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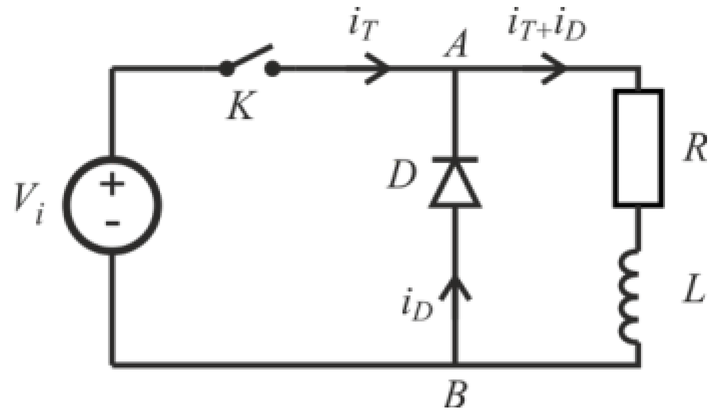
441F

PWM CURRENT REGULATION USING DC-DC CONVERTER IN ONE QUADRANT (n=2, m=441)

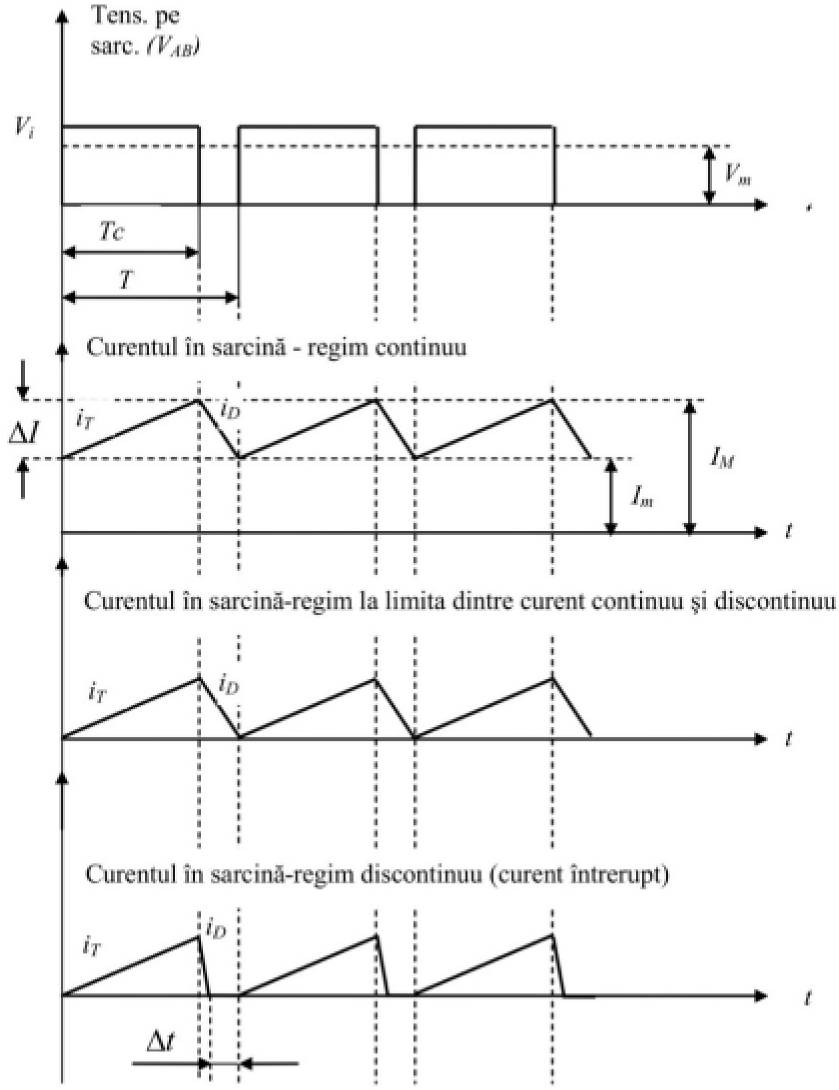
1. Theoretical overview

This project is focused on PWM current regulation using a DC-DC converter in a single quadrant. The converter, as illustrated in the figure below utilizes a static switch K, commonly implemented as an isolated gate bipolar transistor (IGBT) or a grid-isolated field-effect transistor (MOSFET). Operating within one quadrant implies that both the voltage and current applied to the load possess the same polarity. The load consists of a resistance (R) and an inductance (L).



The converter's operation involves the opening and closing of switch K. Closing the switch allows the voltage Vi to be applied to the load for a duration of time (Tc), resulting in an increasing current. Upon opening the switch, the voltage across the load approaches zero (VD≈0). Due to the inductive nature of the load, the current persists and flows through the load, facilitated by the diode D.

For constant frequency and variable duration pulse control (PWM), the steady-state waveforms are depicted in the following figure.



The load current can exist in three distinct regimes: continuous, limit, and discontinuous. In the continuous regime, the current flows continuously through the load without canceling itself (Im > 0). The limit regime lies between the continuous and discontinuous regimes, with the current canceling at the end of each period. The discontinuous regime represents an undesirable state where the current is interrupted during each period for a duration of time (Δt), and it should generally be avoided.

To prevent the occurrence of the discontinuous regime, two methods are proposed: increasing the modulation frequency and introducing an additional inductance in series with the load.

This project further explores PWM regulation of current using a DC-DC converter within a quadrant. This regulation approach involves comparing the shape of a high-frequency unipolar triangular wave with the control voltage obtained from the regulator. The system components include the DC-DC converter in a quadrant, the load (RL), a current measuring resistance (rt), current measuring transducers (AO1, AO2), an adder (AO3), a regulator, a comparator without hysteresis, a symmetric bipolar triangular wave generator (GTLV), an absolute value circuit, and a gate order circuit (driver).

The adder, implemented with AO3, calculates the error by determining the difference between the desired value (Vref) and the measured value. The regulator amplifies the error, generating the control signal that drives the PWM generator and the electronic power converter (CEP). The output signal from the order circuit modifies process parameters to correct the error.

The current transducer measures the current across a small-value measuring shunt resistance. This voltage signal is amplified by AO1 and filtered through the RfCf filter. The measured voltage at the output of the repeater AO2 exhibits the same range of variation as the reference value.

2. Calculation of the controller

<u>Custom parameters: n=2; m=441</u>

- Vi = (16+n) V = 18 V
- L = 2 mH
- R = 4 Ω
- F_{PWM} = 15000 + m*n Hz = 15882 Hz
- V_{TR} = 10 V
- T_F = 4 * (1/ F_{PWM}) = 4 * (1/15.882*10^3) = 0.2518 * 10^{-3} s ≈ 0.25 ms

<u>Filter RC:</u>

- R_F = 1k Ω => R_F * C_F = T_F => C_F = T_F/ R_F = 0.25 ms/1k Ω = 0.25 µF

<u>PI controller:</u>

- R1*C1 = t = L/R = 2/4 = 0.5 ms
- R0*C1 = 2*kext*Tsigma = 2*(Vi/(R*Vtr))*(1/(2*fpwm)+Tf) = 2 * (18/4*10) * (1/(2*15882)+0.25*10^{-3}) = 2* 0.45 * 0.0314 * 10^{-3} = 28.26 µs

<u>For R0 = 10k Ω:</u>

- C1 = 28.26 * 10^{-6}/10*10^3 = 2.826 nF
- R1 = 0.5 * 10^{-3}/2.826*10^{-9} = 176.92 *10^3 Ω ≈ 177 k Ω

<u>Prescribed current:</u>

- $V_{prescris}$ = Imax/2 = (Vi/R)/2 = (18/4)/2 = 2.25 V

AO is supplied at +-15 V. Simulation step is 1 µs.

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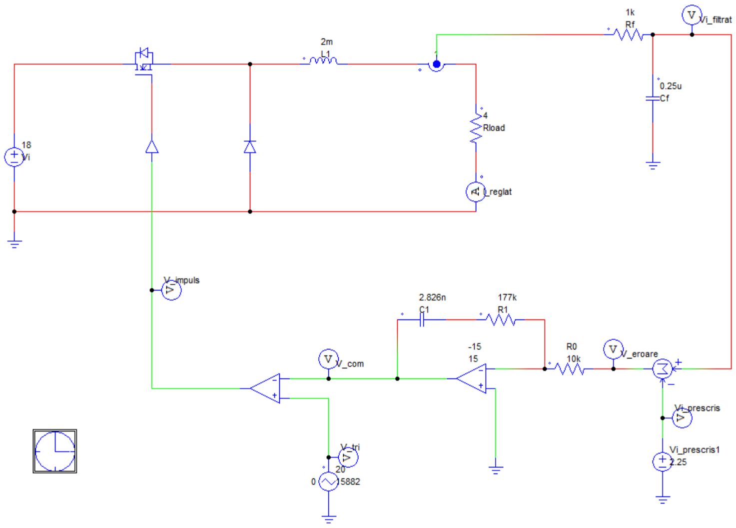
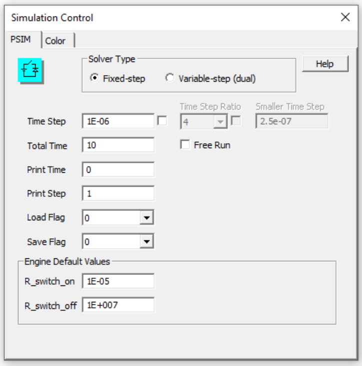
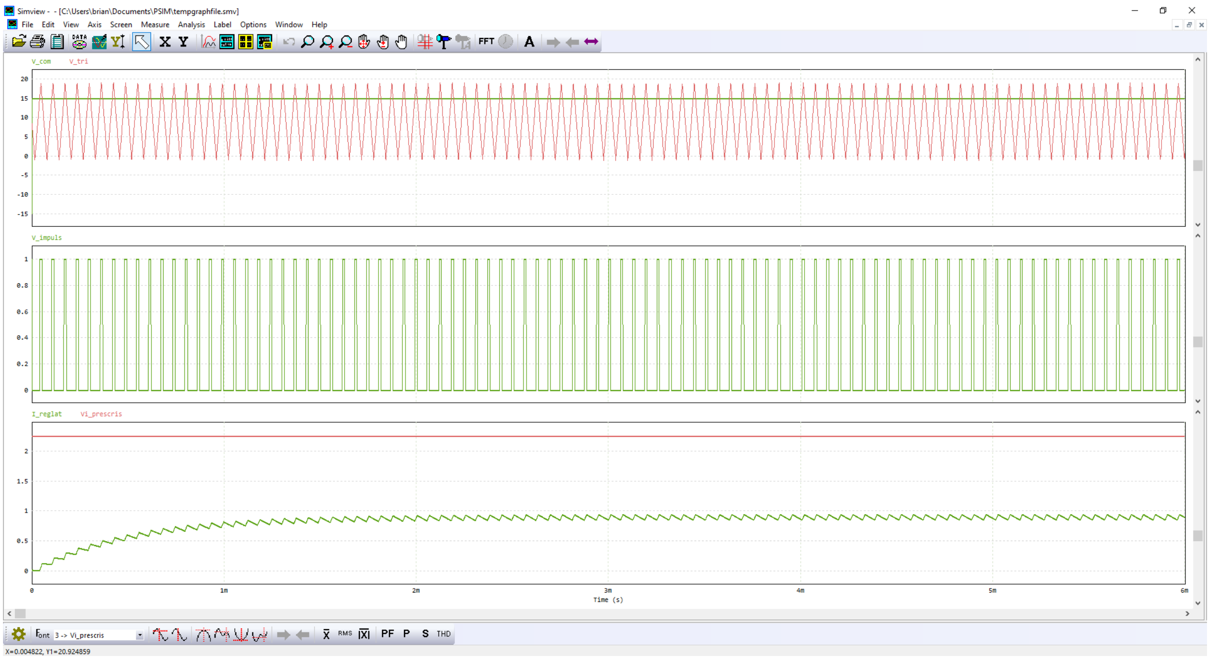
3. Transient simulation in PSIM of the Circuit

***in the first variant I put an OpAmp instead of the Comparator**







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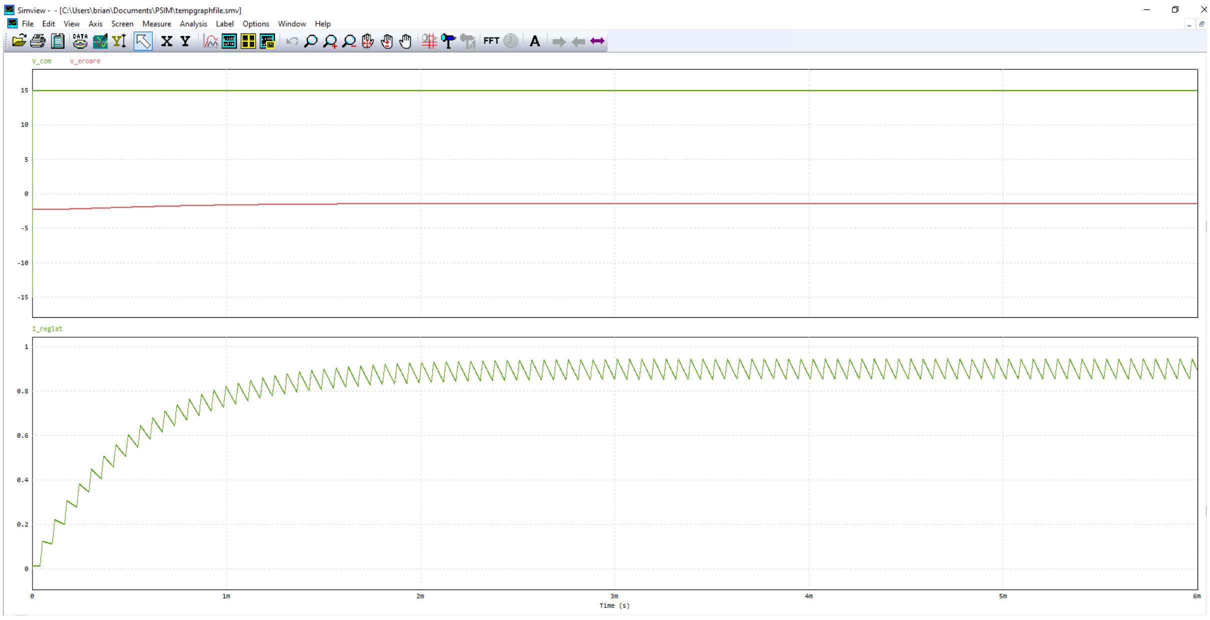

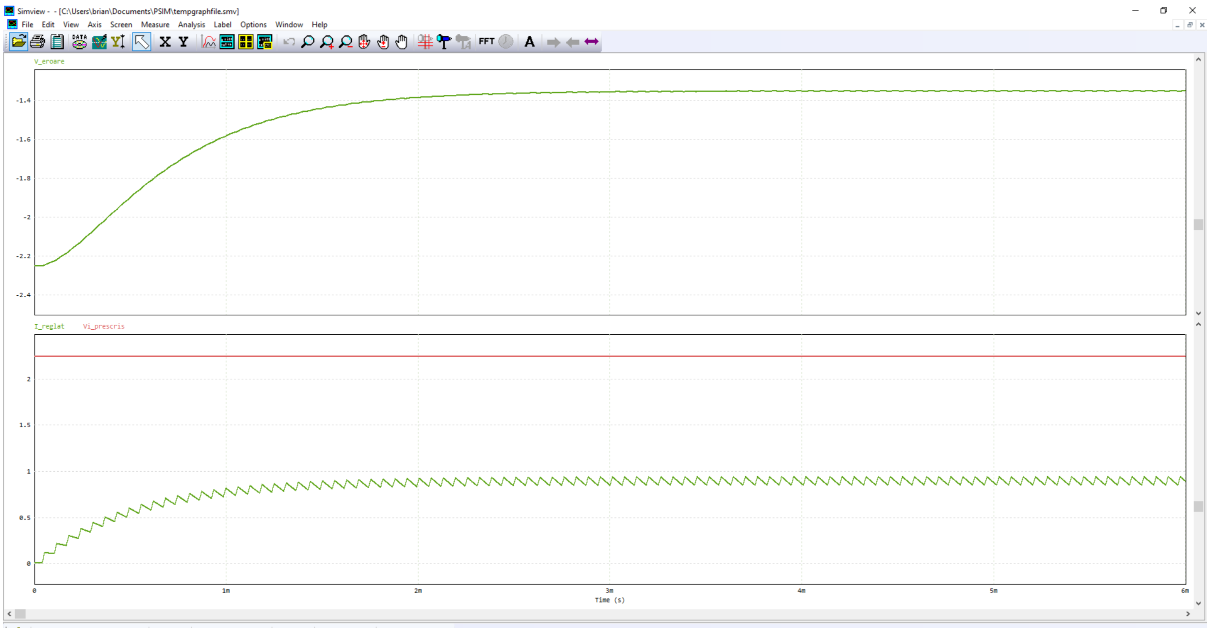

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4. Frequency simulation – stability check