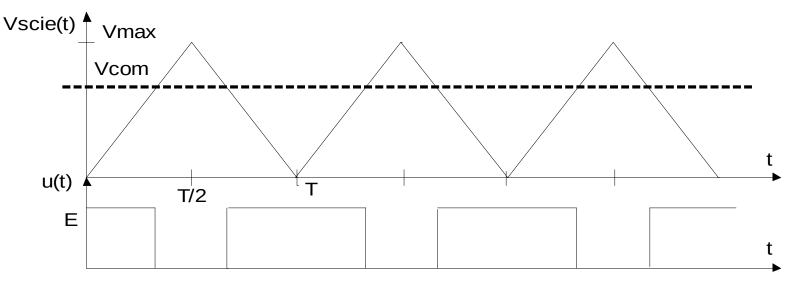
In general a chopper feeds an inductive load. This is the case of a load from a DC motor. The free-wheel diode prevents voltage surges due to commutation of an inductive load and protects the controlled switches. This one quadrant chopper is not reversible.

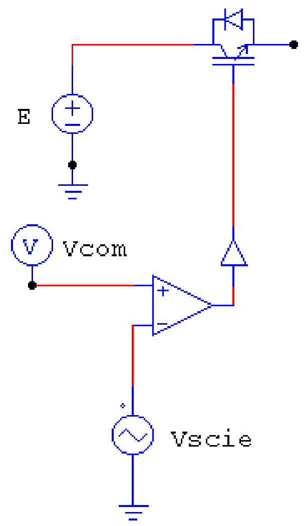
Control by PULS WIDTH MODULATION:

For the most usual applications the switch is controlled by a fixed frequency. We therefore vary the duty cycle (α) of the command signal to vary the average value of the voltage u(t). If the conduction of the current in the is continuous we can show that:

$$\boxed{\mathbf{U_{moy} = \alpha E}}$$

To obtain α , we compare the input voltage (Vcom = command voltage) to a sawtooth signal (Vscie) generated by the command. The signal obtained is used to control the power transistor (bipolar, IGBT, MOS).





If the slopes of the sawtooth wave are symmetrical, we can write:

$$\alpha = \frac{V_{com}}{V_{max}}$$

The relation between U_{moy} and V_{com} can be expressed in the form of a static gain G_0 with:

$$\boxed{G_0 = \frac{E}{V_{com}}}$$

It is possible to improve the model by taking into account the delay induced by the chopper. In dynamic state the voltage V_{com} varies in time so that the response of the chopper is not instantaneous.

If T is the period of the chopper, we can suppose that the delay is, on average, T/2. If it is necessary to take this into account then the transfer function of the chopper becomes:

$$\boxed{G = G_0 . e^{-\frac{Ts}{2}}}$$ (s: Laplace operator)

ASSOCIATION CHOPPER / DCM

Choosing the switch:

This depends on the type of application:

- Current intensity
- Voltage value
- Frequency of the chopper
- Power

It is important to note that SCRs choppers require quenching and firing circuits (forced commutation). For the commutation of large amounts of power (several hundred Kw to 1 Mw), we can use a combination of SCRs in series to distribute reverse voltage, and parallel to reduce switching current.

Moreover, pulsed currents in the chopper circuits induce disturbances in the power lines. The use of low pass filters (LC type) can be used to maintain the condition $I_{line} = \langle i_{line} \rangle$ = constant.

Choice of the chopper frequency:

Of course this value is limited by the characteristics of the switch. It can be determined theoretically according to the application. We must take into account the maximum current ripple as well as the dynamic (response time) of the system (see specialised documents).

For low-powered motors a rule of thumb is :

$$\boxed{f_h = 20 \times \mathrm{Sup}\left(\frac{1}{\tau_e}, \frac{1}{\tau_m}\right)}$$

τ_e and τ_m are, respectively, the electrical and mechanical time constants of the motor (and its load).

Choice of a smoothing inductor:

We consider that the flow of current is continuous.

According to this hypothesis, the intensity of the current varies between I_{max} and I_{min}. The current ripple is defined by:

$$\boxed{\Delta i = I_{max} - I_{min}}$$

This ripple is directly proportional to the electromagnetic torque.

If the inductance value of the motor is not sufficient enough to ensure a continuous flow it is necessary to place one in series with the armature circuit.

For $T_h >> L/R$, we can make the following approximation:

$$\boxed{\Delta i = \frac{\alpha(1-\alpha)ET_h}{L}}$$

We can show that this ripple is maximum for $\alpha = 0{,}5$.
In the worst case:

$$\boxed{\Delta i_{max} = \frac{ET_h}{4L}}$$

Speed control of the motor:

We can use E_{mf}, the electromotive force of the motor. If we ignore the value of the armature resistance we can write:

$$E_{mf} = \alpha E \quad \text{with} \quad E_{mf} = k\Phi\Omega$$

(and still based on the hypothesis of continuous flow)

We can deduce:

$$\boxed{\Omega = \frac{\alpha E}{k\Phi}}$$

The speed of the motor is proportional to the duty cycle α.