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SYNTHESIS OF CANONICAL ELEMENTS FOR POWER PROCESSING BASED ON SLIDING-MODE CONTROL

LUIS MARTINEZ-SALAMERO
SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING
ROVIRA I VIRGILI UNIVERSITY
TARRAGONA, SPAIN

GAEI
Grup d'Automàtica i Electrònica Industrial

Escola Tècnica Superior Enginyeria

Universitat Rovira i Virgili

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Research Activities

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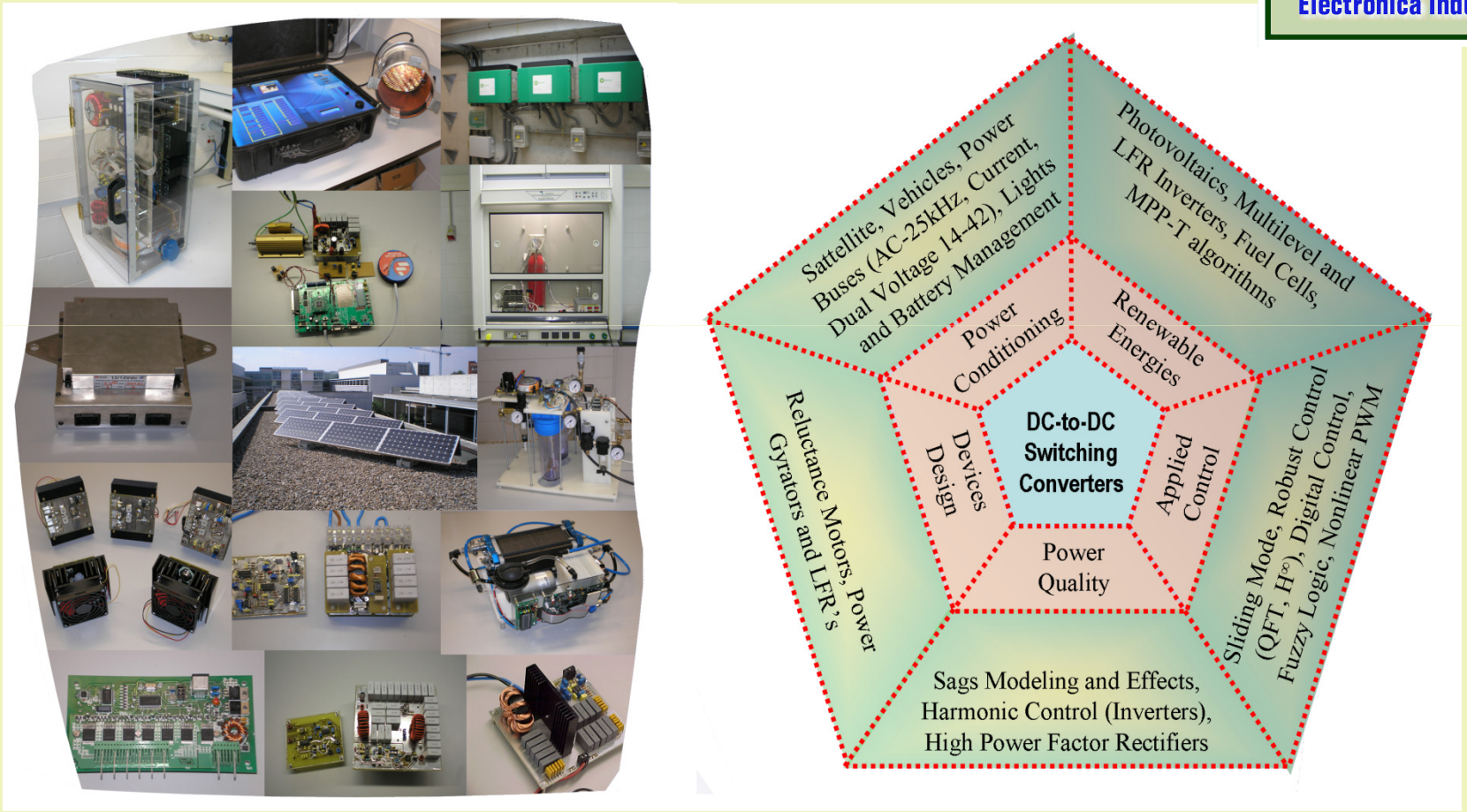

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OUTLINE

I. POWER SUPPLY ARCHITECTURES

II. CANONICAL ELEMENTS FOR POWER CONVERSION

III. GENERALIZED CANONICAL ELEMENT

IV. IMPEDANCE MATCHING

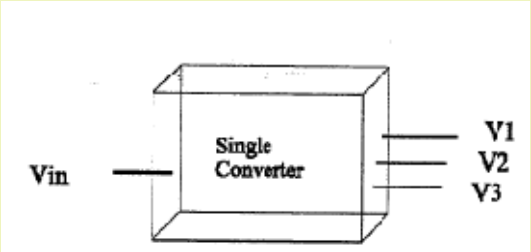
V. POWER DISTRIBUTION

VI. POWER FACTOR CORRECTION

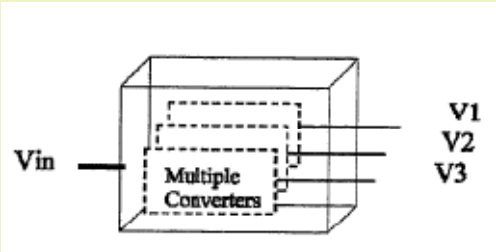
VII. CONCLUSIONS

❑ POWER SUPPLY ARCHITECTURES

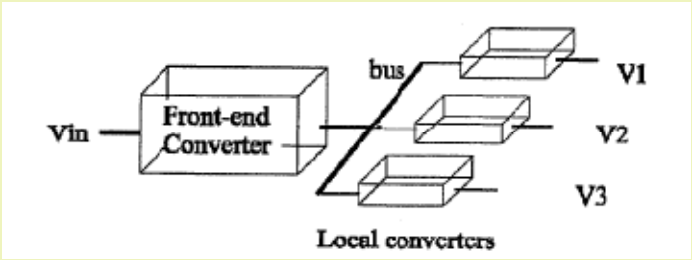
• **CENTRALIZED POWER**



• **MODULAR POWER SYSTEM**



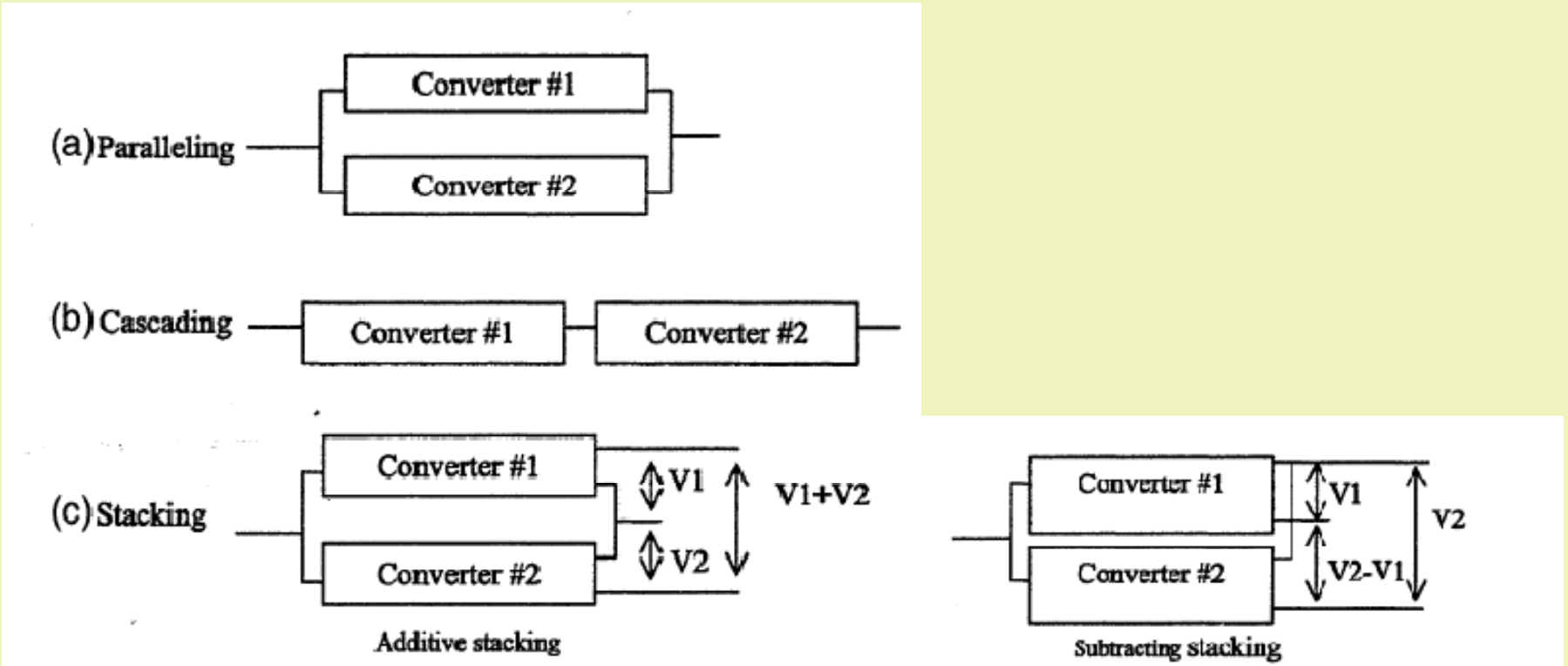
• **DISTRIBUTED POWER SYSTEM**



• S. Luo and I. Batarseh, "A Review of Distributed Power Systems. Part I: DC Distribute Power System" IEEE Aerospace and Electronic Systems Magazine, August 2005, Vol 20, No. 8, pp 5-15

❑ POWER SUPPLY ARCHITECTURES

•BASIC DISTRIBUTION ARCHITECTURES



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❑ POWER SUPPLY ARCHITECTURES

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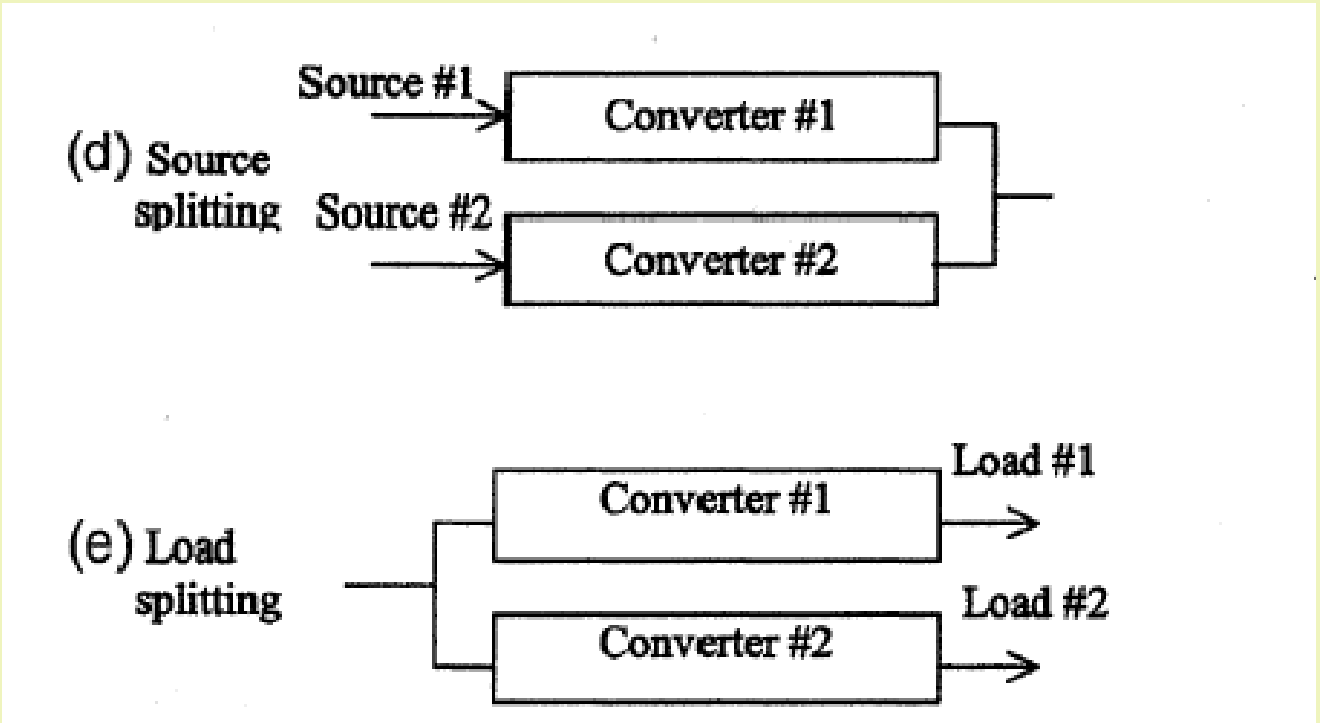
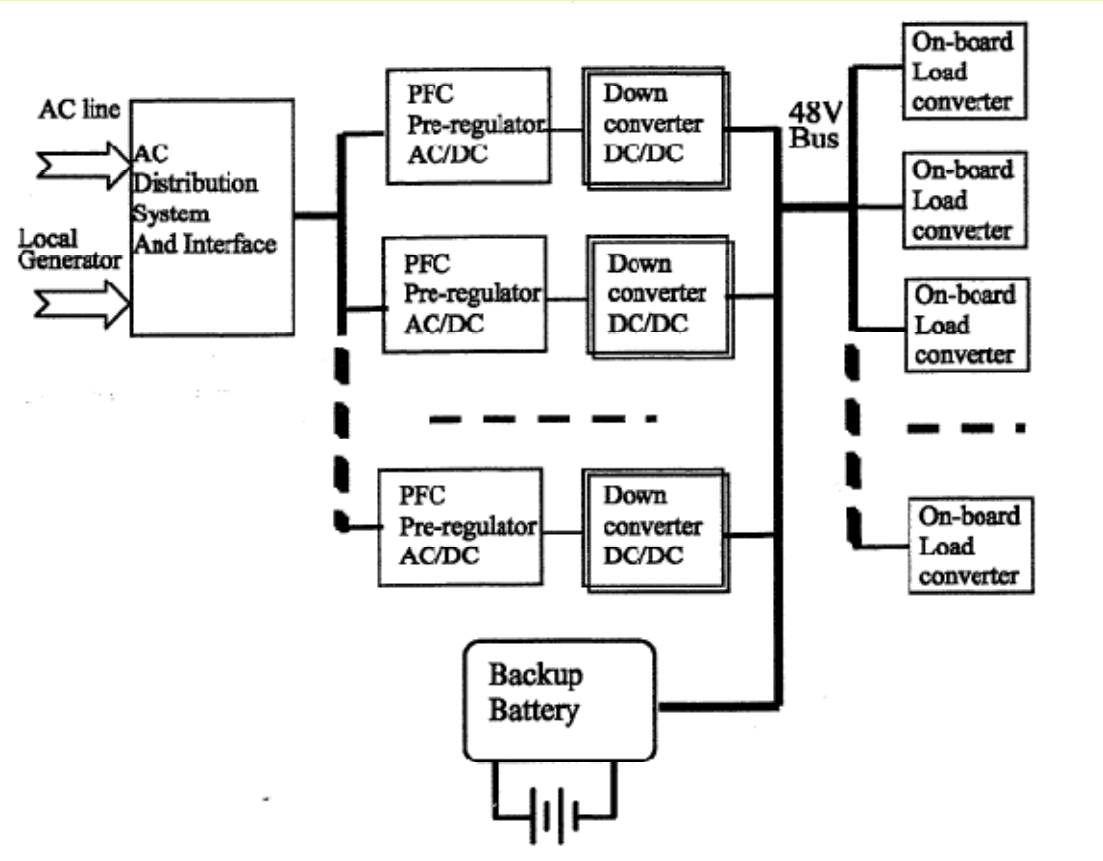


• S. Luo and I. Batarseh, "A Review of Distributed Power Systems. Part I: DC Distributed Power System" IEEE Aerospace and Electronic Systems Magazine, August 2005, Vol 20, No. 8, pp 5-15

❑ POWER SUPPLY ARCHITECTURES

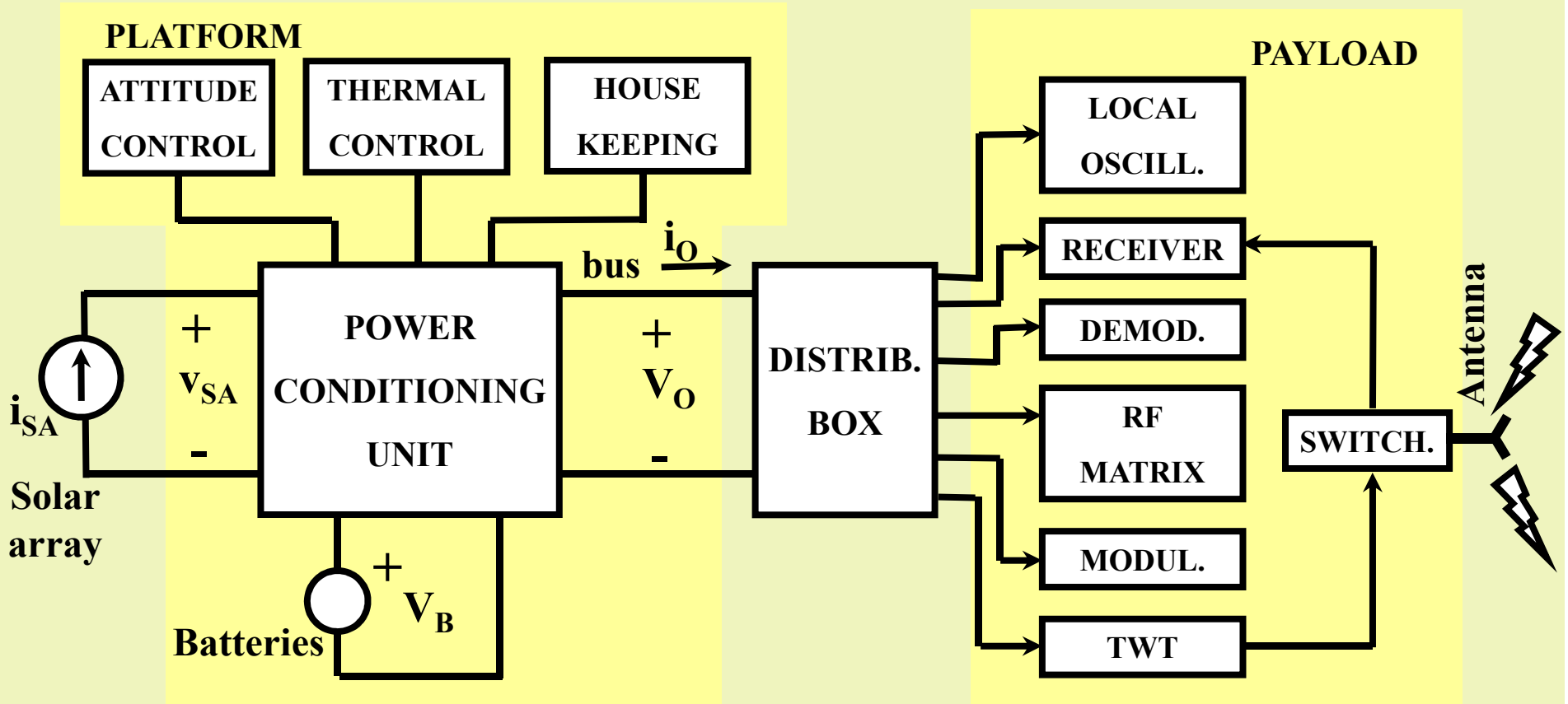
•BASIC DISTRIBUTION EXAMPLES



• S. Luo and I. Batarseh, "A Review of Distributed Power Systems. Part I: DC Distributed Power System" IEEE Aerospace and Electronic Systems Magazine, August 2005, Vol 20, No. 8, pp 5-15

❑ POWER SUPPLY ARCHITECTURES

ELECTRICAL ARCHITECTURE OF A TELECOMUNICATION SATELLITE



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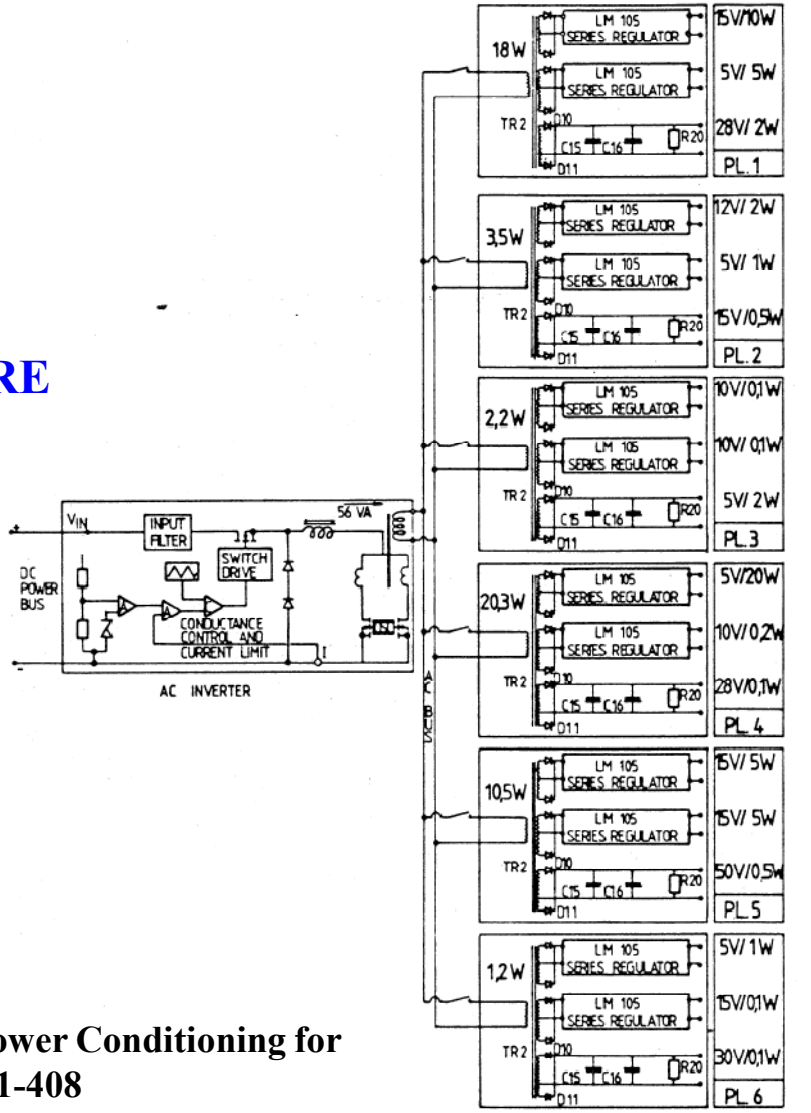
❑ POWER SUPPLY ARCHITECTURES

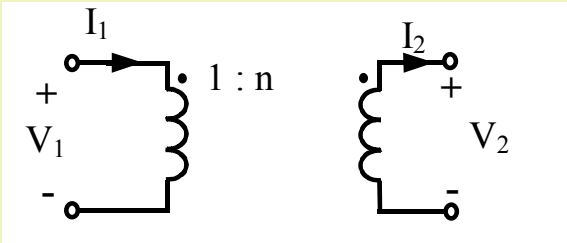
CENTRALIZED ARCHITECTURE



• A. Capel, D. O'Sullivan, J.C. Marpinard, High-Power Conditioning for Space Applications" Proc. IEEE, April 1988, pp 391-408

CANONICAL ELEMENTS FOR POWER CONVERSION STATE OF THE ART

DC TRANSFORMER

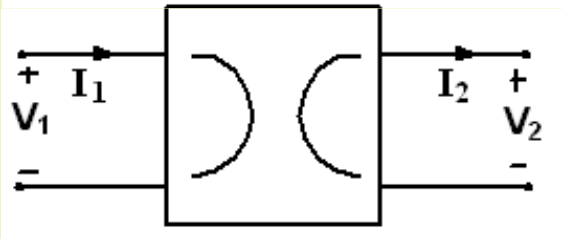


$$V_2 = nV_1$$

$$I_2 = \frac{I_1}{n}$$

$$P_2 = P_1$$

POWER GYRATOR



$$I_1 = gV_2$$

$$I_2 = gV_1$$

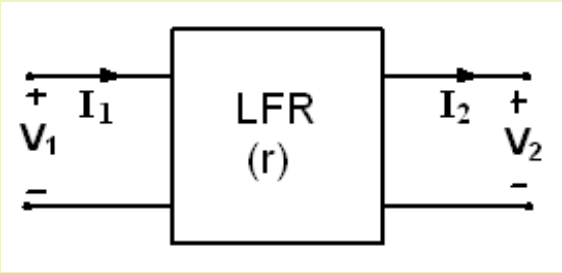
or

$$V_1 = rI_2$$

$$V_2 = rI_1$$

$$P_2 = P_1$$

LOSS-FREE RESISTOR



$$V_1 = rI_1$$

$$P_2 = P_1$$

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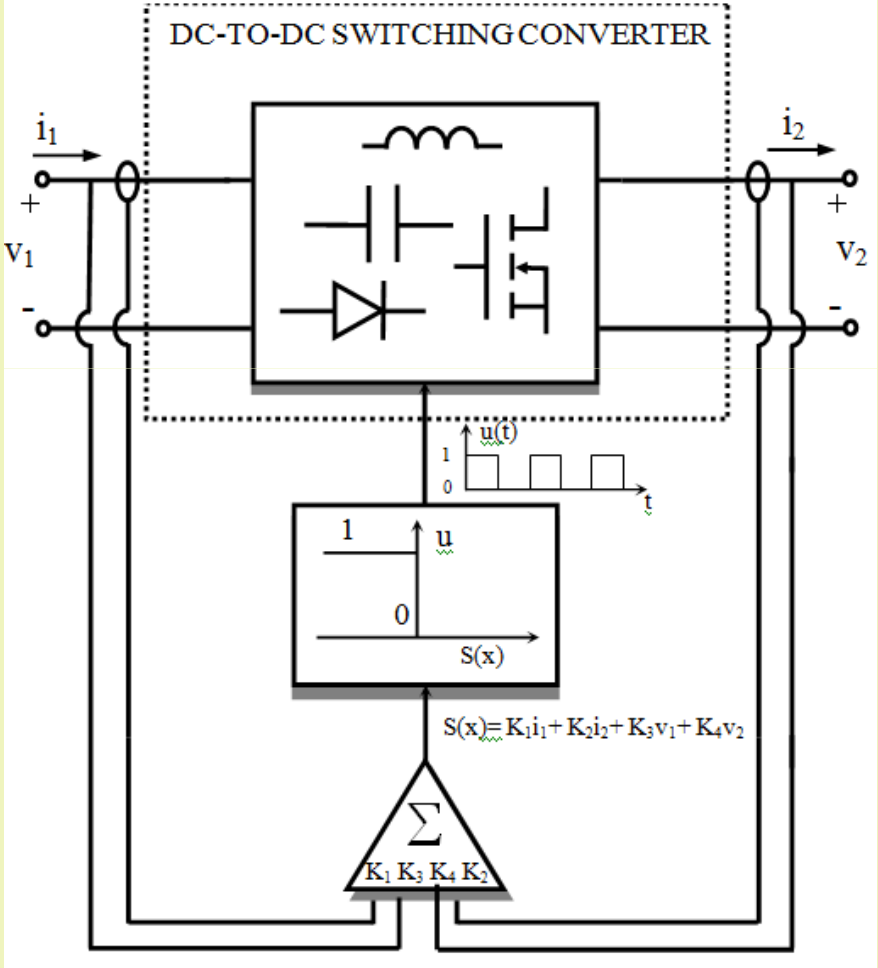
GENERALIZED CANONICAL ELEMENT

Block diagram of a generalized canonical element for power processing



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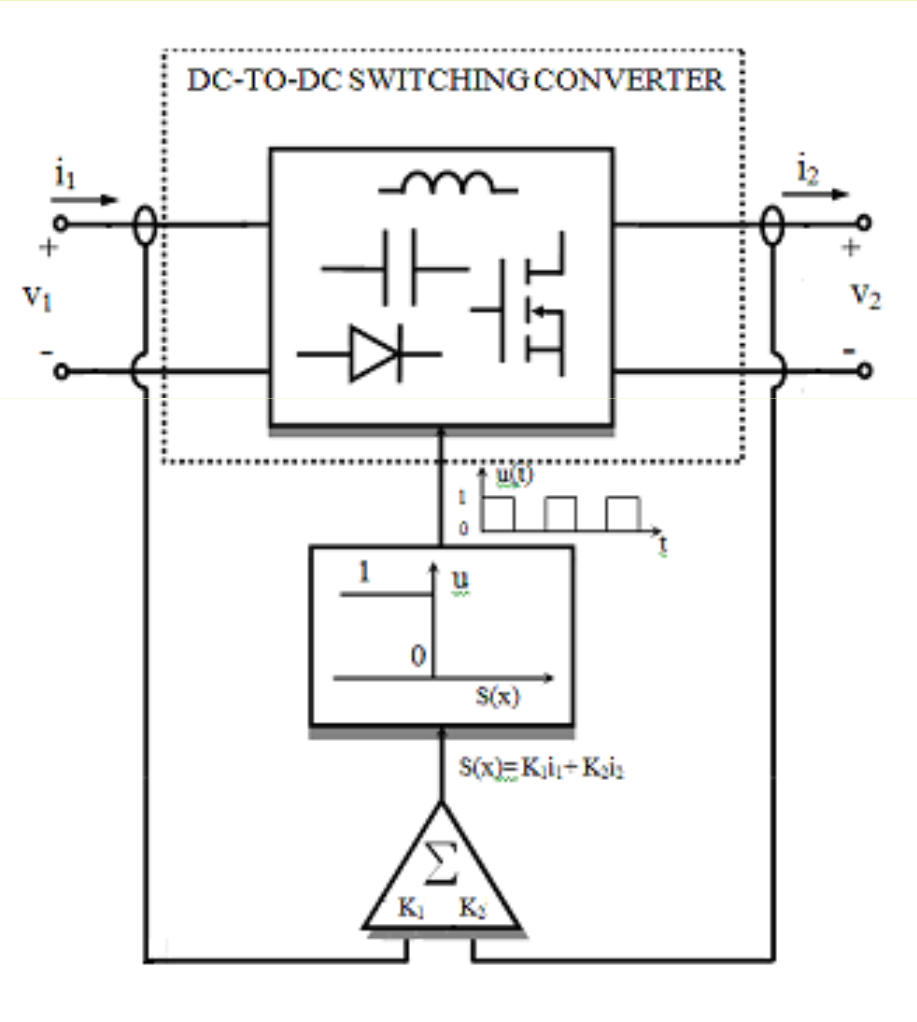
❑ GENERALIZED CANONICAL ELEMENT
DC TRANSFORMER



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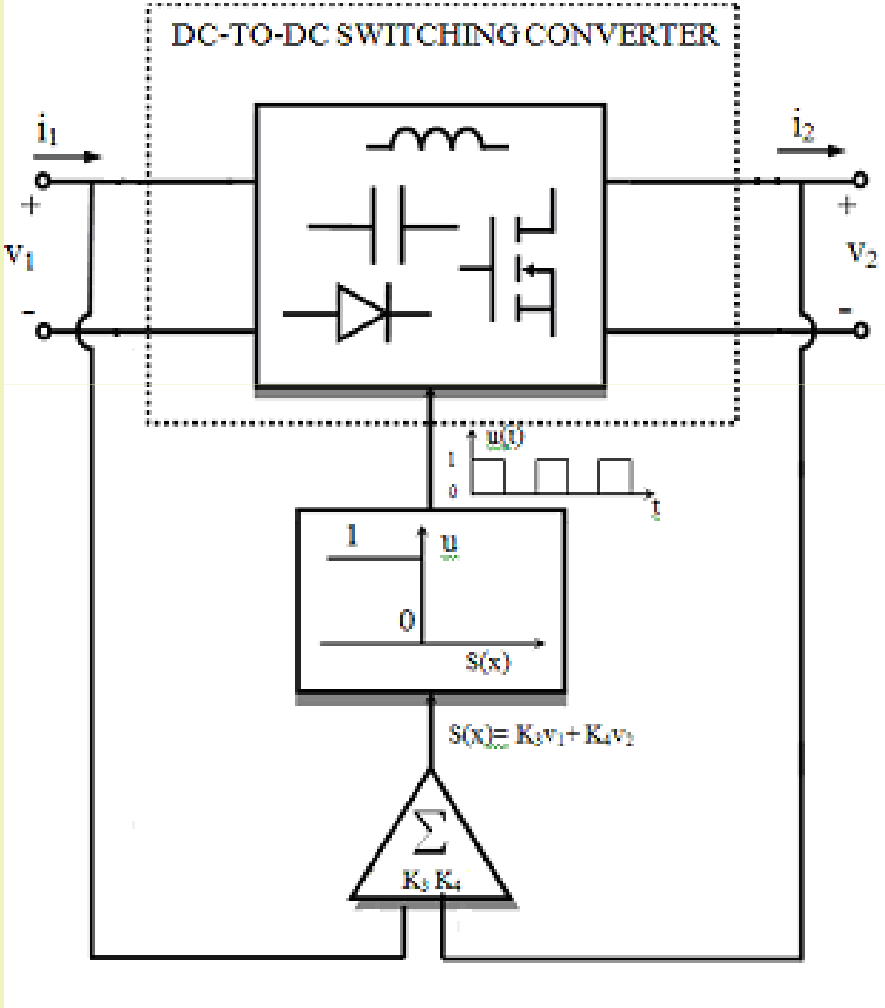
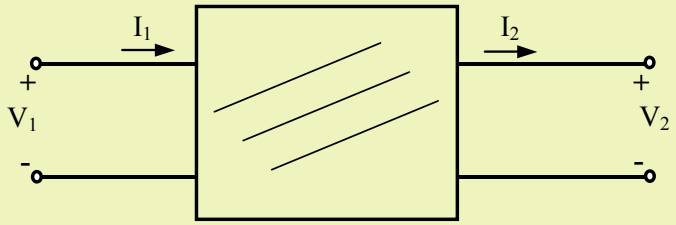
GENERALIZED CANONICAL ELEMENT
DC TRANSFORMER



❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

- **DC TRANSFORMER SYNTHESIS**

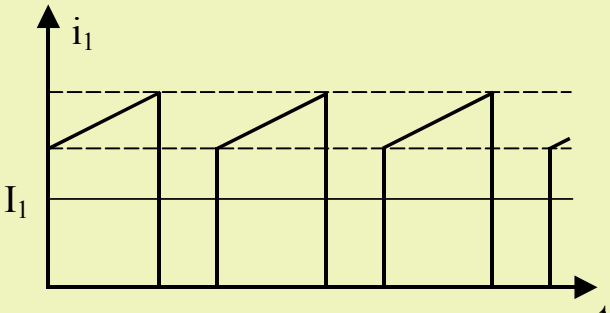


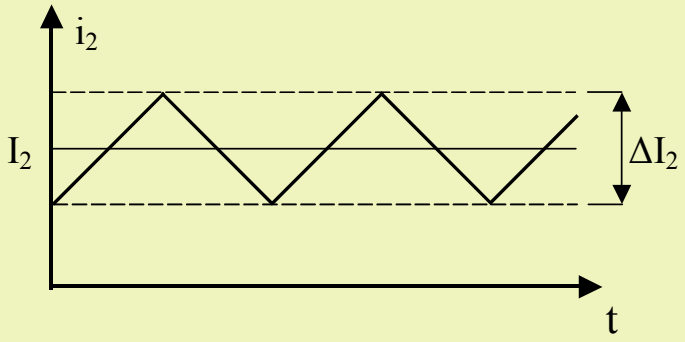
$$V_2 = n(D)V_1$$

$$I_2 = \frac{I_1}{n(D)}$$

- **POSSIBLE CURRENT BEHAVIOR (CONTINUOUS CONDUCTION MODE, CCM)**

1.





It results in an important EMI level at the input port

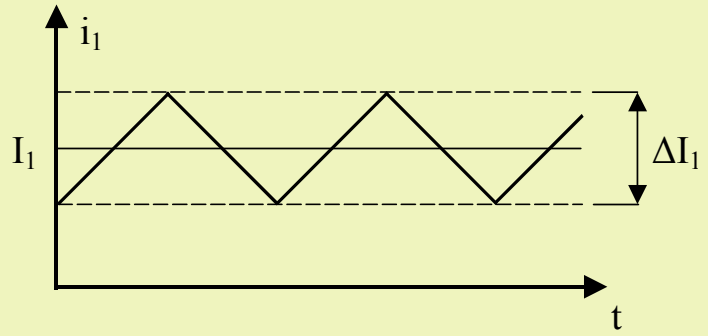
• L. Martinez-Salamero, H. Valderrama-Blavi, R. Giral, C. Alonso, B. Estibals, and A. Cid-Pastor, "Self-Oscillating dc-to-dc switching converters with transformer characteristics" IEEE Trans. On Aerospace and Electronic Systems, Vol. 41, no 2, April 2005 pp 710 – 716.

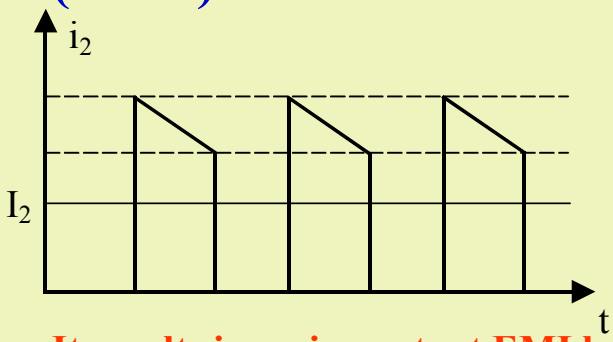
❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

- **POSSIBLE CURRENT BEHAVIOR (CCM)**

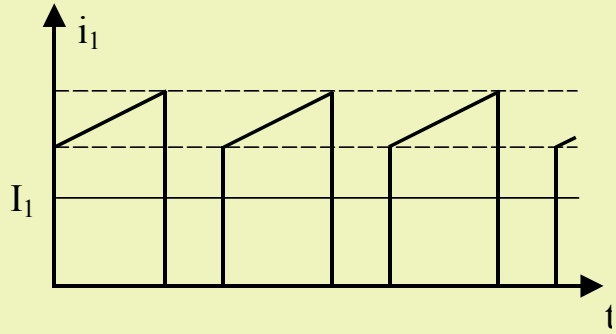
2.



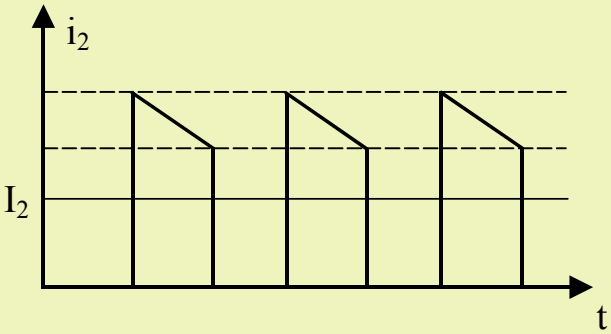


It results in an important EMI level at the output port

3.



It results in an important EMI level at the input port

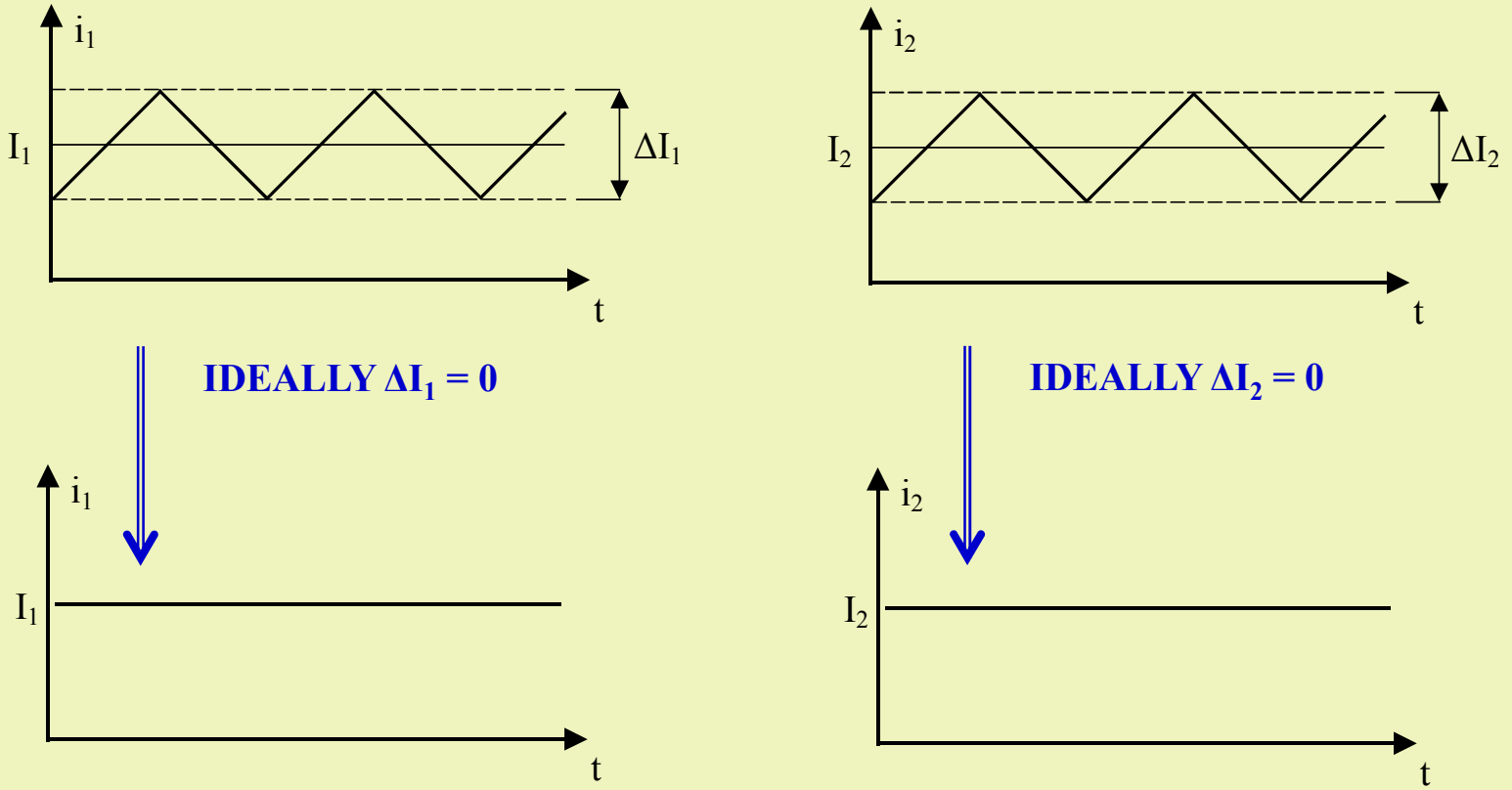


It results in an important EMI level at the output port

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

4.



IDEAL SOLUTION ⟹ **A SERIES INDUCTOR WITH THE INPUT PORT**
A SERIES INDUCTOR WITH THE OUTPUT PORT

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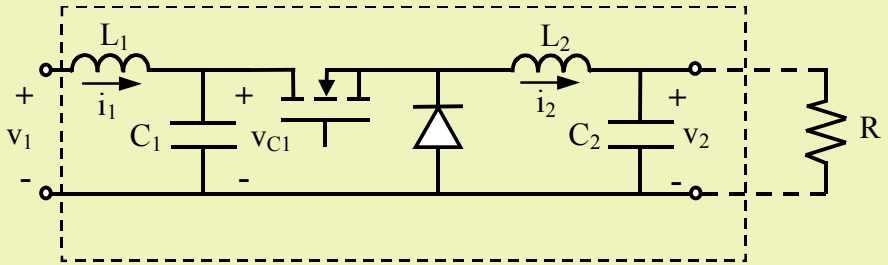
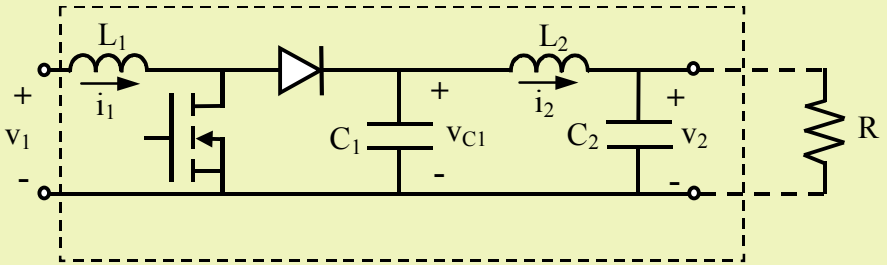
❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

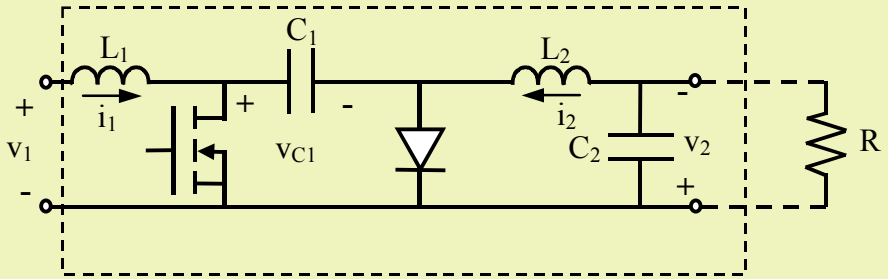
❑ 4 STRUCTURES WITH NON-PULSATING INPUT AND OUTPUT CURRENT



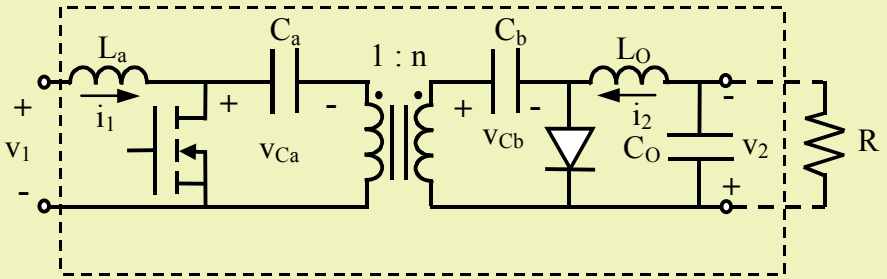
BIF



BOF



Čuk

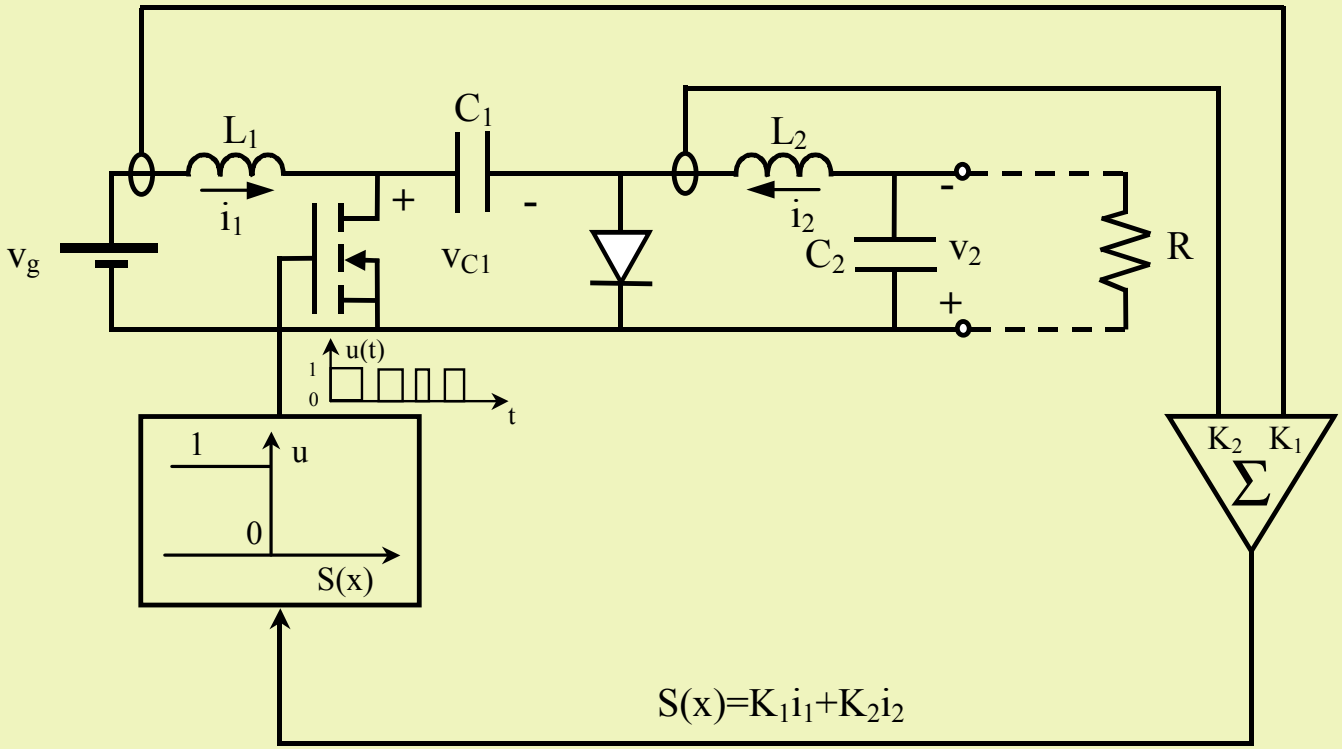


Ćuk with galvanic isolation

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE



CONTINUOUS CONDUCTION MODE

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

• **EQUILIBRIUM POINT** $x^* = [I_1,\ I_2,\ V_{C1},\ V_2]$

$$x^* = \left[\left(\frac{K_2}{K_1}\right)^2 \frac{V_g}{R},\ -\frac{K_2}{K_1}\frac{Vg}{R},\ \left(1-\frac{K_2}{K_1}\right)V_g,\ -\frac{K_2}{K_1}V_g\right]$$

• **EQUILIBRIUM POINT**

$$\left.\begin{aligned} V_2 &= -\frac{K_2}{K_1}\ V_g \\ I_2 &= -\frac{K_1}{K_2}\ \mathrm{I}_1 \end{aligned}\right\} \Rightarrow \begin{cases} -\dfrac{K_2}{K_1} > 1 & \text{STEP-UP} \\ -\dfrac{K_2}{K_1} < 1 & \text{STEP-DOWN} \end{cases}$$

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

- **STABILITY CONDITIONS**

CHARACTERISTIC EQUATION:

$$s^3+\frac{C_1K_1(K_1-K_2)(L_1K_2+L_2K_1)-C_2K_2\left(L_1K_2^2+L_2K_1^2\right)}{C_1C_2RK_1(K_1-K_2)(L_1K_2+L_2K_1)}s^2+$$

$$+\frac{C_1R^2K_1^2(K_1-K_2)-K_2\left(L_1K_2^2+L_2K_1^2\right)}{C_1C_2R^2K_1(K_1-K_2)(L_1K_2+L_2K_1)}s-\frac{K_1K_2}{C_1C_2R(K_1-K_2)(L_1K_2+L_2K_1)}=0$$

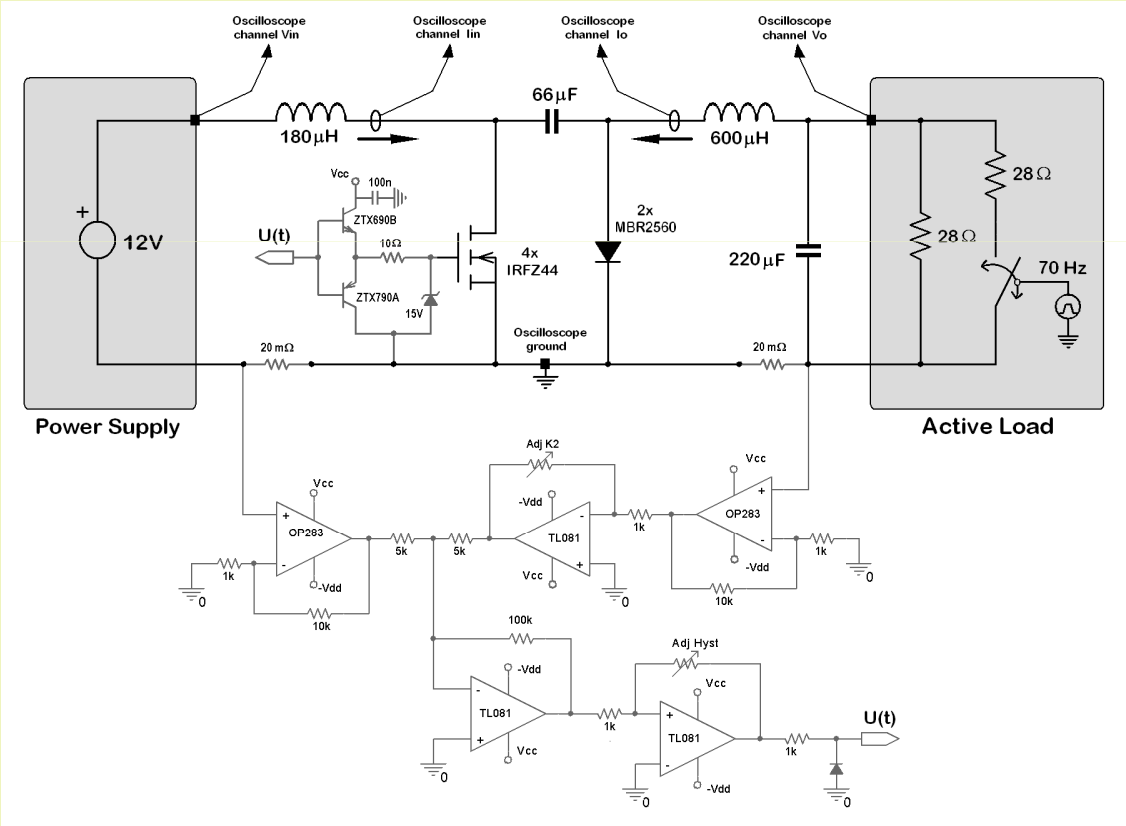
$L_1K_2+L_2K_1 > 0$ with $K_1 > 0$ and $K_2 < 0$ ➡ **STABLE SYSTEM**

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

CIRCUIT SCHEME

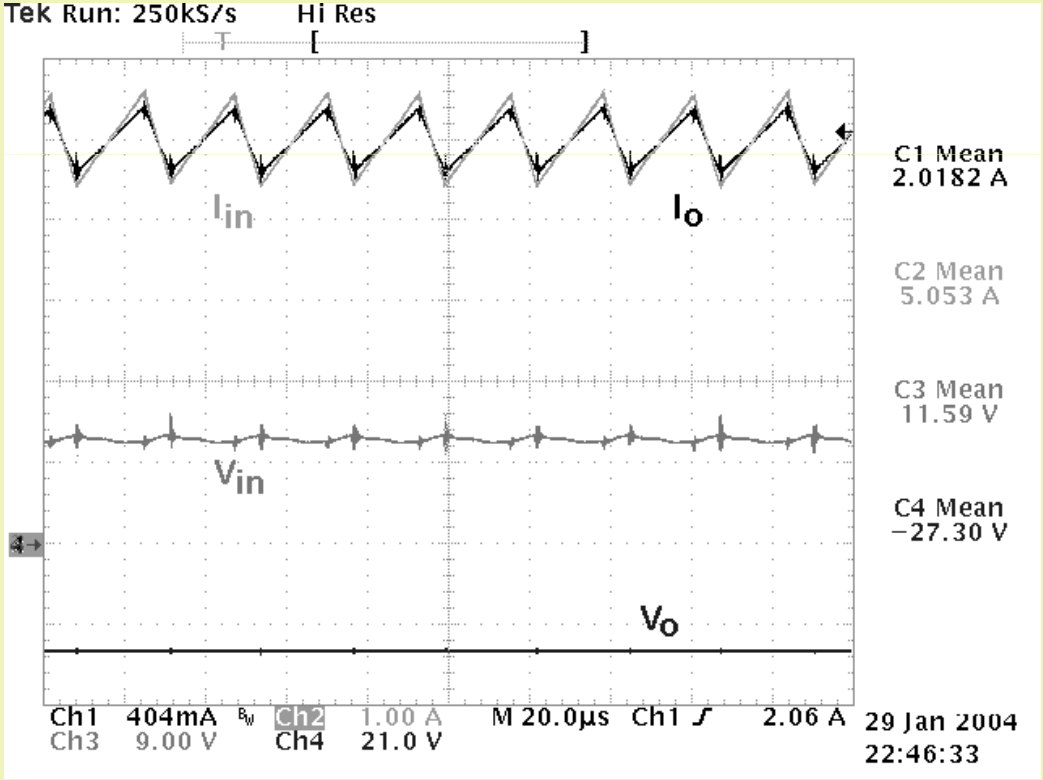


❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

EXPERIMENTAL RESULTS: STEADY-STATE

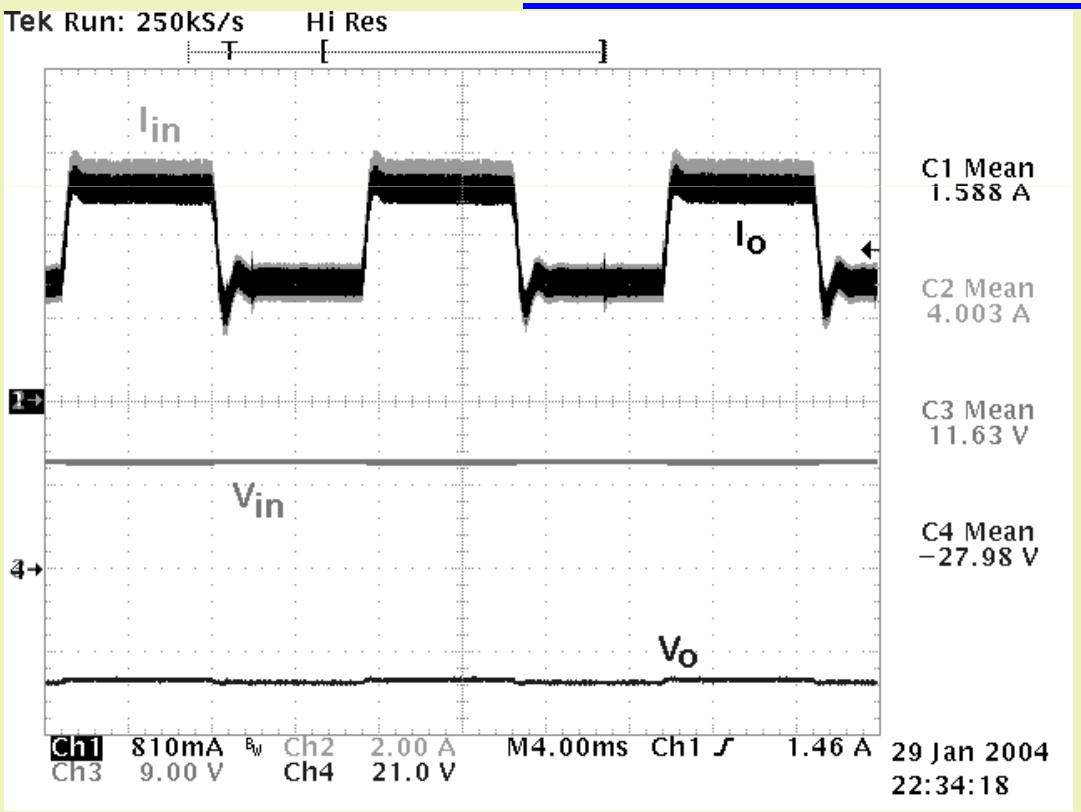


❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

EXPERIMENTAL RESULTS: RESPONSE TO LOAD VARIATIONS



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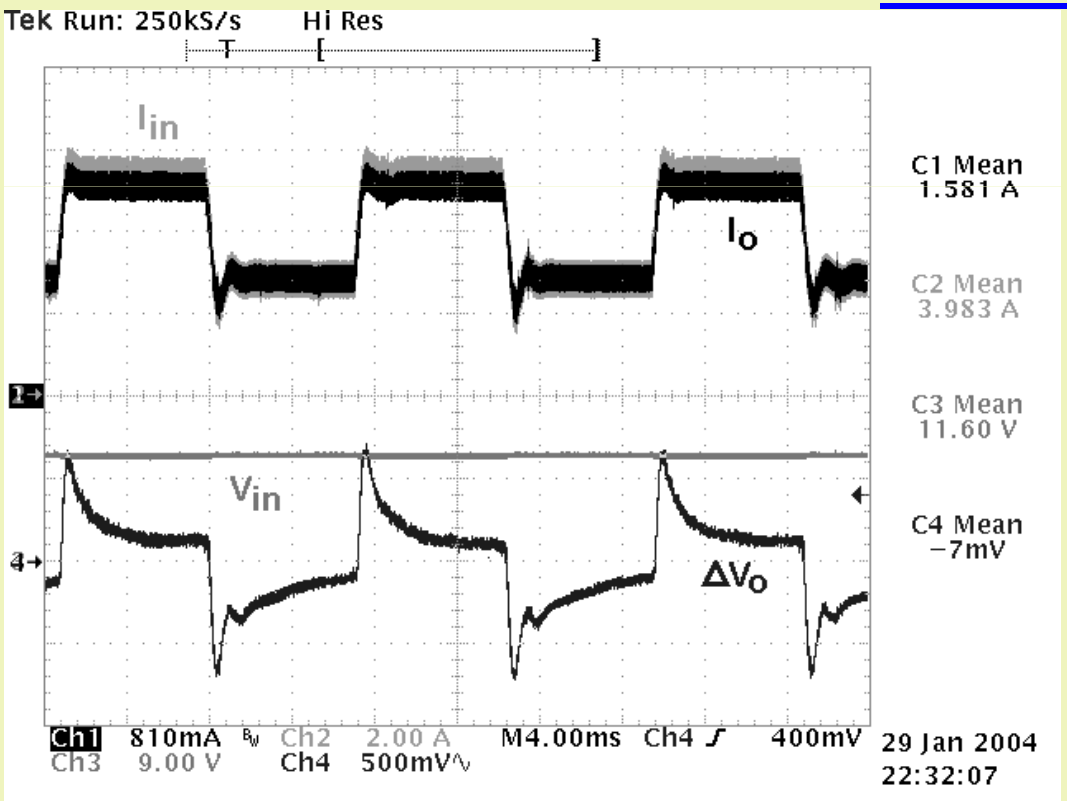
❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

❑ SELF OSCILLATING ĆUK CONVERTER IN SLIDING-MODE

EXPERIMENTAL RESULTS: RESPONSE TO LOAD VARIATIONS



DETAILED BEHAVIOR OF THE TRANSIENT OUTPUT VOLTAGE

❑ GENERALIZED CANONICAL ELEMENT

DC TRANSFORMER:
SELF-OSCILLATING FOURTH ORDER CONVERTERS IN SLIDING-MODE

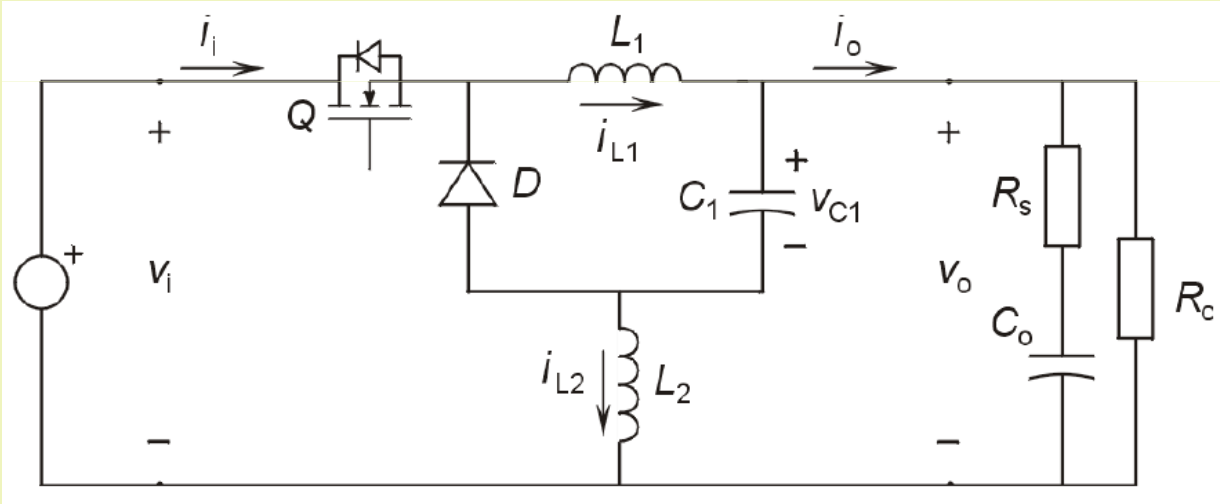
- **OTHER CONVERTERS**

CONV.	S(X)	$u_{eq}(X)$	Stability Condition	Step-up Condition	Step-down Condition
BIF	$S = K_1 i_1 + K_2 i_2$	$\frac{v_2}{v_{C1}} + \frac{K_1 L_2}{K_2 L_1}\left(1 - \frac{v_1}{v_{C1}}\right)$	Instable	-	$-\frac{K_2}{K_1} < 1$
BOF	$S = K_1 i_1 + K_2 i_2$	$1 - \frac{v_g}{v_1} - \frac{K_2 L_1}{K_1 L_2 - K_2 L_1}\left(1 - \frac{v_2}{v_1}\right)$	Stable	$-\frac{K_2}{K_1} > 1$	-

❑ GENERALIZED CANONICAL ELEMENT

• DC TRANSFORMER BASED ON $S(x)=K_3v_1+K_4v_2$

STABLE SLIDING REGIME



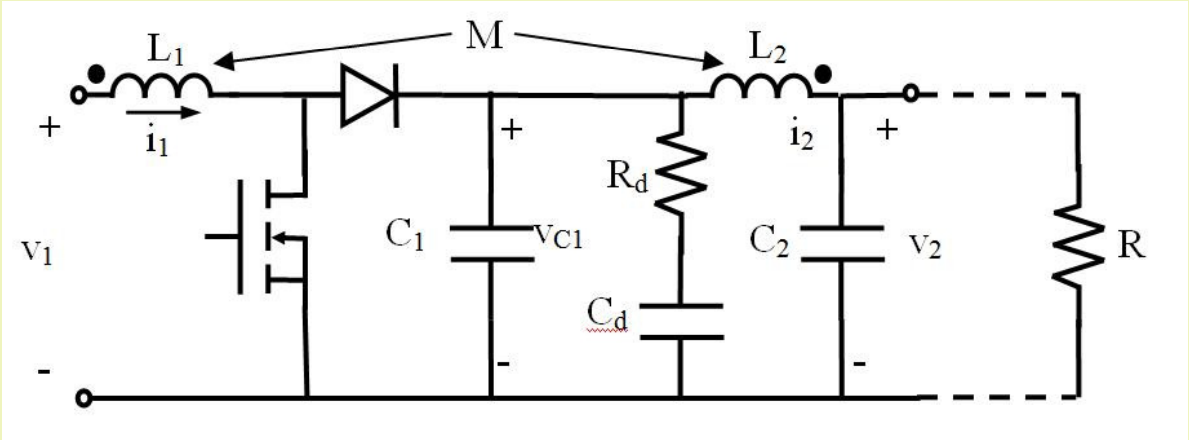
Two inductor voltage step down–converter

❑ GENERALIZED CANONICAL ELEMENT

- **DC TRANSFORMER BASED ON $S(x)=K_3v_1+K_4v_2$**

STABLE LIMIT CYCLE

- **BUCK CONVERTER**



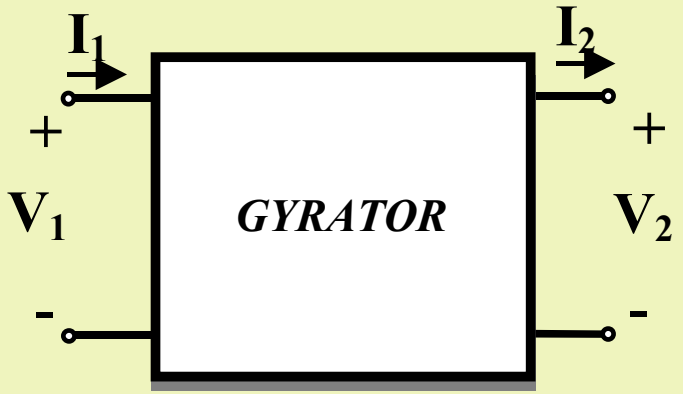
Boost converter with output filter, magnetic coupling and capacitive damping

❑ GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

❑ GYRATOR DEFINITION

FROM A CIRCUIT POINT OF VIEW A GYRATOR CAN BE CHARACTERIZED BY THE EQUATIONS



$$I_1 = gV_2 \qquad I_2 = gV_1 \qquad \text{OR} \qquad V_1 = rI_2 \qquad V_2 = rI_1$$

where

g = gyrator conductance

r = gyrator resistance

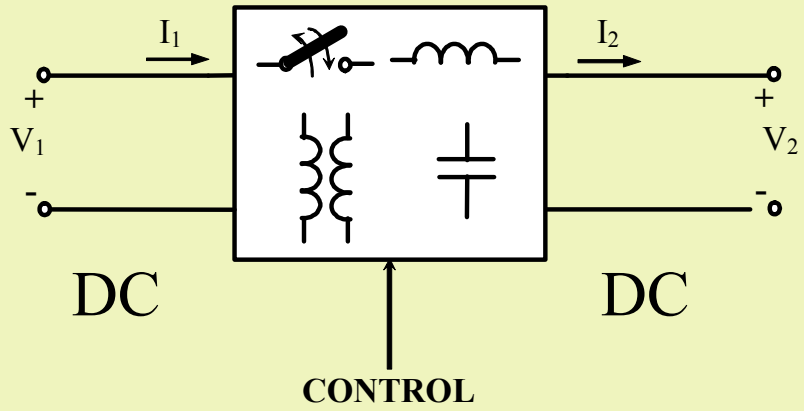
with $g = r^{-1}$

• A. Cid-Pastor, Martinez-Salamero, L.; Alonso, C.; Schweitz, G.; Calvente, J.; Singer, S.;"Classification and synthesis of power gyrators", Electric Power Applications, IEE Proceedings, Vol. 153, no. 6, Nov. 2006 pp 802-808.

GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

CLASSIFICATION OF GYRATORS



From the definition equations:

$$I_1 = gV_2$$
$$I_2 = gV_1$$

POWER GYRATORS OF TYPE G

$$V_1 = rI_2$$
$$V_2 = rI_1$$

POWER GYRATORS OF TYPE R

❑ GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

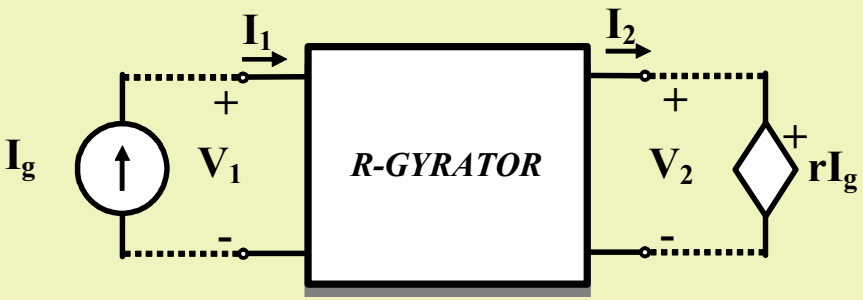
❑ CLASSIFICATION OF GYRATORS

POWER GYRATORS OF TYPE G

Voltage-current conversion by means of a G-gyrator

$$I_1 = gV_2$$
$$I_2 = gV_1$$

POWER GYRATORS OF TYPE R



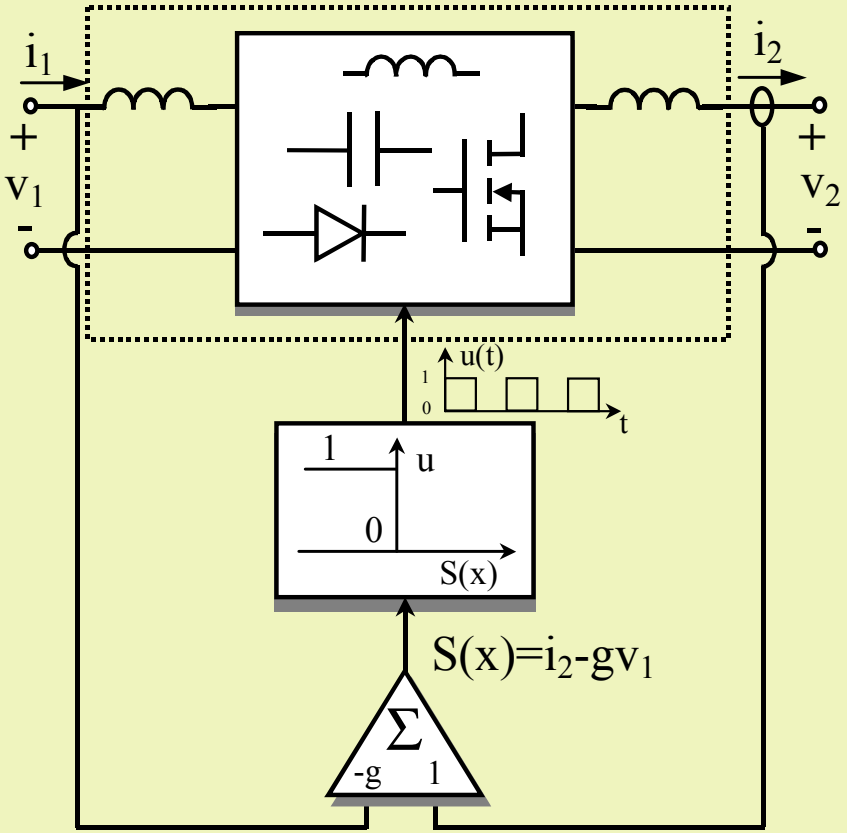
Current-voltage conversion by means of a R-gyrator

$$V_1 = rI_2$$
$$V_2 = rI_1$$

GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

POWER GYRATORS OF TYPE G



SLIDING MODE CONTROL WITH

$$S(x)=i_2 - gv_1$$

In steady-state

$$I_1 = gV_2$$
$$I_2 = gV_1$$

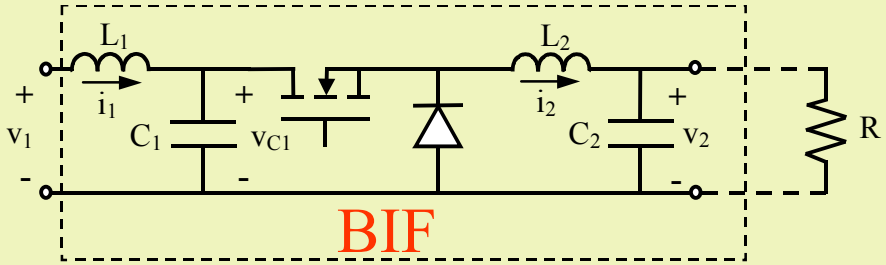
GENERALIZED CANONICAL ELEMENT

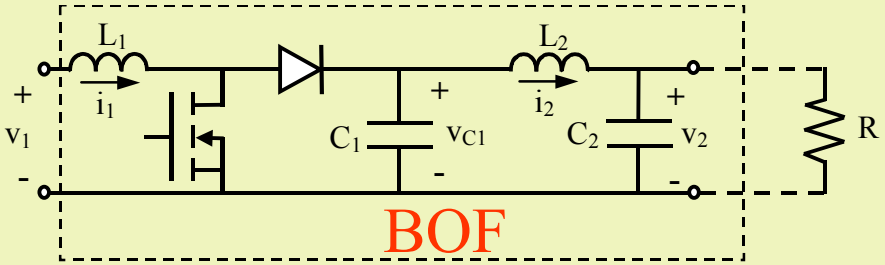
• POWER GYRATOR

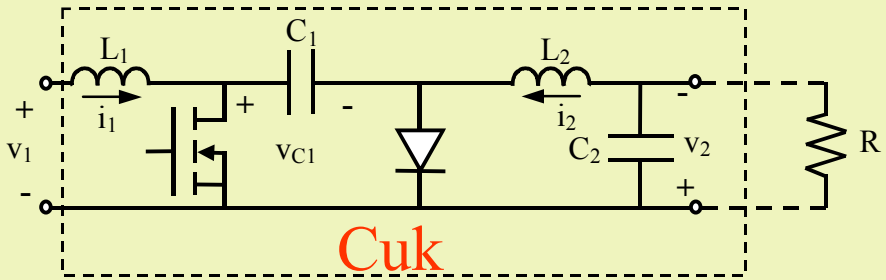
POWER GYRATORS OF TYPE G

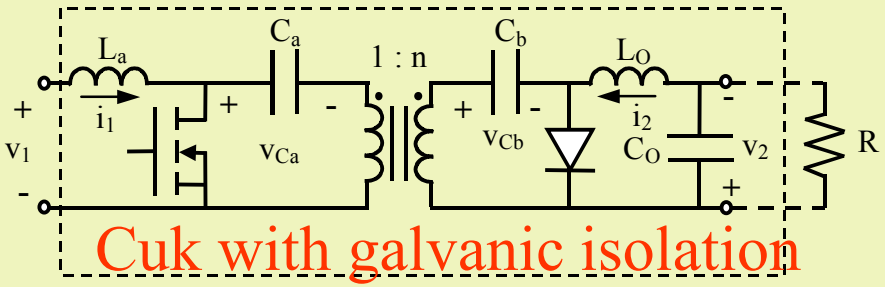
Non-pulsating input and output currents

4 POSSIBLE CONVERTER STRUCTURES









❑ GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

❑ ANALYSIS OF 4TH ORDER STRUCTURES WITH IMPOSED G-GYRATOR BEHAVIOR

STABILITY ANALYSIS IN THE EQUILIBRIUM POINT:

CHARACTERISTIC EQUATION

- **BIF**

$$\left(s+\frac{1}{RC_2}\right)\left(s^2-\frac{g^2R}{C_1}s+\frac{1}{L_1C_1}\right)=0 \Longrightarrow \textbf{UNSTABLE}$$

- **BOF**

$$\left(s-\frac{1}{g^2L_1R}\right)\left(s+\frac{1}{RC_2}\right)=0 \Longrightarrow \textbf{UNSTABLE}$$

- **CUK**

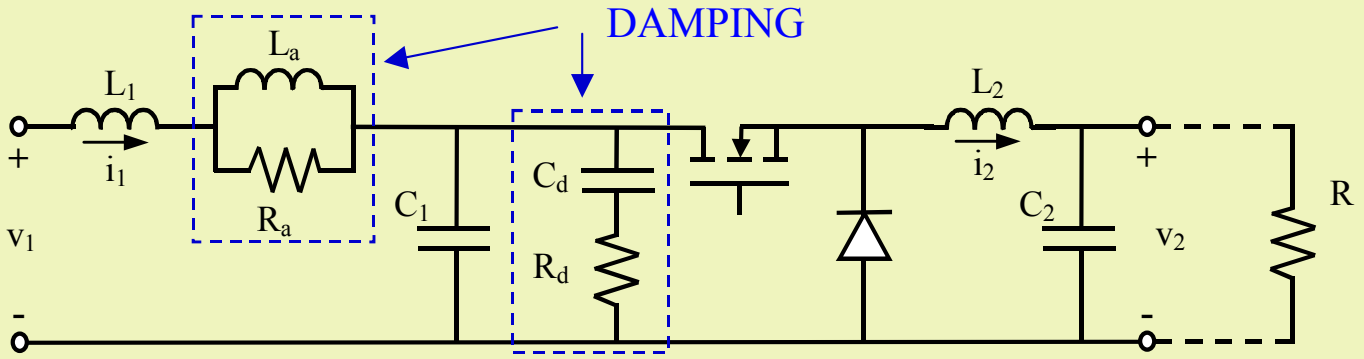
$$\left(s^2-\frac{g^2R}{1+gR}\frac{1}{C_1}s+\frac{1}{L_1C_1(1+gR)}\right)\left(s+\frac{1}{RC_2}\right)=0 \Longrightarrow \textbf{UNSTABLE}$$

GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

STABILIZATION OF 4TH ORDER STRUCTURES WITH IMPOSED G-GYRATOR BEHAVIOR

- **DAMPING NETWORK (BIF)**



Characteristic equation: $\left(s+\frac{1}{RC_2}\right)P(s)=0$ (without L_a // R_a)

$$P(s)=s^3+\left(\frac{1}{R_dC_d}+\frac{1}{R_dC_1}-\frac{g^2R}{C_1}\right)s^2+\left(\frac{1}{L_1C_1}-\frac{g^2R}{R_dC_dC_1}\right)s+\frac{1}{L_1C_1R_dC_d}=0$$

Stability conditions:

$$R_dC_d<\frac{(C_1+C_d)}{g^2R} \qquad R_dC_d>g^2RL_1$$

$$g^2RR_d{}^2C_d{}^2+g^2RL_1(C_1+C_d)(1+gR)<(g^4R^2L_1+C_d(1+gR))R_dC_d$$

GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

STABILIZATION OF 4TH ORDER STRUCTURES WITH IMPOSED G-GYRATOR BEHAVIOR

- DAMPING NETWORKS
  - BOF

Characteristic equation: (without La//Ra)

$$\left(s+\frac{1}{RC_2}\right)\left(s-\frac{1}{L_1 g^2 R}\right)\left(s+\frac{1}{R_d C_d}\right)=0$$

  - ČUK

Characteristic equation: (without La//Ra)

$$\left(s+\frac{1}{RC_2}\right)P(s)=0$$

$$P(s)=s^3+\left(\frac{1}{R_dC_d}+\frac{1}{R_dC_1}-\frac{g^2R}{C_1(gR+1)}\right)s^2+\left(\frac{1}{L_1C_1(gR+1)}-\frac{g^2R}{R_dC_dC_1(gR+1)}\right)s+\frac{1}{L_1C_1R_dC_d(gR+1)}$$

Stability conditions:

$$R_dC_d > g^2RL_1$$

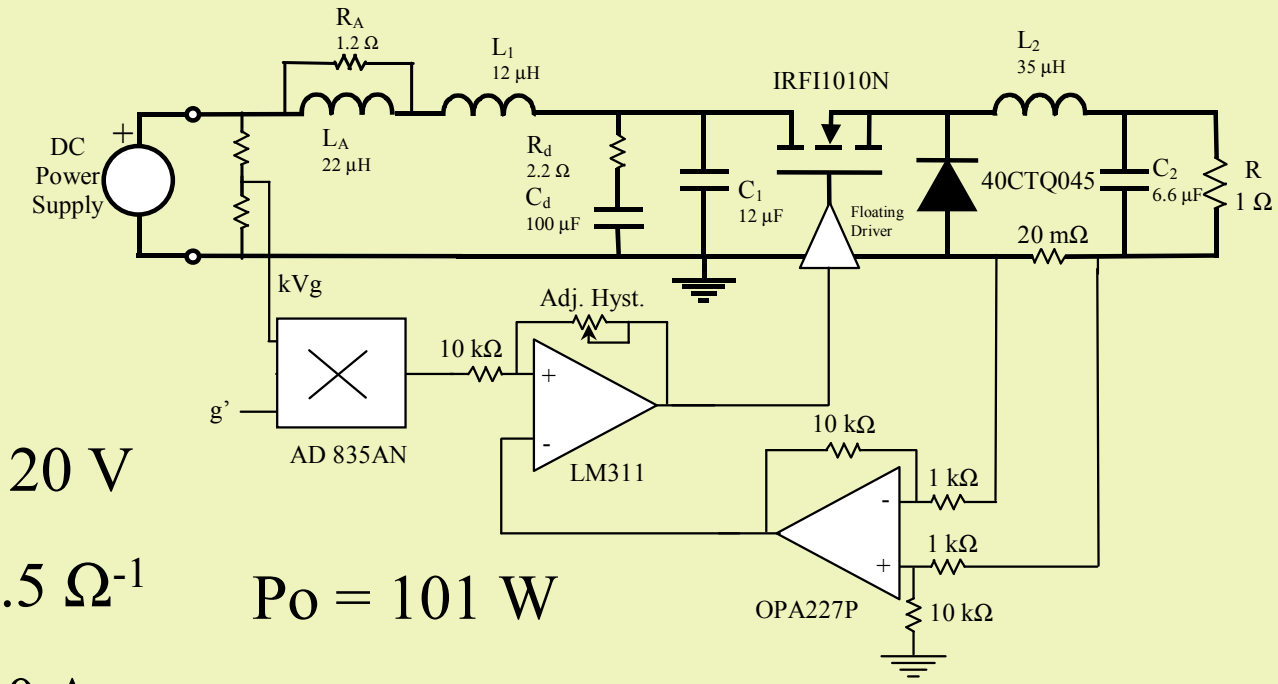
$$R_dC_d < \frac{(C_1+C_d)(1+gR)}{g^2R}$$

$$g^2RR_d^2C_d^2+g^2RL_1(C_1+C_d)(1+gR)<(g^4R^2L_1+C_d(1+gR))R_dC_d$$

❑ GENERALIZED CANONICAL ELEMENT

• POWER GYRATOR

PRACTICAL IMPLEMENTATION OF A BIF BASED-G-GYRATOR



$Vg = 20$ V

$g = 0.5\ \Omega^{-1}$ $\quad Po = 101$ W

$I_2 = 10$ A $\quad \eta = 90$ %

$R = 1\ \Omega$ $\quad F = 175$ kHz

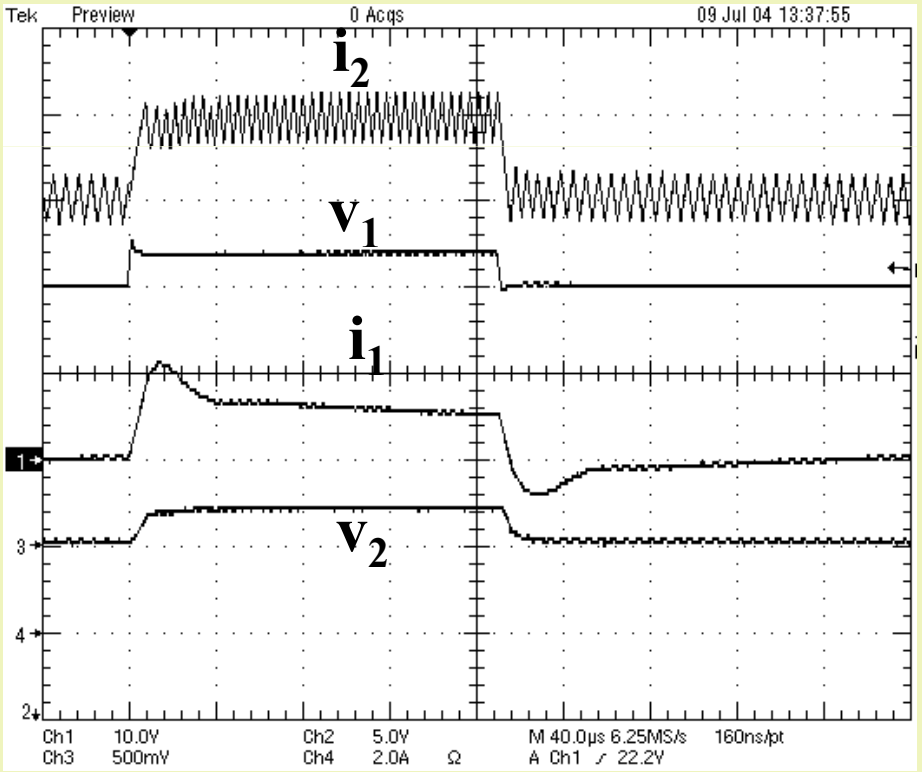
❑ GENERALIZED CANONICAL ELEMENT

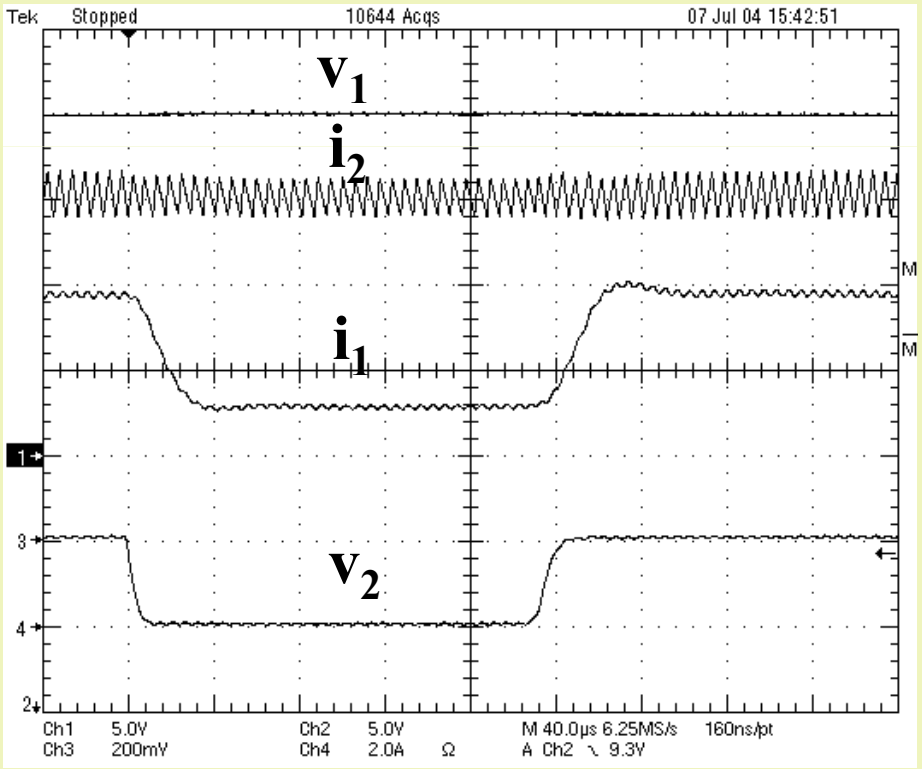
• POWER GYRATOR

EXPERIMENTAL RESULTS OF A BIF BASED-G-GYRATOR IN SLIDING MODE OPERATION

Pulsating input voltage:20–24–20 V

Pulsating load resistance:
1 - 0.5 - 1 Ω

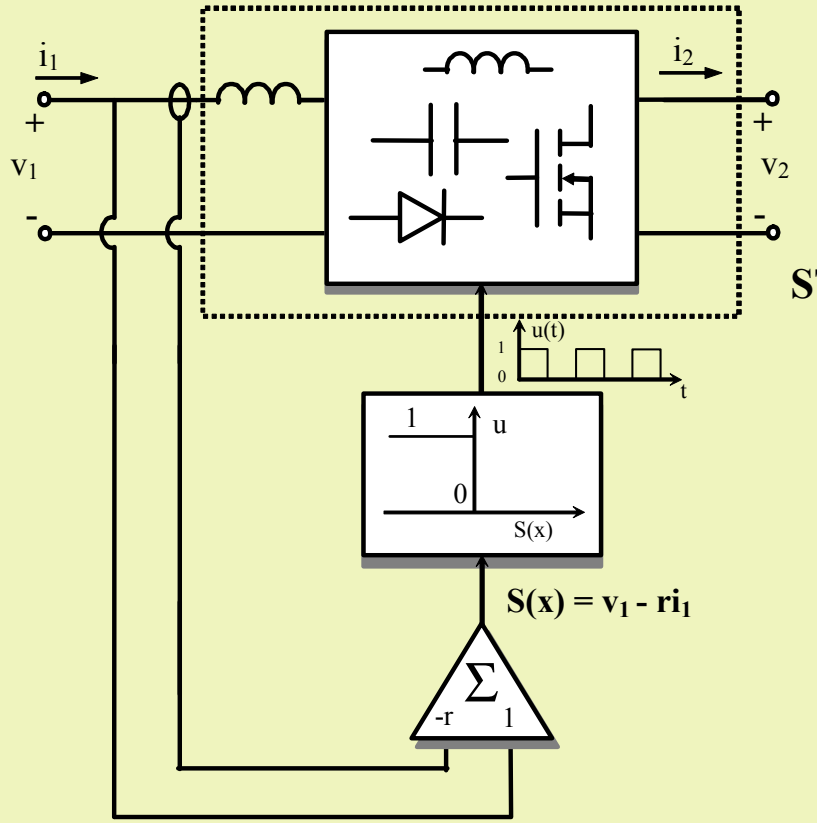




❑ GENERALIZED CANONICAL ELEMENT

• LOSS –FREE RESISTORS

❑ BLOCK DIAGRAM OF A SWITCHING CONVERTER WITH LFR CHARACTERISTICS



SLIDING MODE CONTROL WITH

$$S(x)=v_1 - ri_1$$

STABILITY AROUND THE EQUILIBRIUM POINT

BOOST CONVERTER:

CHARACTERISTIC EQUATION

$$\left(s+\frac{2}{RC}\right)=0 \qquad \text{STABLE}$$

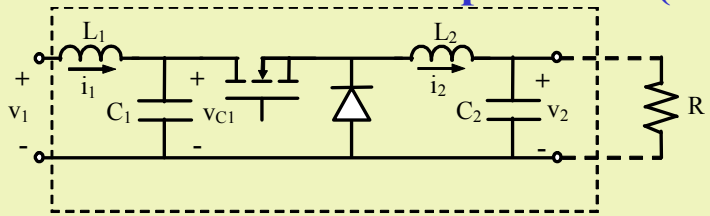
In steady-state: $\begin{cases} V_1 = rI_1 \\ V_1 I_1 = V_2 I_2 \end{cases}$

❑ GENERALIZED CANONICAL ELEMENT

• LOSS –FREE RESISTORS

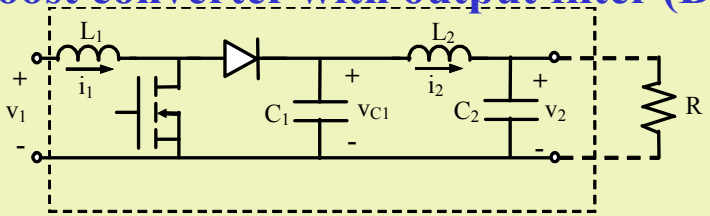
❑ STABILITY ANALYSIS: OTHER CONVERTERS

Buck converter with input filter (BIF)



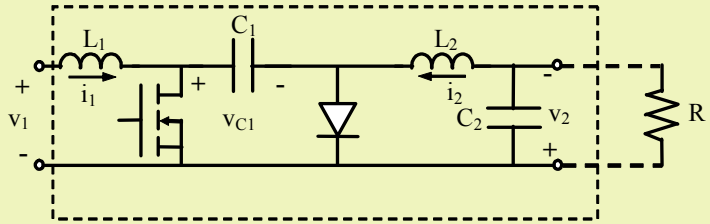
NO SLIDING MOTIONS

Boost converter with output filter (BOF)



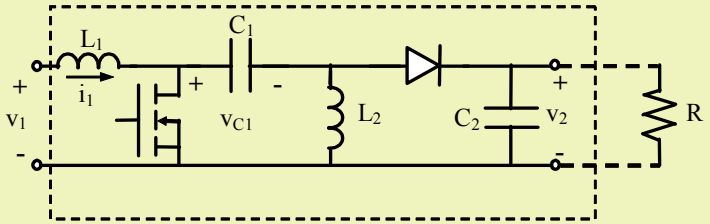
STABLE

Ćuk



STABLE

SEPIC

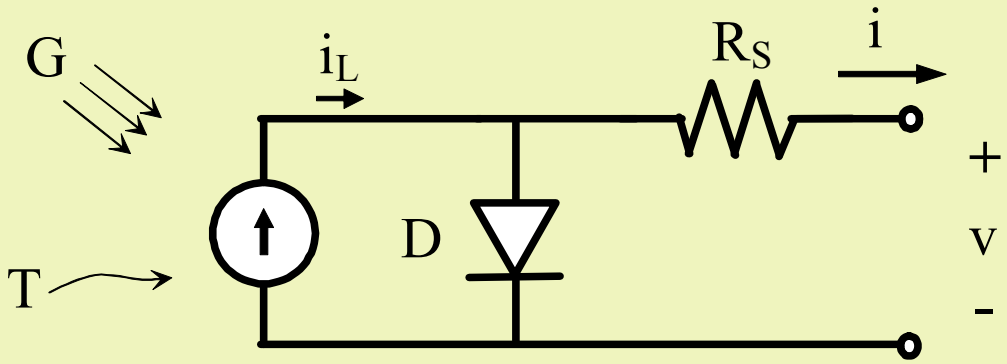


STABLE WITH CONDITIONS

❑ IMPEDANCE MATCHING

❑PHOTOVOLTAIC GENERATION

• MODELLING THE SOLAR CELL



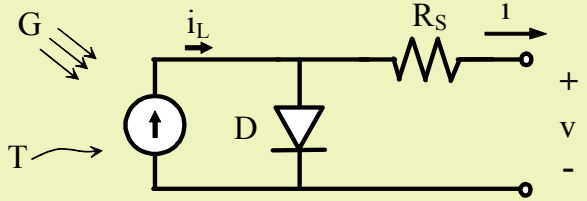
I_L ≡ PHOTO-CURRENT (A)
G = IRRADIANCE (Wm^{-2})
T = TEMPERATURE (K)

• J. A. Gow, C.D. Manning "Development of a Photovoltaic array model for use in power electronics simulation studies" IEE Proc. On Electric Power Applications, Vol. 146, No. 2, pp 193-200, March 1999

❑ IMPEDANCE MATCHING

❑PHOTOVOLTAIC GENERATION

• MODELLING THE SOLAR CELL



$$i = i_L - I_0\left(e^{q(v+iR_S)/nKT} - 1\right) \qquad i_L = i_L(T_1)\left(1 + K_0(T - T_1)\right)$$

$$i_L(T_1) = \frac{G \cdot I_{SC}(T_1, nom)}{G(nom)} \qquad K_0 = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{T_2 - T_1}$$

$$I_0 = I_0(T_1)\left(\frac{T}{T_1}\right)^{3/n} e^{-qV_g / nK\left(1/T - 1/T_1\right)} \qquad I_0(T_1) = \frac{I_{SC}(T_1)}{e^{qV_{OC}(T_1)/nKT_1} - 1}$$

$$R_S = -dV / dI_{V_{OC}} - 1/X_V \qquad X_V = I_0(T_1)\frac{q}{nKT1} e^{\frac{qV_{OC}(T_1)}{nKT_1}}$$

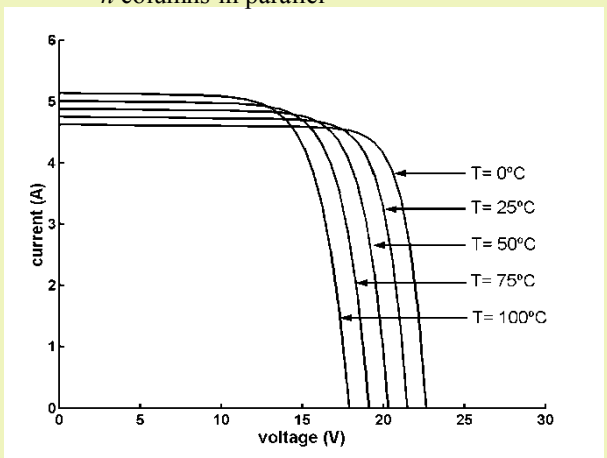
$$1 < n < 2$$

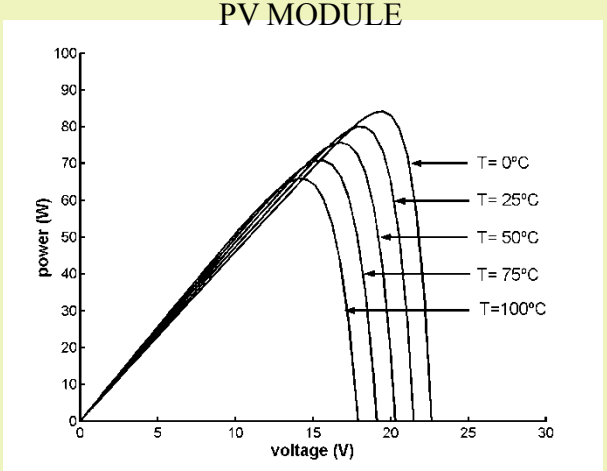
• J. A. Gow, C.D. Manning “Development of a Photovoltaic array model for use in power electronics simulation studies” IEE Proc. On Electric Power Applications, Vol. 146, No. 2, pp 193-200, March 1999

❑ IMPEDANCE MATCHING

❑PHOTOVOLTAIC GENERATION

• MODELLING THE PV MODULE



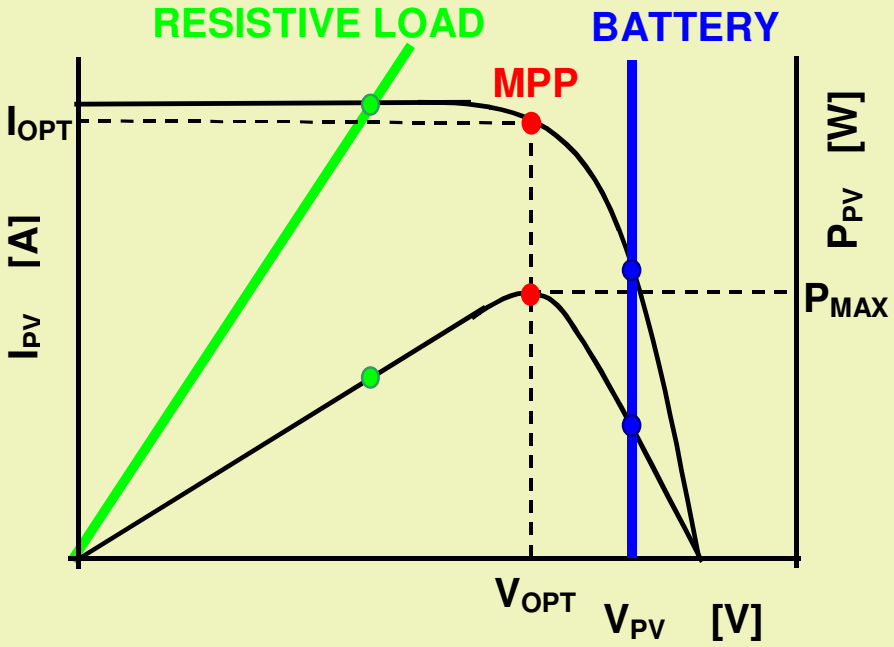


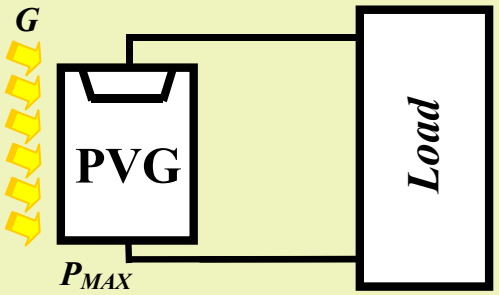
• G. Walker "Evaluating MPPT Converter Topologies Using a MATLAB PV Model" Journal of Electrical and Electronics Engineering, Australia, 2001, 21(1), pp 49-55

❑ IMPEDANCE MATCHING

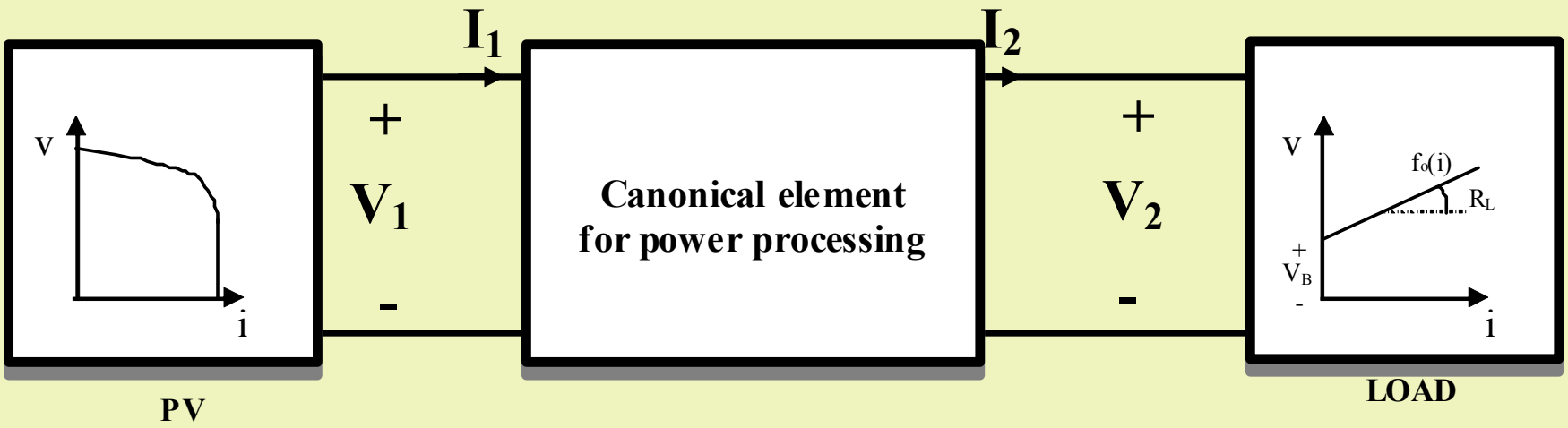
❑PHOTOVOLTAIC GENERATION

- **PHOTOVOLTAIC GENERATOR**
  - **NON-LINEAR CHARACTERISTICS**
  - **MAXIMUM POWER POINT (MPP)**
  - **DEPENDENCE ON IRRADIATION AND TEMPERATURE**





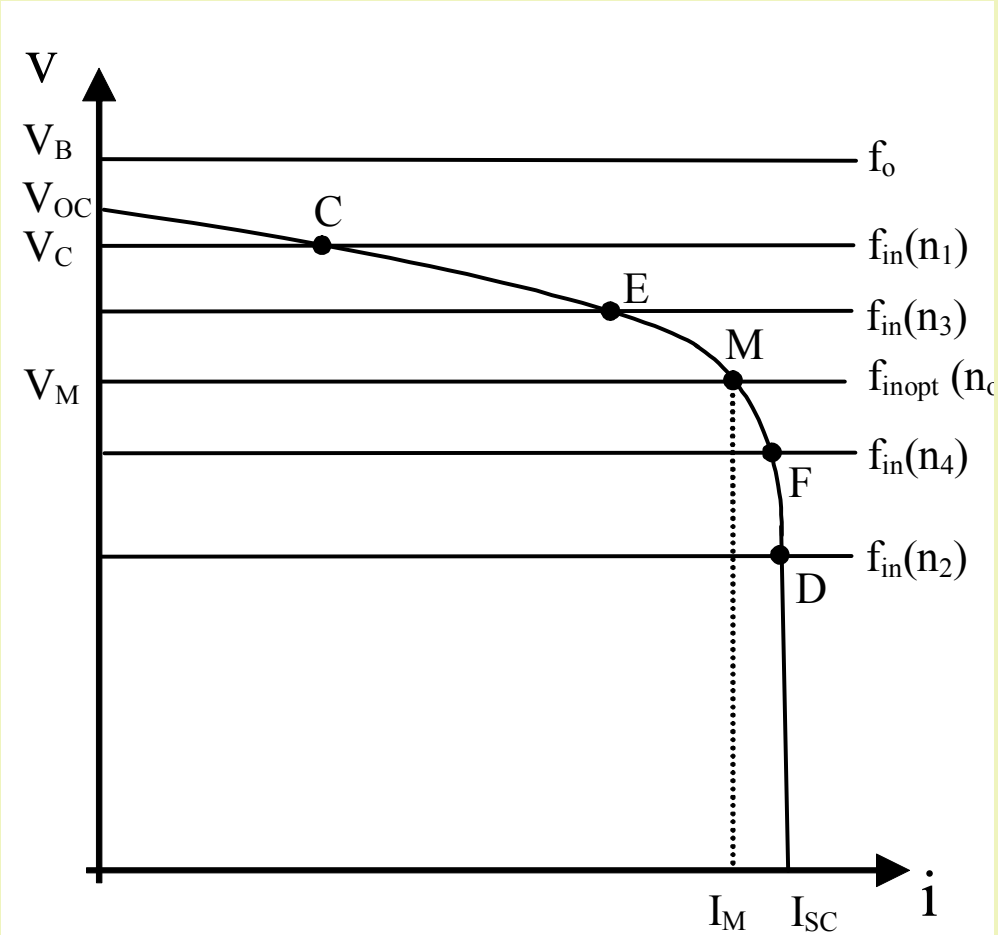
❑ IMPEDANCE MATCHING



Matching a PV generator to a dc load using a canonical element for power processing

Universidad de los Andes

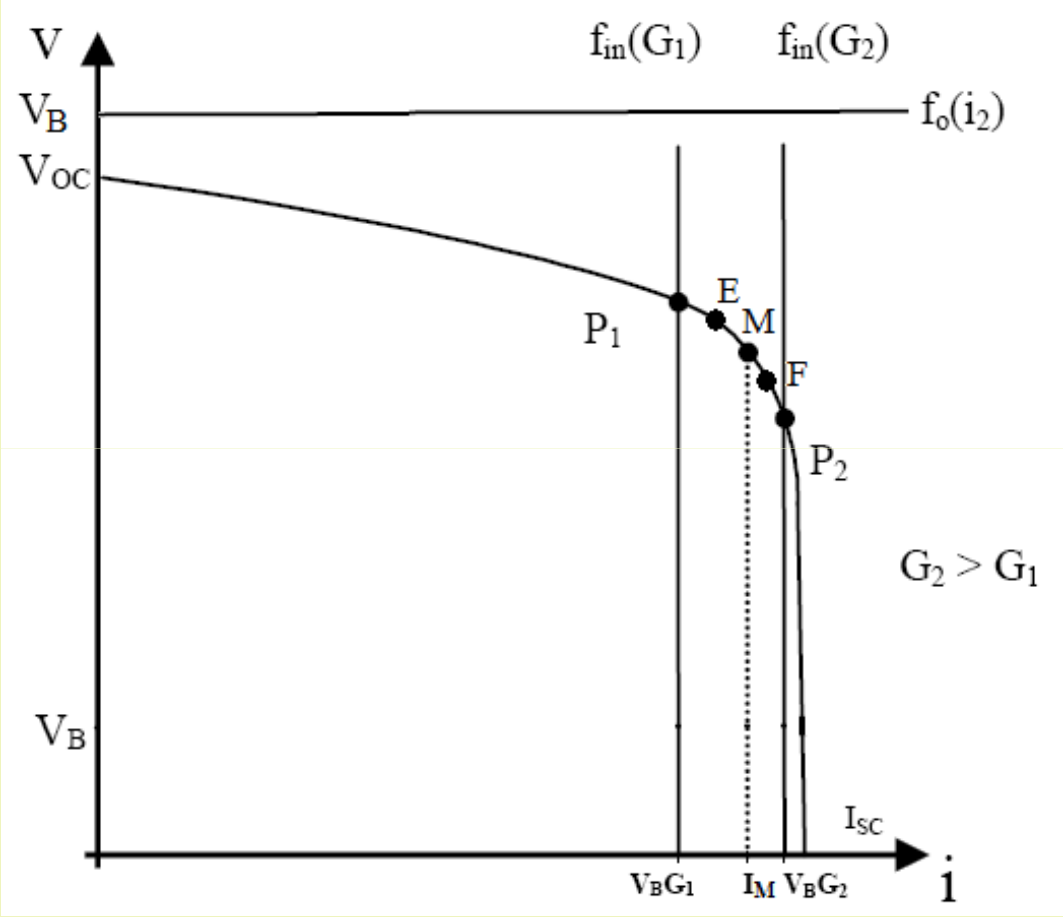
❑ IMPEDANCE MATCHING



PV panel operating points for an impedance matching with a dc transformer

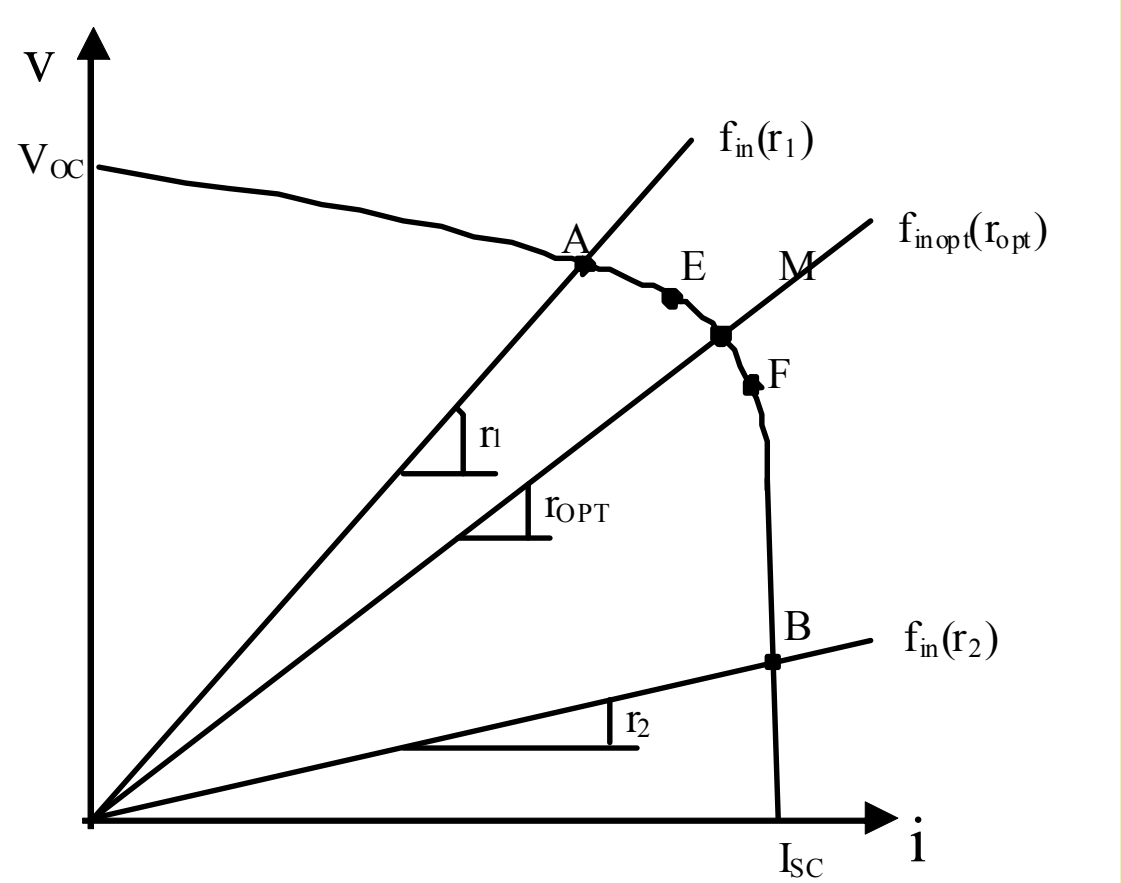
Universidad de los Andes

❑ IMPEDANCE MATCHING



PV panel operating points for an impedance matching with a power gyrator

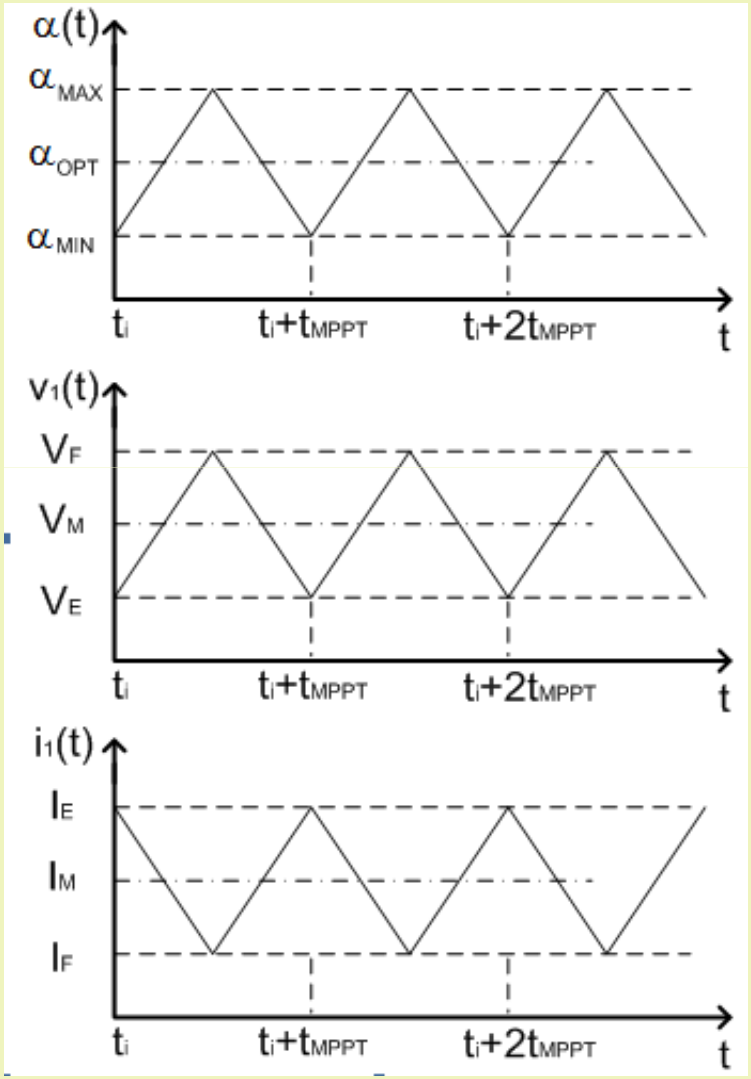
❑ IMPEDANCE MATCHING



PV panel operating points for an impedance matching with a loss-free resistor

Universidad de los Andes

❑ IMPEDANCE MATCHING

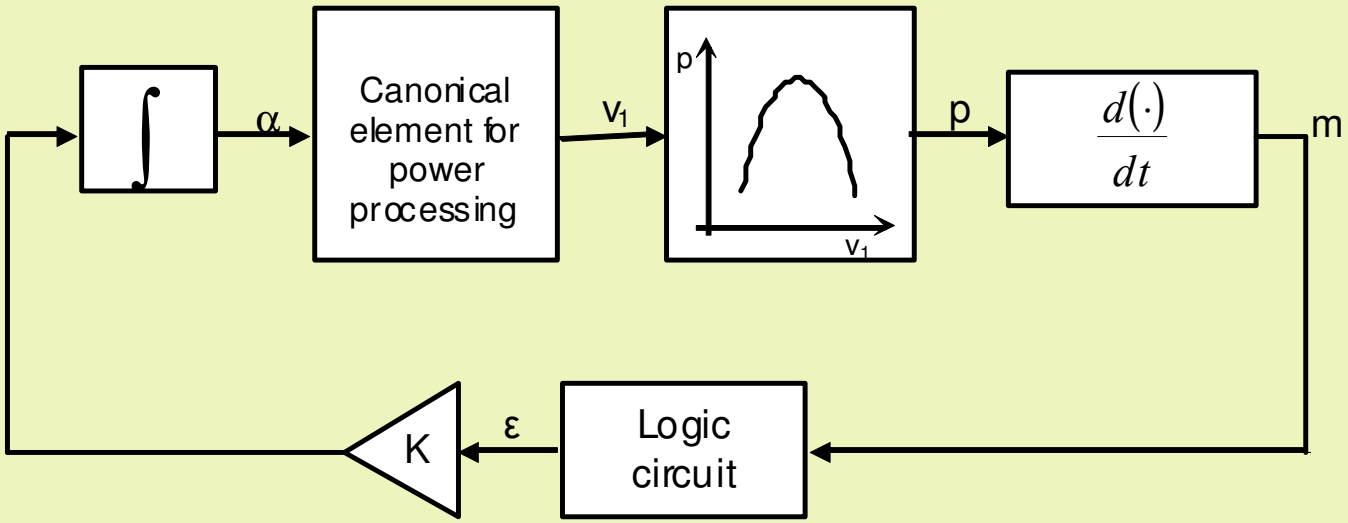


a) Periodic behaviour in steady-state of the defining parameter of a canonical power processing element.

b) panel voltage

c) panel current

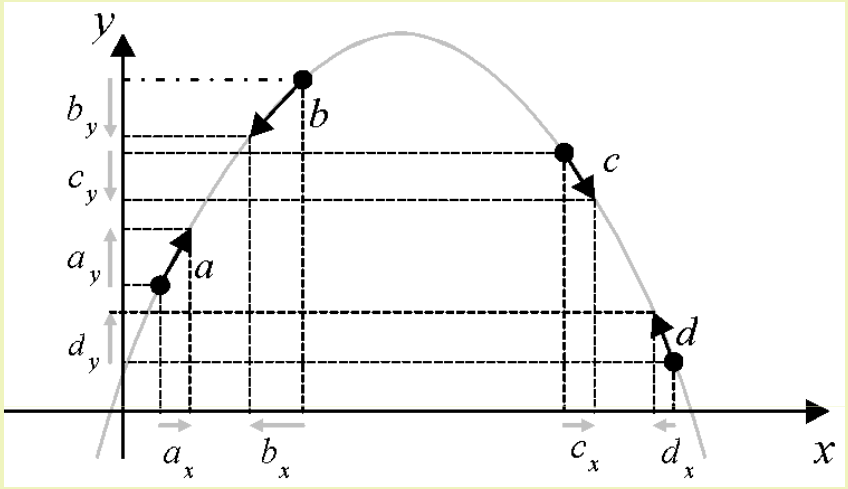
❑ IMPEDANCE MATCHING



Generation of α(t) by means of means of a maximum power point tracking scheme based on extremum –seeking control

❑ IMPEDANCE MATCHING

• MPPT USING EXTREMUM-SEEKING CONTROL



$$\frac{dy}{dx} = \frac{dy/dt}{dx/dt} \Rightarrow \left\{ \begin{array}{l} \left.\frac{dx}{dt}\right|_{t^+} = K \quad if \quad \left.\frac{dy}{dx}\right|_{t^-} > 0 \\ \\ \left.\frac{dx}{dt}\right|_{t^+} = -K \quad if \quad \left.\frac{dy}{dx}\right|_{t^-} < 0 \end{array} \right\} \Rightarrow \frac{dx}{dt} = K\, sign\left(\frac{dy}{dx}\right)$$

• Leyva, R., Queinnec I., Alonso, C., Cid-Pastor, A., Lagrange D. and Martinez-Salamero L., " Maximum power point tracking of PV systems using extremum seeking control" IEEE Trans. on Aerospace and Electronic Systems, Vol. 42, No. 1, January 2006, pp 249-258

❑ IMPEDANCE MATCHING

• MPPT USING EXTREMUM-SEEKING CONTROL

STABILITY AT THE EQUILIBRIUM POINT

$$V(t)=\frac{1}{2}\left(\frac{dy}{dx}\right)^2$$

POSITIVE DEFINITE

$$\dot{V}(t)=\frac{dy}{dx}\frac{d^2y}{dx^2}\frac{dx}{dt}=\frac{dy}{dx}\frac{d^2y}{dx^2}\left(K\ sign\left(\frac{dy}{dx}\right)\right)$$

The concavity of *y(x)* implies $\frac{d^2y}{dx^2}<0$

In addition, $\frac{dy}{dx}sign\left(\frac{dy}{dx}\right)>0$

Therefore, for *K>0* ⇒ $\dot{V}(t)<0$ **NEGATIVE DEFINITE: GLOBAL STABILITY**

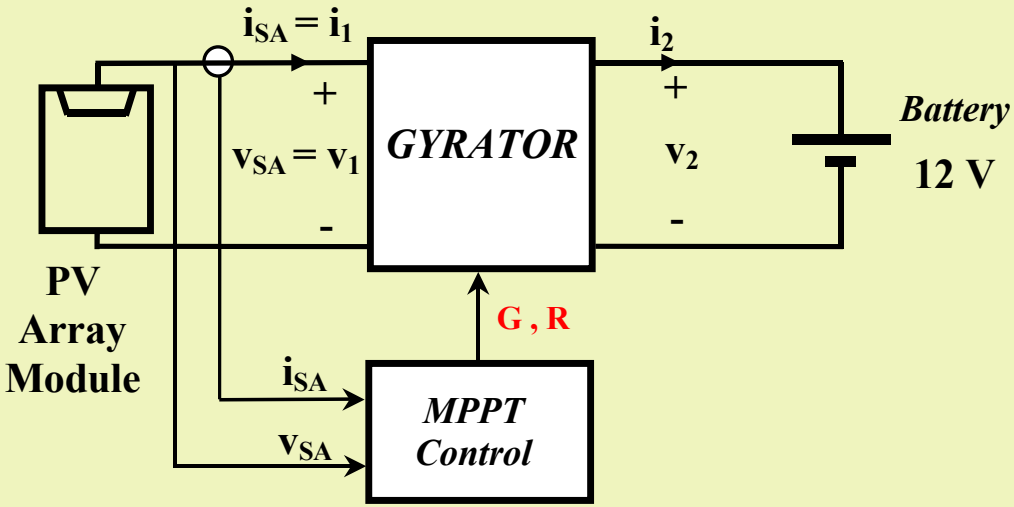
❑ IMPEDANCE MATCHING

▪ IMPEDANCE MATCHING OF A PV ARRAY BY MEANS OF A DC GYRATOR

MPPT INTRODUCES VARIATIONS IN :

- CONDUCTANCE OF A G-GYRATOR (G)

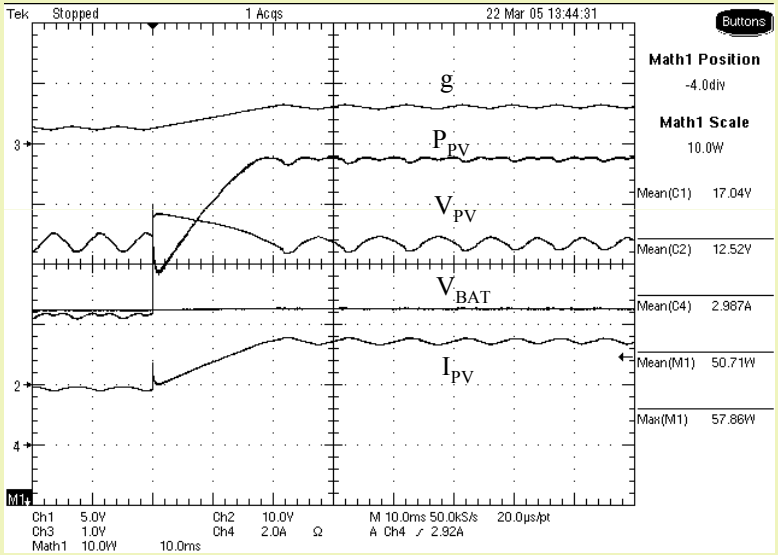
- RESISTANCE OF A R-GYRATOR (R)



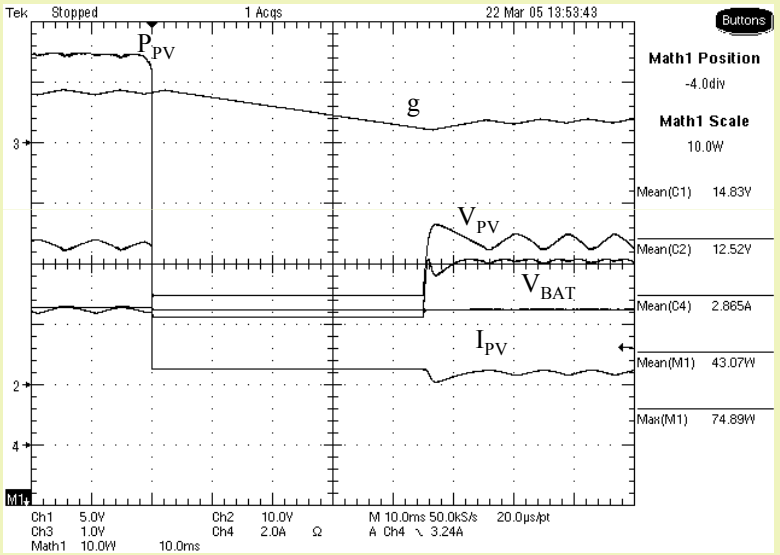
❑ IMPEDANCE MATCHING

▪ IMPEDANCE MATCHING OF A PV ARRAY BY MEANS OF A BIF CONVERTER BASED G-GYRATOR OPERATING IN SLIDING MODE

Experimental response to a parallel connection of an additional panel



connection

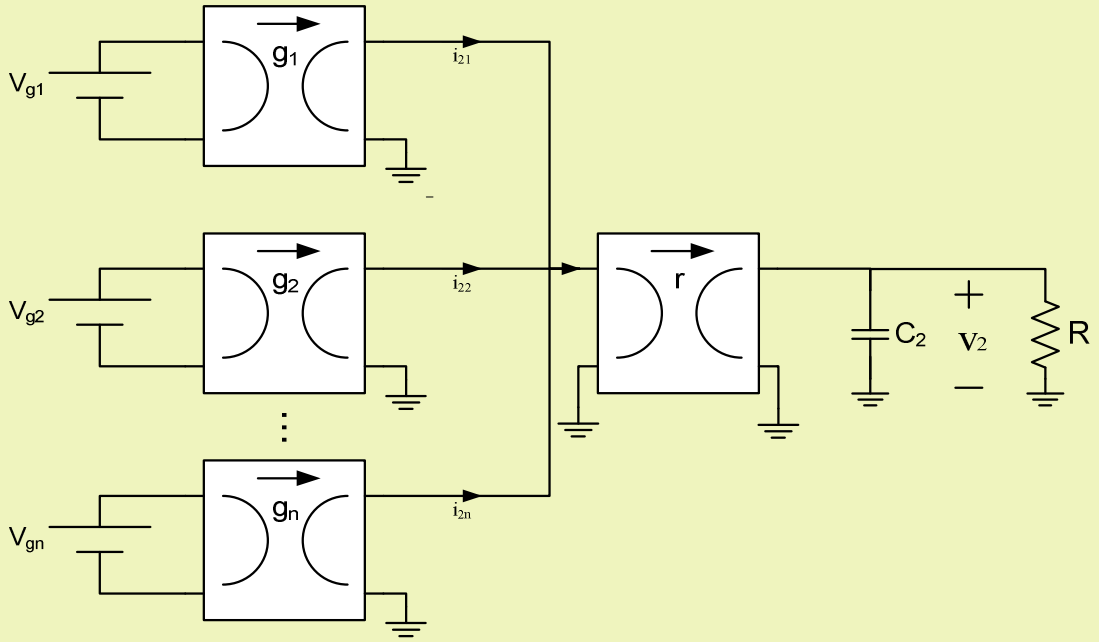


disconnection

❑ POWER DISTRIBUTION

❑ COMBINING OF V-I AND I-V CONVERSION

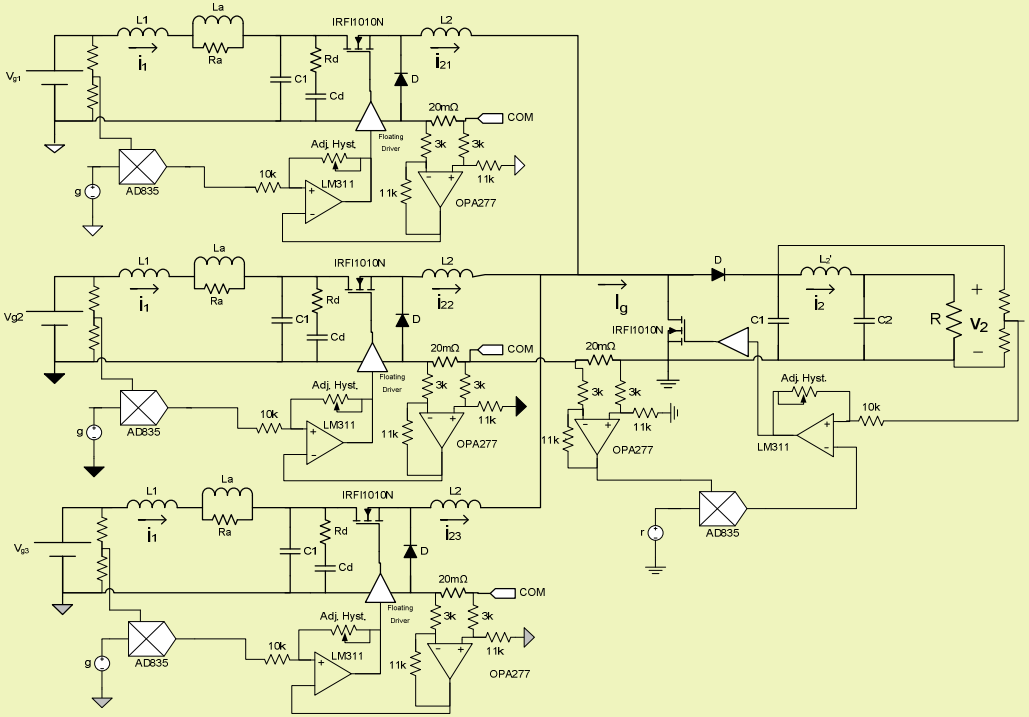
CASCADE CONNECTION OF 3 PARALLELED POWER G-GYRATORS AND A POWER R-GYRATOR



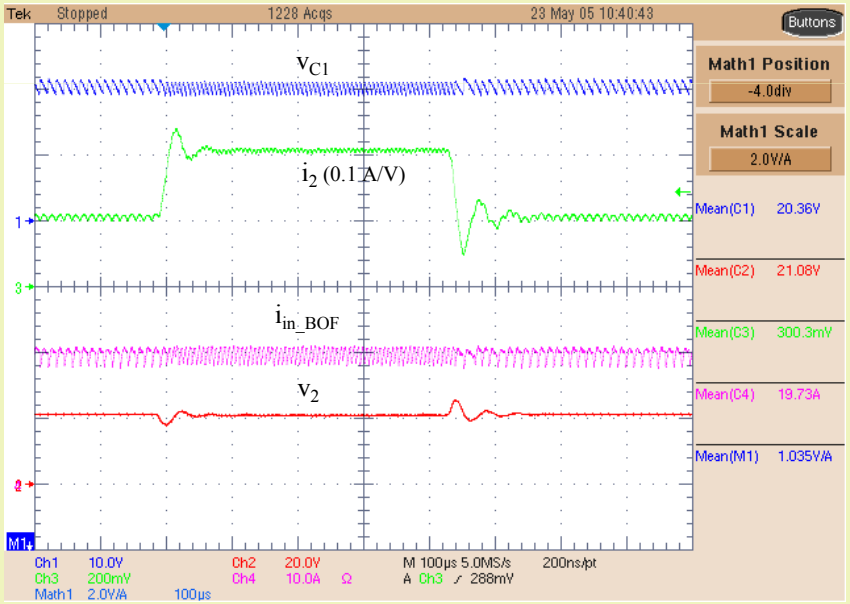
❑ POWER DISTRIBUTION

❑ COMBINING OF V-I AND I-V CONVERSION

PRACTICAL IMPLEMENTATION OF A CASCADE CONNECTION OF 3 PARALLELED POWER G-GYRATORS AND A POWER R-GYRATOR



EXPERIMENTAL RESULTS

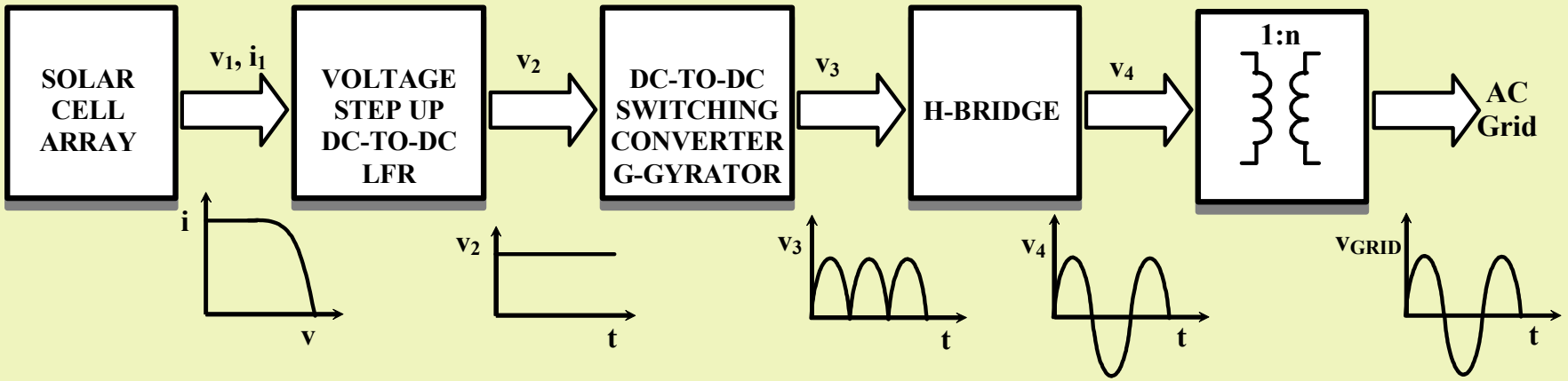


❑ POWER DISTRIBUTION

• DC-AC CONVERSION

❑ MODULAR STRUCTURE

❑ BLOCK DIAGRAM OF A MODULAR ONE-PHASE PV INVERTER

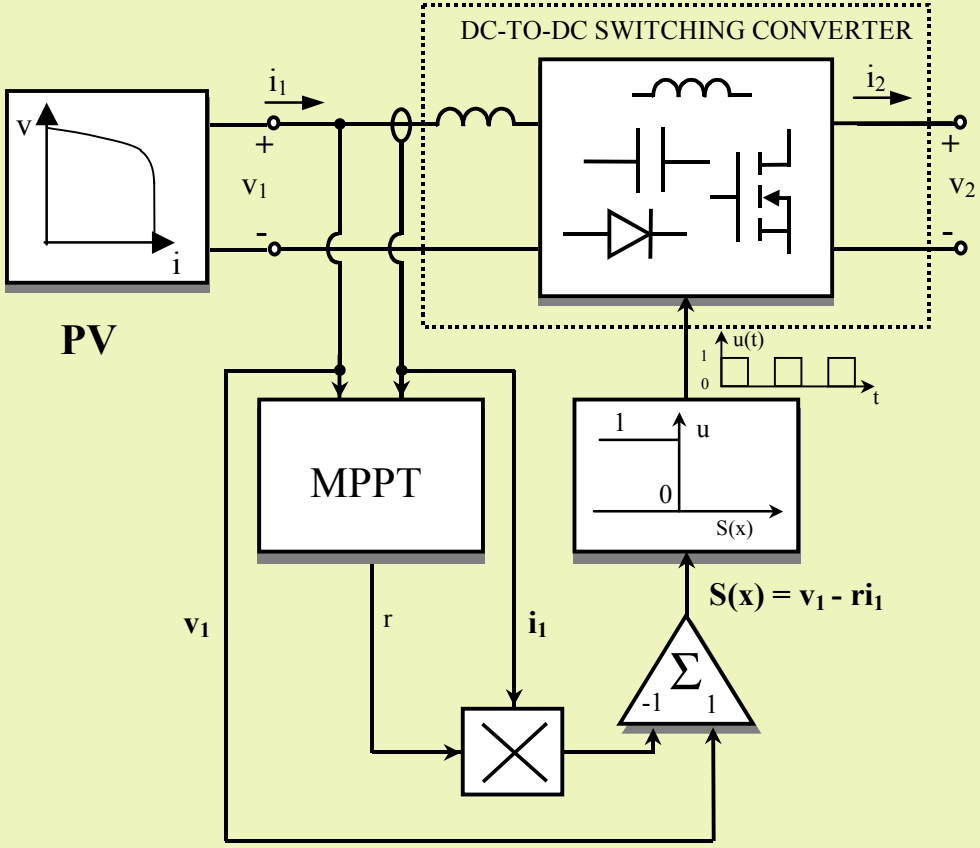


❑ POWER DISTRIBUTION

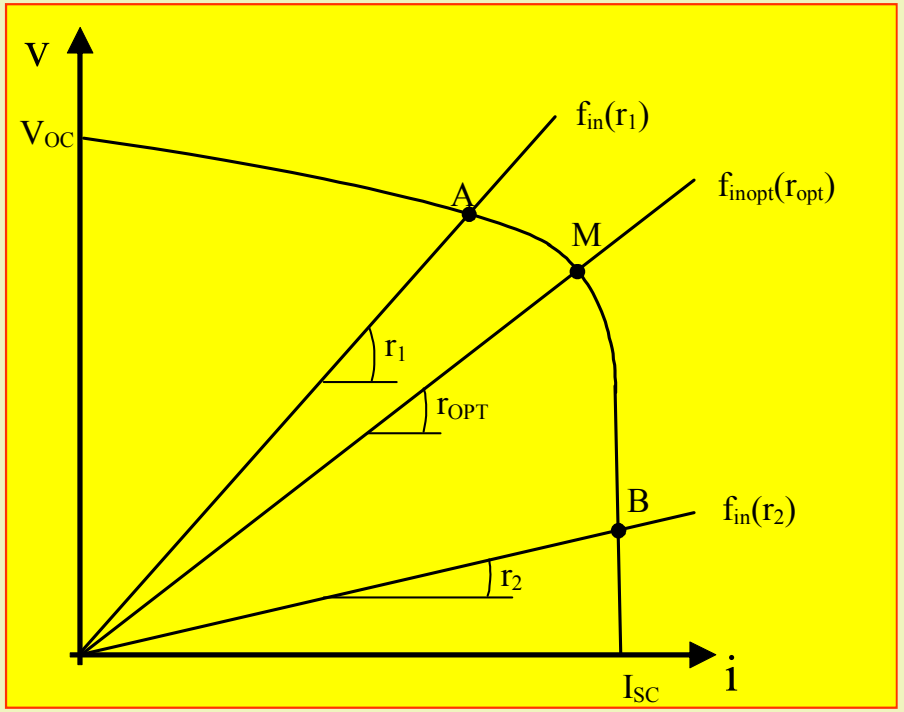
• DC-AC CONVERSION

❑ MODULAR STRUCTURE

➢ VOLTAGE STEP-UP STAGE: LFR WITH MPTT FUNCTION



Solar panel working point due to the LFR connection

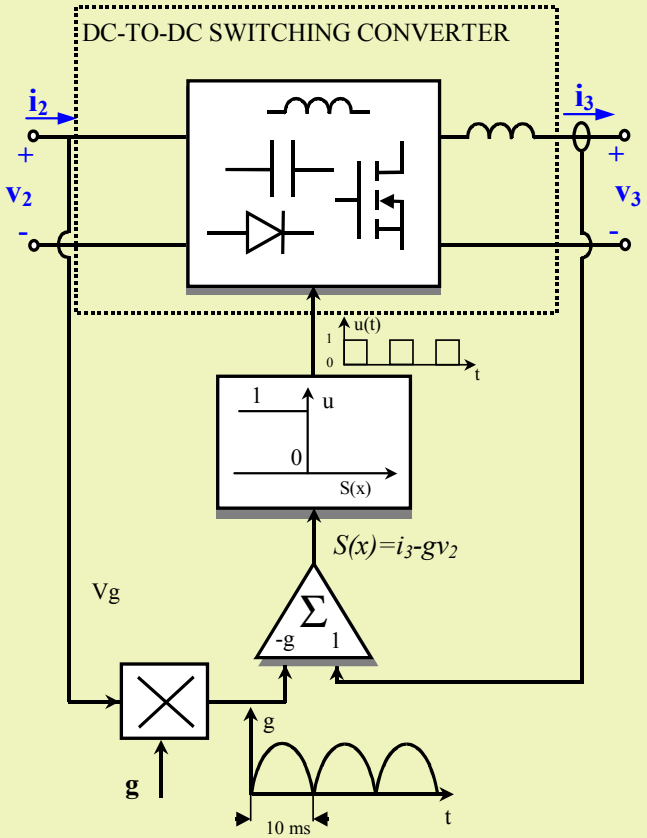


❑ POWER DISTRIBUTION

• DC-AC CONVERSION

❑ MODULAR STRUCTURE

➢ BUCK CONVERTER STAGE: GYRATOR



Switching converter in sliding-mode operation with semi-gyrator characteristics

$$S(x) = i_3 - g v_2$$

In steady-state

$$I_2 = g V_3$$

$$I_3 = g V_2$$

Power G-Gyrator with controlled output current

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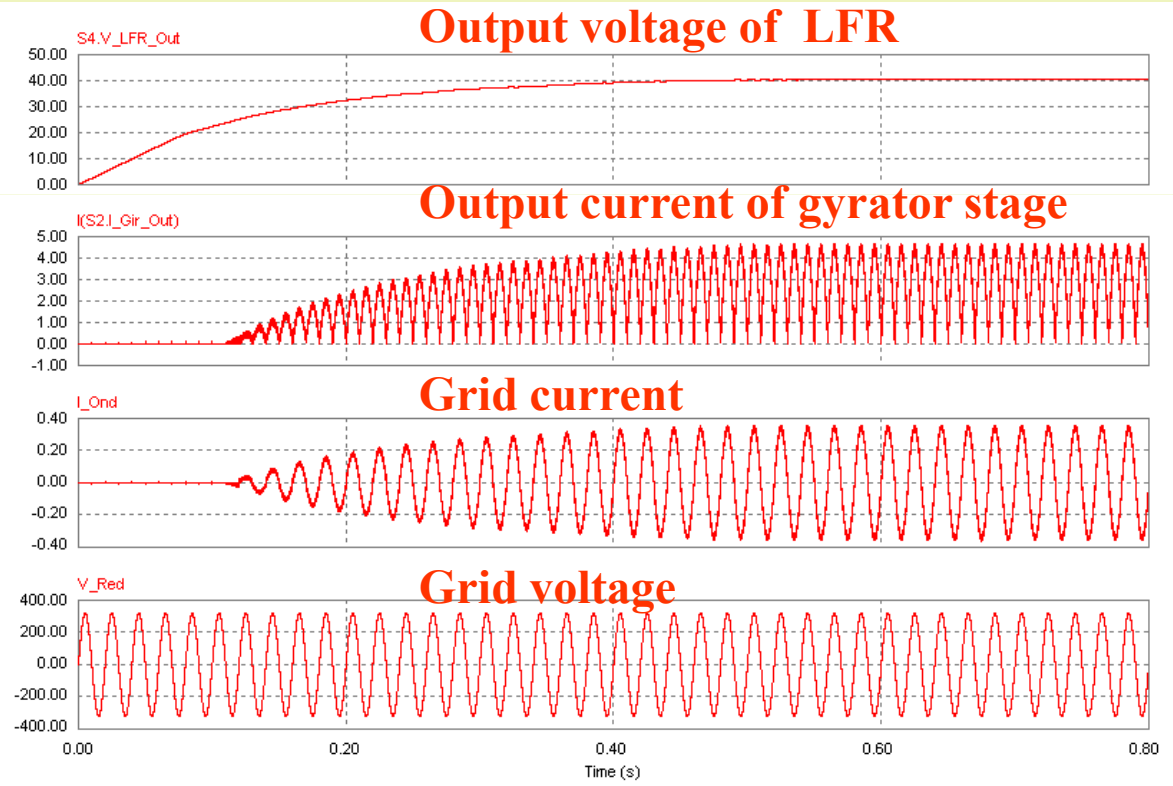
❑ POWER DISTRIBUTION

• DC-AC CONVERSION

❑ MODULAR STRUCTURE

➢ SIMULATIONS RESULTS

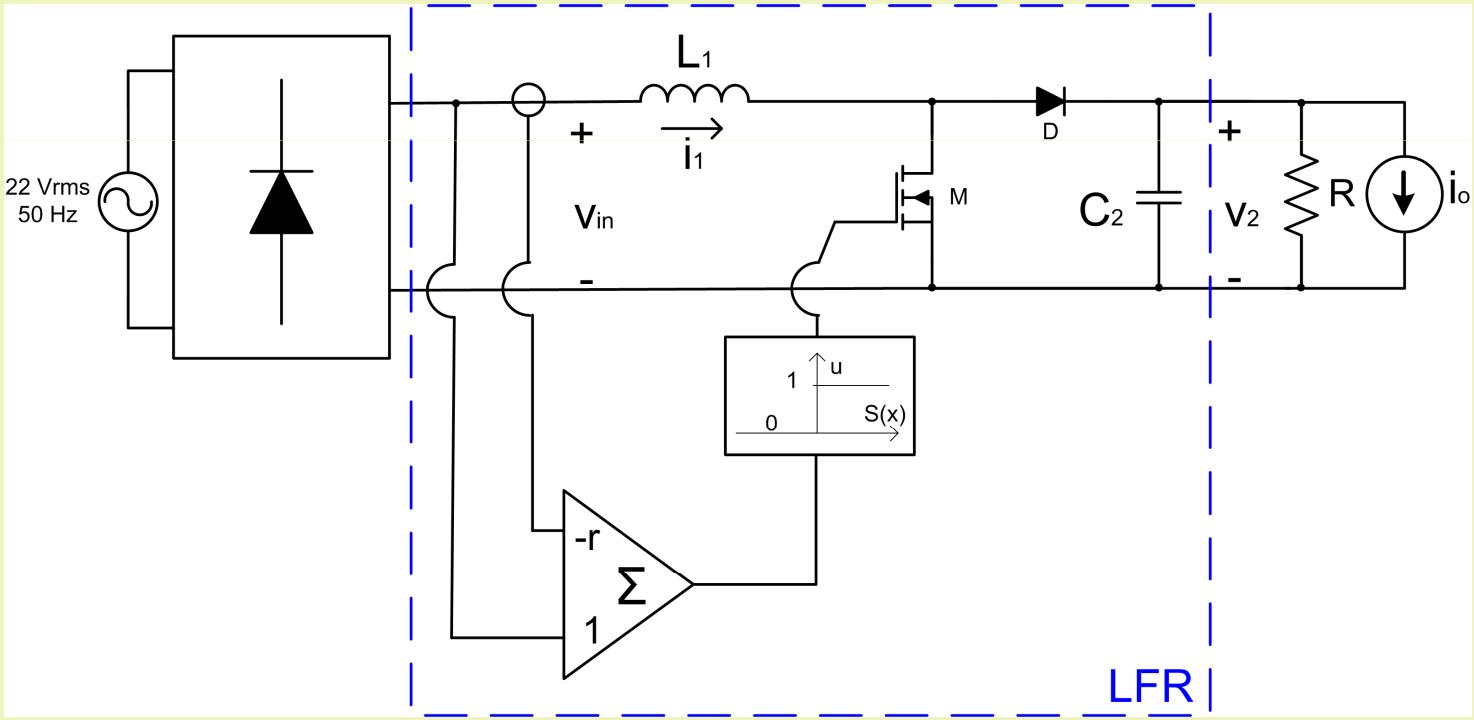
Start-up of the PV inverter



❑ POWER FACTOR CORRECTION

❑ APPLICATION IN POWER FACTOR CORRECTION PRE-REGULATORS

❑ BOOST CONVERTER-BASED LFR AS PRE-REGULATOR FOR PFC OPERATING IN SLIDING-MODE.

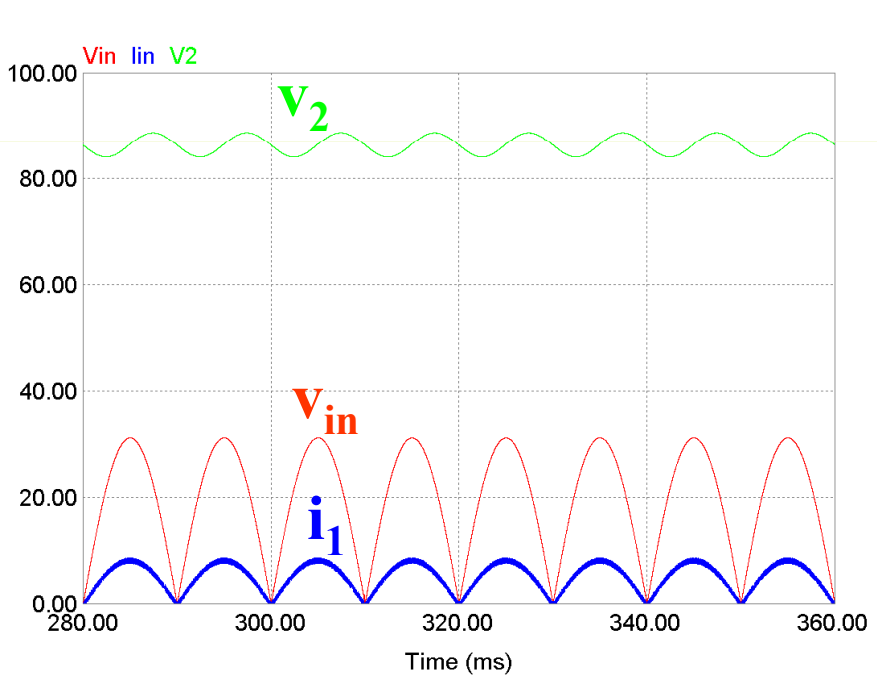


❑ POWER FACTOR CORRECTION

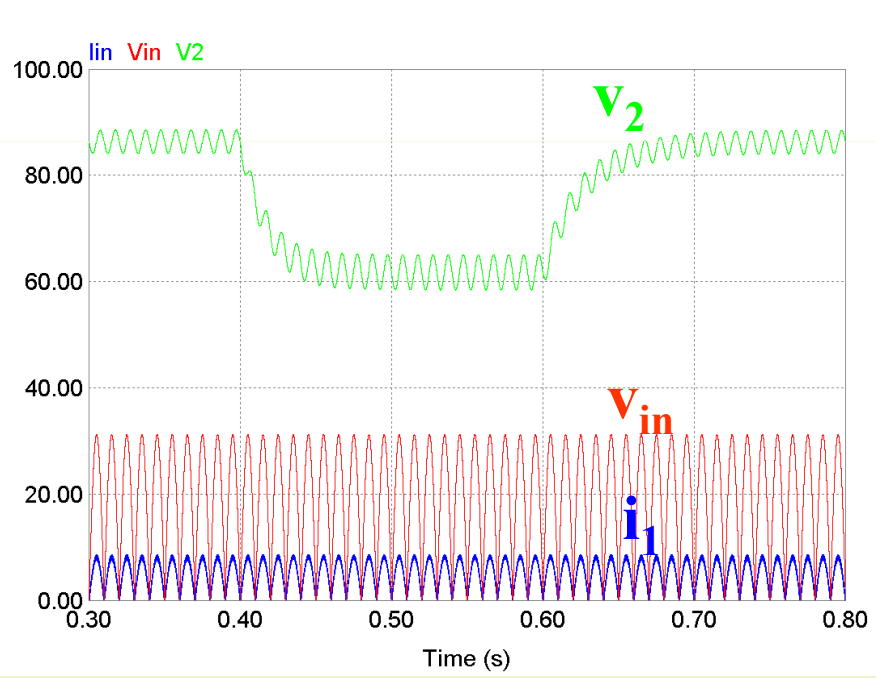
❑ APPLICATION IN POWER FACTOR CORRECTION PRE-REGULATORS

❑ PSIM SIMULATIONS OF A BOOST CONVERTER-BASED LFR FOR PFC

Steady-state response



Transient response to load perturbations of step type (60 Ω-30 Ω-60 Ω)



V_{AC}=22 Vrms 50Hz, R=60 Ω, L=100 μH, C=1000 μF and r = 3.75 Ω.

❑ CONCLUSIONS

- A SYSTEMATIC PROCEDURE TO IMPLEMENT THE THREE CANONICAL ELEMENTS
- ALL CANONICAL ELEMENTS HAVE "SLIDING INSIDE"
- THEY CAN BE DESIGNED AS STANDARIZED MODULES
- LOW-POWER TECHNIQUES FOR IMPLEMENTATION
- MODULARITY IN POWER DISTRIBUTION
- HIGH-POWER CAN BE ACHIEVED BY INCREASING THE NUMBER OF ELEMENTS
- ALL CANONICAL ELEMENTS SOLVE THE DC MATCHING PROBLEM
- PREREGULATION FOR POWER FACTOR CORRECTION BASED ON LOSS-FREE RESISTOR
- MICROELECTRONIC INTEGRATION OF THE GENERALIZED CANONICAL ELEMENT

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THANK YOU FOR YOUR ATTENTION