CRESITT INDUSTRIE

Centre de Ressources
Technologiques en Électronique

Atelier technique :

Recharges sans-fils, solutions et contraintes

C.Alayrac & D.Chariag – 10/10/2024 – V1.0

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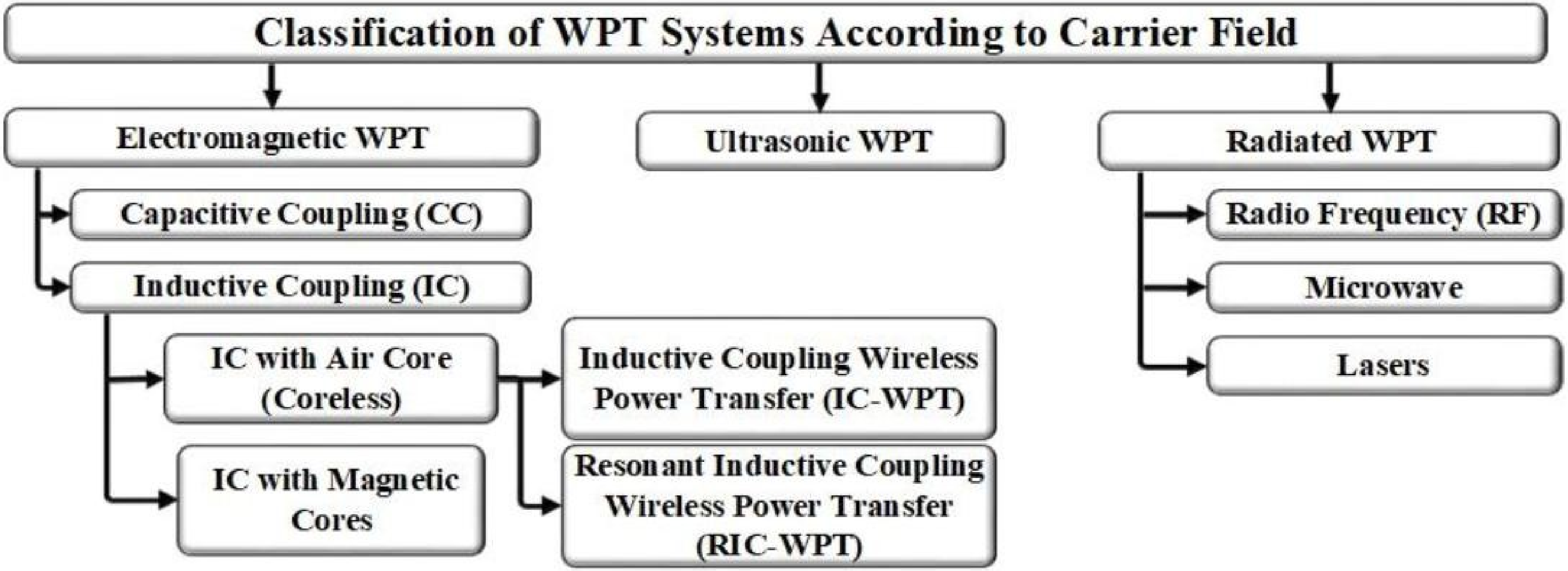
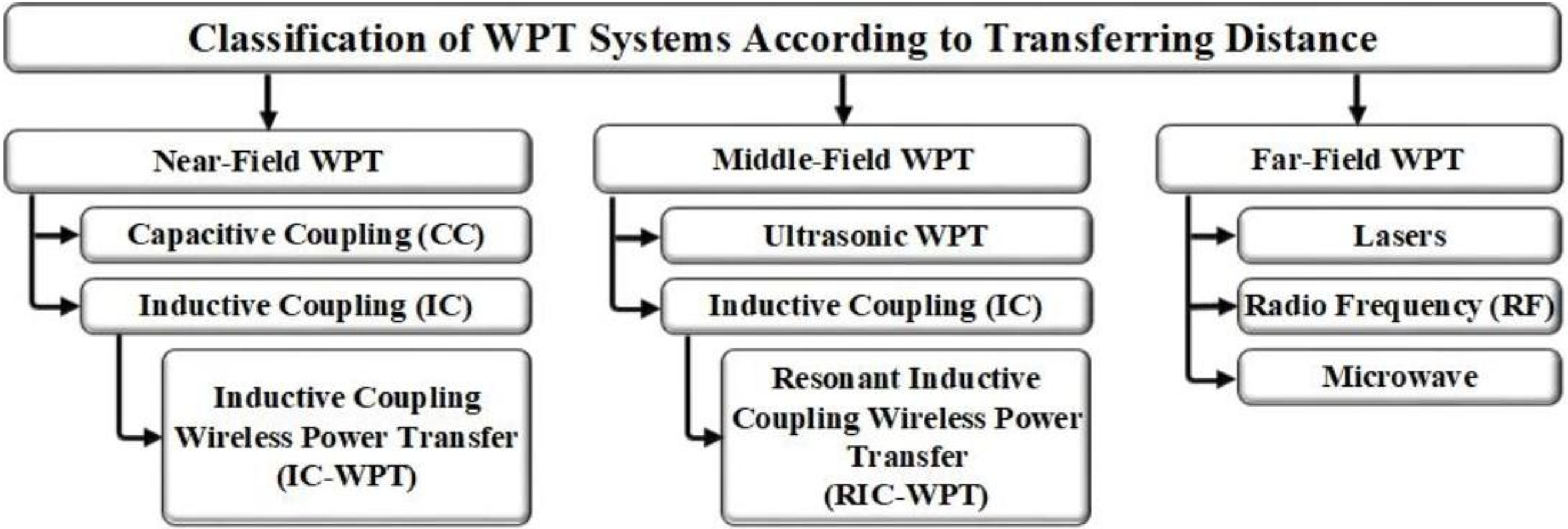
SOMMAIRE

Classification par technologies



Classification par distance

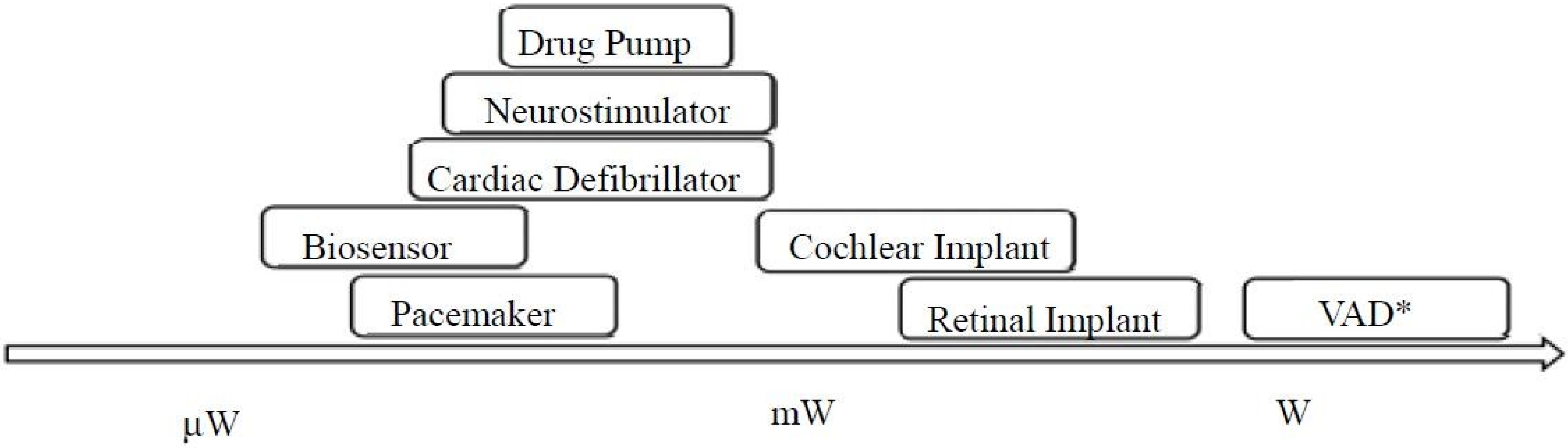


d < 1cm

d < 10cm

d > 10cm

Applications médicales



** Ventricular Assist Device*

Applications médicales

centre de ressources technologiques

Non Radiative

Powering Scheme	Year/Ref	Implant Type	Implant WPTRX Size	Distance (mm)	Frequency (MHz)	Input Power (W)	PTE (%)	Test Model	SAR (W/kg)	Remarks	Maturity for IMD
NRCC Capacitive Couling	2017/[53]	Generic	20 mm × 20 mm	7	100–150	1	56	non-human primate cadaver	8.02	TX and RX are large. Separation distance and tissue safety low.	Low
Inductive Couling NRIC	2018/[40]	Brain	Diameter: 4 mm (around-CMOS)	11	318.8	0.01	3.05	Lamb ribs	0.155	Acceptable PTE for medium separation distance. Wide range of application. Tissue safety is achieved. The circuit for TX and RX is easily implementable and cheap.	High(implemented in some commercial IMDs)
	2017/[106]	Brain	Volume: 0.9 mm^3, Gap: 0.1 mm	3	402	0.082	0.08	Piglet	1.97		
	2015/[111]	Peripheral Nerve	20	5	1	0.18	65.8	Rat stomach	0.1		
	2017/[112]	Ocular	Diameter: 20 mm	8 (Max. 40 mm distance)	2	-	60 (5% PTE for 40 mm)	Beef muscle	0.66		
	2015/[113]	Ocular	Diameter: 10 mm	20	13.56	2	17.5	Pig eye	0.021		
	2007/[99]	Capsule	10 mm × 13 mm	-	1	-	1	Air	0.32		
	2010/[122]	Capsule	10 mm × 12 mm	-	0.4	-	1.2	Air	0.329		
	2011/[121]	Capsule	11.5 mm × 11.5 mm	200	0.218	-	5.5	Air	8		
	2012/[103]	Capsule	Diameter:11 mm	-	13.56	8	3.04	Phantom	0.1		
NRMRC Magnetic Resonnance Coupling	2017/[145]	Brain	Diameter: 1.2 mm	16	60	-	3	Fresh lamb head	Less than 1.6	RX size is smaller than NRIC and the separation distance is higher. Tissue safety is within the limit. Better impedance matching than NRIC.	High (possible to implement in commercial IMDs)
	2012/[146]	Ocular	Diameter: 15 mm	10	3.37	-	62.5	Air	-		
	2011/[147]	Ocular	Diameter: 15 mm	5	6.78	-	8.8	Human head	-		
	2015/[148]	Capsule	Diameter: 9 mm	70	16.47	150	0.7	Chopped pig tissue	1.74		
	2016/[149]	Capsule	15 mm × 7 mm × 6 mm	50	433.9	1	1.21	Duck intestine	2.54		
NRRMF Non-radiative and radiative mid-field	2014/[156]	Cardiac	Diameter: 2 mm	50	1600	0.5	0.04	Epicardium of rabbit	0.89	Higher separation distance for smaller RX. PTE is low. Tissue safety is alarming.	Medium (more research required for IMD)
	2017/[160]	Peripheral Nerve	20 mm	15	2400	0.18	20	Right neck of pig	2		
	2017/[161]	Capsule	Printed on capsule	-	402–405	-	0.08	A phantom containing a porcine heart	-		

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Applications médicales

CRT centre de ressources technologiques — afaq ISO 9001 Qualité AFNOR CERTIFICATION

Powering Scheme	Year/Ref	Implant Type	Implant WPTRX Size	Distance (mm)	Frequency (MHz)	Input Power (W)	PTE (%)	Test Model	SAR (W/kg)	Remarks	Maturity for IMD
RFF Radiated Far field	2011/[183]	Generic	10 mm × 10 mm × 2 mm	-	433	0.005	15	Minced pork of 65 mm × 92 mm × 50 mm	1.6	Higher distance. Lower PTE and tissue safety is alarming.	Medium
	2010/[181]	Cardiac	-	100	3700	3.2	-	Chest cavity of porcine	2.2898		
APT Acoustic	2011/[206]	Micro-oxygen generator	5 mm^2	30 mm	2.15	-	-	Pancreatic tumor of athymic mice	-	Promising WPT technique with smaller RX and large separation distance compared to NRIC and NRMRC. Tissue safety study is necessary.	High (more research required to implement in commercial IMDs)
	2014/[203]	Bladder pressure	20 mm × 2 mm × 0.38 mm	100	0.00035	-	1.4×10^{-4}	Pig bladder	-		
	2015/[207]	Photo dynamic therapy	2 mm × 2 mm × 2 mm	10	0.672	-	-	Porcine tissue	-		
	2018/[205]	Peripheral nerves	-	105	1.314	-	-	Frog static nerve	-		
OPT Optical	2015/[19]	Generic	0.5 mm × 0.5 mm	3	-	-	0.4	Chicken skin	-	Early stage in research.	Low

Les deux solutions Recharge Inductive et Ultrasons sont les plus matures pour le moment
Le contexte en fréquence est encore libre (bande ISM et autres)

La réglementation

Focus sur la recharge inductive

EN 303-417

Wireless power transmission systems, using technologies other than radio frequency beam in the 19 - 21 kHz, 59 - 61 kHz, 79 - 90 kHz, 100 - 300 kHz, 6 765 - 6 795 kHz ranges

Table 2: Overview of operational modes within a WPT system

Operational Mode	Set-up	Function of base station	Function of mobile device	Test scenario	Conformance Requirements
Mode 1: base station in stand-by, idle mode	Single device	Transmitter	Not applicable	Single radiation test (TX) with the base station/charging pad. The test set-up as described in clause 6.1.2 shall be used.	• Operating frequency range (clause 4.3.3) • H-Field emission (clause 4.3.4) • TX spurious (clauses 4.3.5, 4.3.6 and 4.3.7) • Performance criteria test (RX test) (clause 4.4)
Mode 2: Communication before charging, adjustment charging mode / position	In combination	TX and RX	TX and RX	Specific test setup, declared by the manufacturer. Manufacturer shall declare the maximal distance between base station and mobile device the WPT system is able to communicate (distance D). The test setup- up shall be performed with the largest communication distance. The test set-up as described in clause 6.1.3 shall be used.	• Operating frequency range (clause 4.3.3) • H-Field emission (clause 4.3.4) • TX spurious (clauses 4.3.5, 4.3.6 and 4.3.7) • Wanted performance criteria test (RX test) (clause 4.4)
Mode 3: Communication	WPT system alignment	TX and RX	TX and RX	Worst case alignment Both tests can be performed within one set-up, worst-case alignment. The test set-up as described in clause 6.1.4 shall be used.	• Operating frequency range (clause 4.3.3) • H-Field emission (clause 4.3.4) • TX spurious (clauses 4.3.5, 4.3.6 and 4.3.7) • Wanted Performance criteria test (RX test) (clause 4.4)
Mode 4: energy transmission	WPT system alignment	TX and RX	TX and RX		

Focus sur la recharge inductive

EN 55011

Appareils industriels, scientifiques et médicaux
Caractéristiques de perturbations radioélectriques
Limites et méthodes de mesure

EN 300-330

Short Range Devices (SRD) Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz

Limitations en puissance

EN 300-330

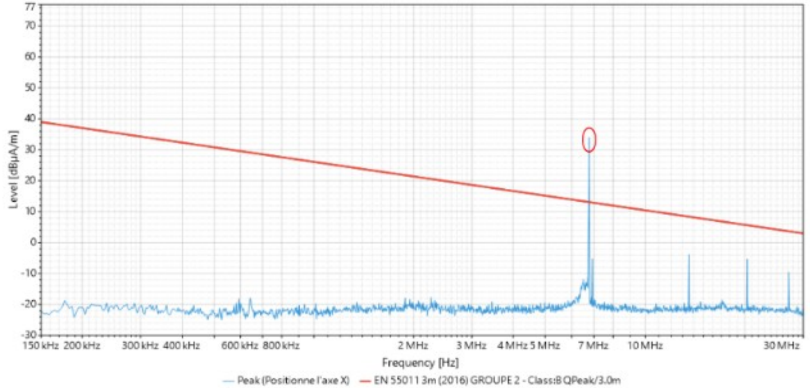
Table 2: H-field limits at 10 m

Frequency range (MHz)	H-field strength limit (H_f) dBµA/m at 10 m or specified in mW e.r.p.
0,009 ≤ f < 0,090	72 descending 3 dB/oct above 0,03 MHz or according to note 1 (see note 5)
0,09 ≤ f < 0,119	42
0,119 ≤ f < 0,135	66 descending 3 dB/oct above 0,119 MHz or according to note 1 (see notes 3 and 5)
0,135 ≤ f < 0,140	42
0,140 ≤ f < 0,1485	37,7
0,1485 ≤ f < 30	-5 (see note 4)
0,315 ≤ f < 0,600	-5
3,155≤ f < 3,400	13,5
4,234	9 (see note 9)
4,516	7
7,400 ≤ f < 8,800	9
10,2 ≤ f < 11,00	9
12,5 ≤ f ≤ 20	-7
6,765 ≤ f ≤ 6,795	42 (see notes 3 and 7)
26,957 ≤ f ≤ 27,283	42 (see note 3)
13,410 ≤ f ≤13,553, 13,567 ≤ f ≤ 13,710	9 (see note 6)
13,110 ≤ f ≤ 13,410, 13,710 ≤ f ≤ 14,010	-3,5 (see note 6)
12,660 ≤ f ≤ 13,110, 14,010 ≤ f ≤ 14,460	-10 (see note 6)
11,810 ≤ f ≤ 12,660, 14,460 ≤ f ≤ 15,310	-16 (see note 6)
13,460 ≤ f ≤ 13,553, 13,567 ≤ f ≤ 13,660	27 (see note 6)
13,360 ≤ f ≤ 13,460, 13,660 ≤ f ≤ 13,760	Linear transition from 27 to -3,5 (see note 6)
13,110 ≤ f ≤ 13,360, 13,760 ≤ f ≤ 14,010	-3,5 (see note 6)
12,660 ≤ f ≤ 13,110, 14,010 ≤ f ≤ 14,460	-5 (see note 6)
13,553 ≤ f ≤ 13,567	42 (see note 3) or 60 (see notes 2 and 3)
27,095	42

EN 55011

Tableau 12 – Limites du rayonnement électromagnétique perturbateur pour les appareils de classe B, groupe 2, mesurées sur un site d'essai

Plage de fréquences MHz	Limites pour une distance de mesure D en m				
	Champ électrique				Champ magnétique
	D = 10 m		D = 3 m [b]		D = 3 m
	Quasi-crête	Valeur moyenne [a]	Quasi-crête	Valeur moyenne [a]	Quasi-crête
	dB(µV/m)		dB(µV/m)		dB(µA/m)
0,15 – 30	–	–	–	–	39 Décroissant linéairement avec le logarithme de la fréquence jusqu'à 3



La standardisation

AirFuel™ Alliance

- Fréquence : 6.78 MHz ± 15 kHz
- Puissance : 0,5W à 70W
- Com : BLE
- Placement : Sans alignement
- Multi équipement : Oui avec P var
- Mode : Résonance

Créé en 2017 de la fusion de l'Alliance for Wireless Power (A4WP) et Power Matters Alliance (PMA)

https://airfuel.org/

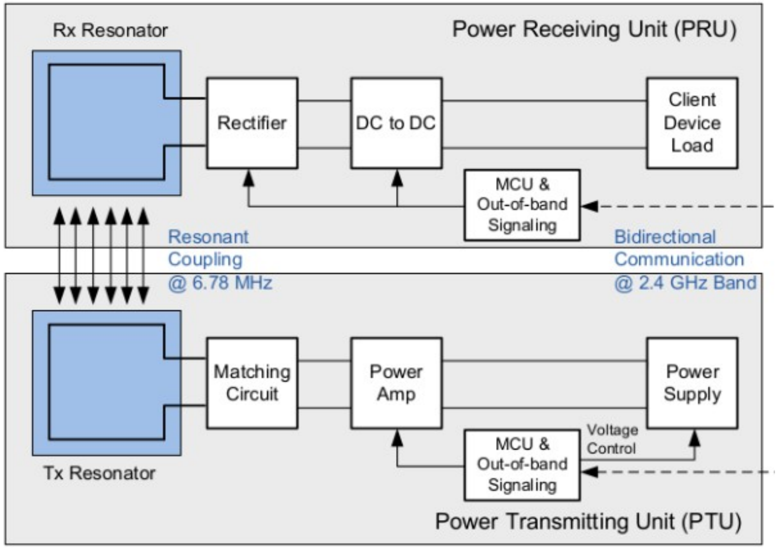
WIRELESS POWER CONSORTIUM

- Fréquence : 87 à 205 kHz.
- Puissance : 5, 15, 60W & 2,4kW
- Com : In Band
- Placement : alignement
- Multi équipement : Un seul device
- Mode : Couplage inductif

Créé en 2010, 9000 produits certifiés
Autres standard Ki (plaque cuisson), LEV (automobile)

https://www.wirelesspowerconsortium.com

A4WP



PTU	$P_{TX\_IN\_MAX}$'	Minimum Category Support Requirements	Minimum Value for Max Number of Devices Supported
Class 1	2 W	1 x Category 1	1 x Category 1
Class 2	10 W	1 x Category 3	2x Category 2
Class 3	16 W	1 x Category 4	2x Category 3
Class 4	33 W	1 x Category 5	3x Category 3
Class 5	50 W	1 x Category 6	4x Category 3
Class 6	70 W	1 x Category 7	5x Category 3

PRU	$P_{RX\_OUT\_MAX}$'	Example Applications
Category 1	TBD	BT Headset
Category 2	3.5 W	Feature Phone
Category 3	6.5 W	Smart Phone
Category 4	13 W	Tablet, Phablet
Category 5	25 W	Small Form Factor Laptop
Category 6	37.5 W	Regular Laptop
Category 7	50 W	

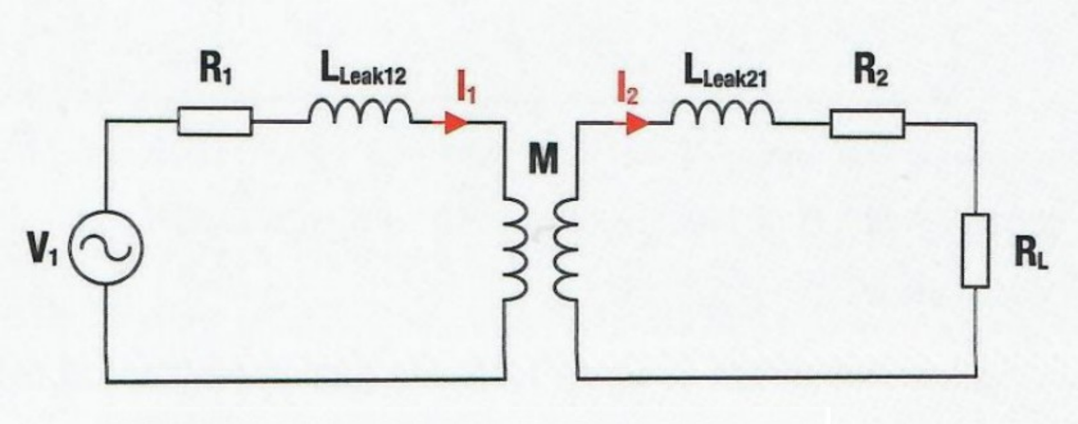
Table 4.3.1-1 Minimum RCE (percent and dB) between PRU and PTU (*Resonator Coupling Efficiency*)

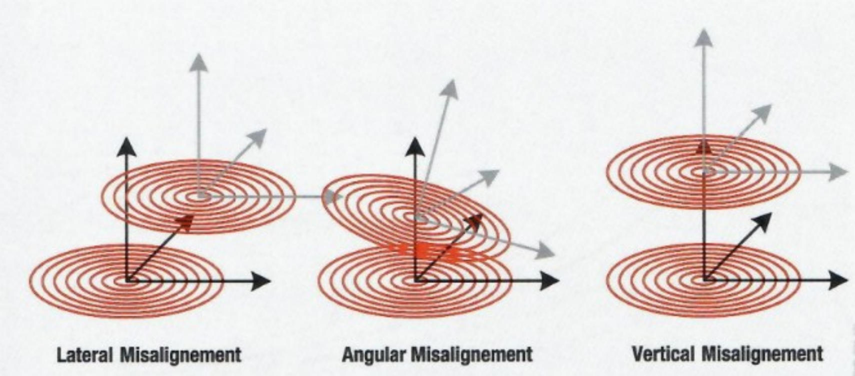
	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7
Class 1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Class 2	N/A	74% (-1.3)	74% (-1.3)	N/A	N/A	N/A	N/A
Class 3	N/A	74% (-1.3)	74% (-1.3)	76% (-1.2)	N/A	N/A	N/A
Class 4	N/A	50% (-3)	65% (-1.9)	73% (-1.4)	76% (-1.2)	N/A	N/A
Class 5	N/A	40% (-4)	60% (-2.2)	63% (-2)	73% (-1.4)	76% (-1.2)	N/A
Class 6	N/A	30% (-5.2)	50% (-3)	54% (-2.7)	63% (-2)	73% (-1.4)	76% (-1.2)

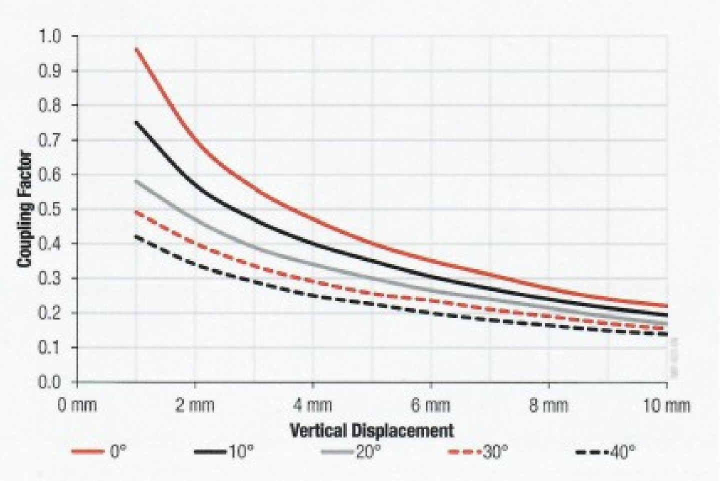
NOTE: When multiple PRUs are used, the coupling efficiency will increase.

AirFuel™

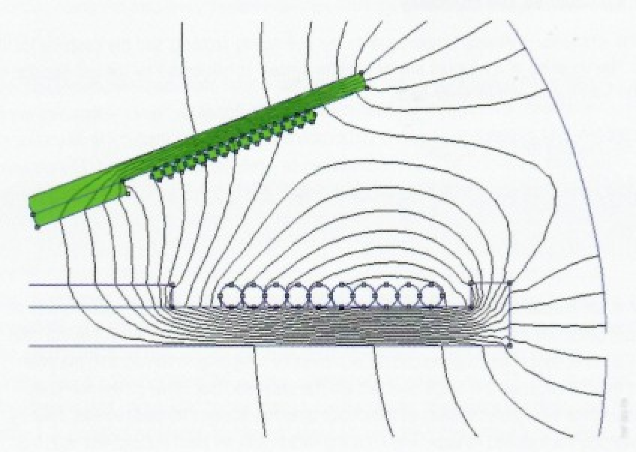
Les principes



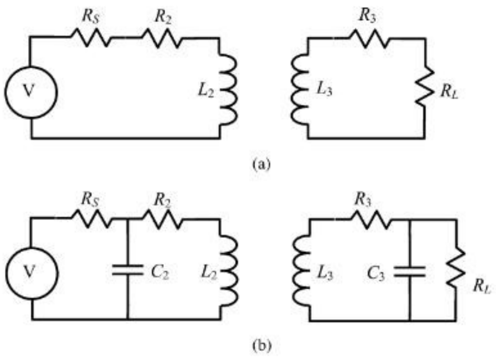


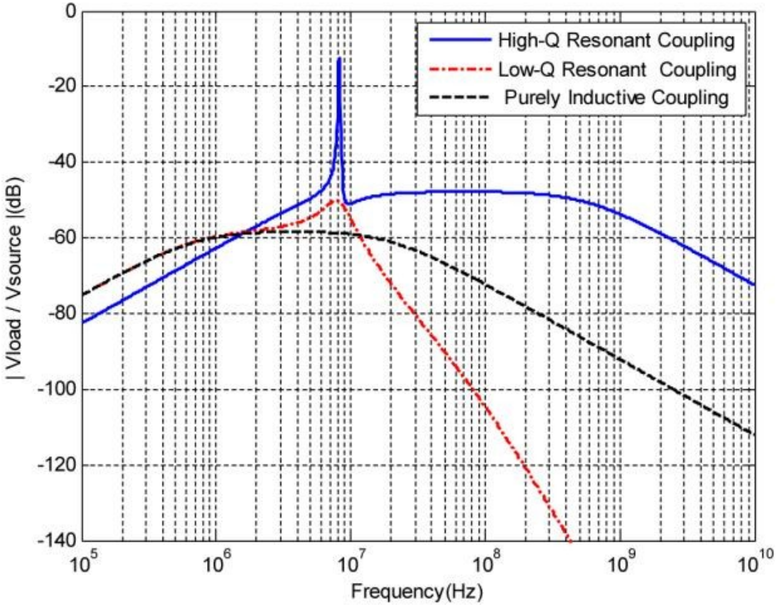


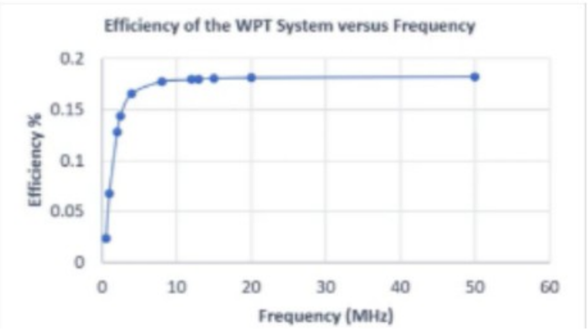
$$k=\frac{M}{\sqrt{L_1 * L_2}}$$

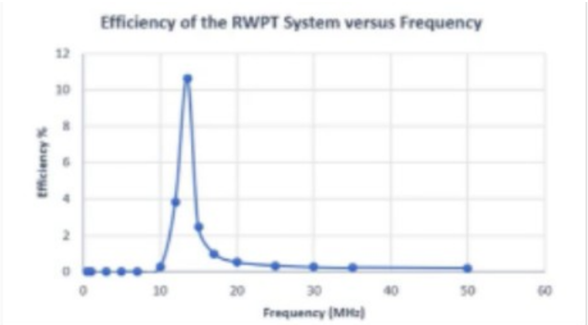


Pourquoi la résonnance



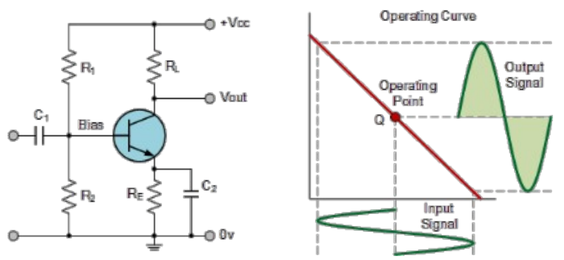


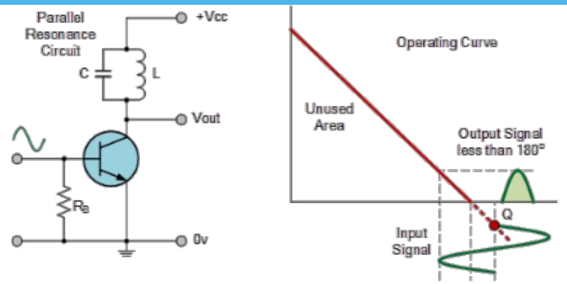


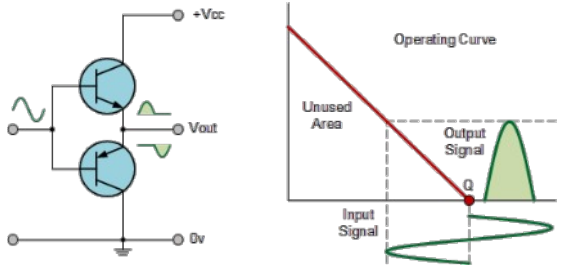


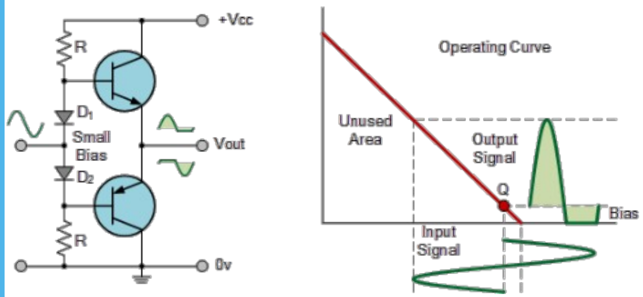
Résonnance série : Max courant
Résonnance parallèle : Max tension

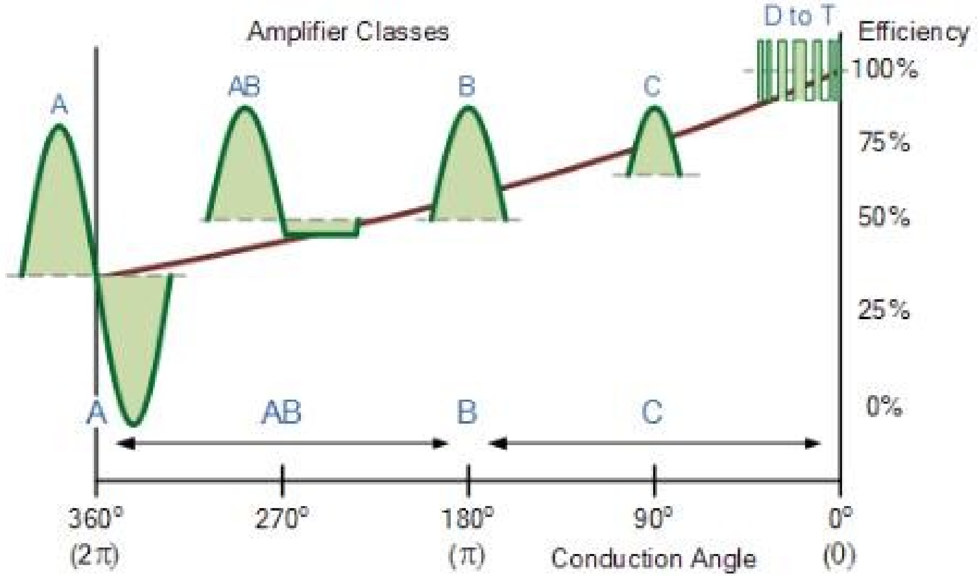
Les classes d'amplificateurs



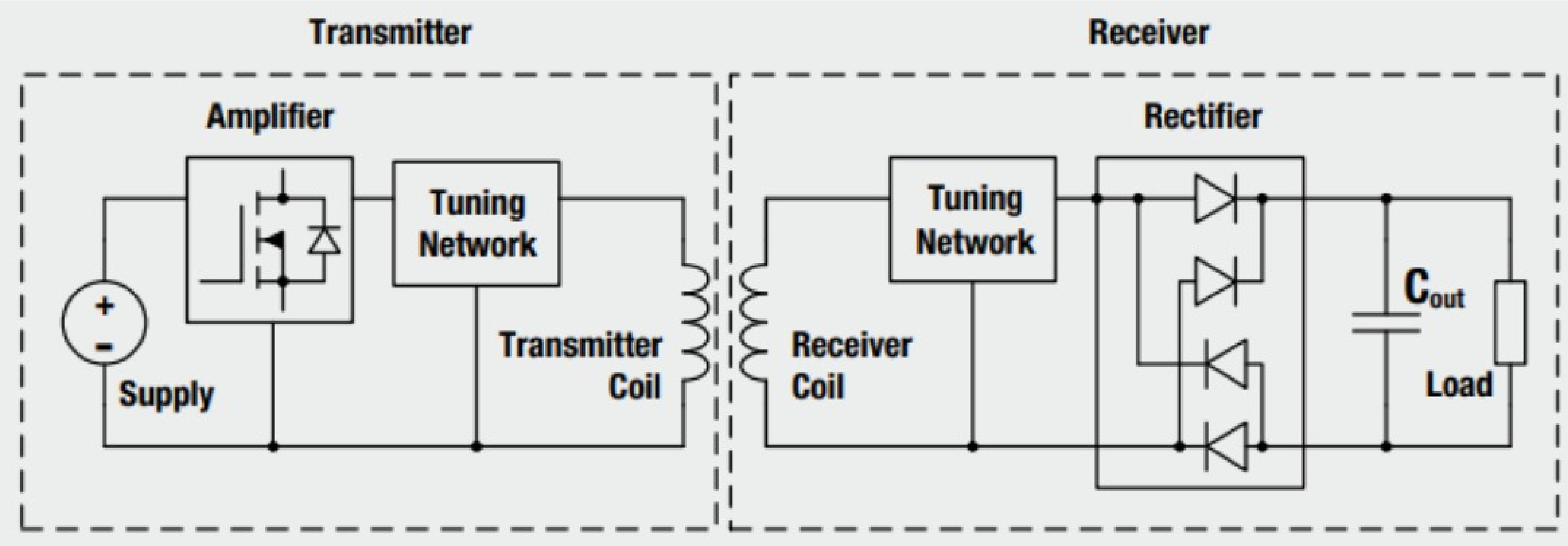






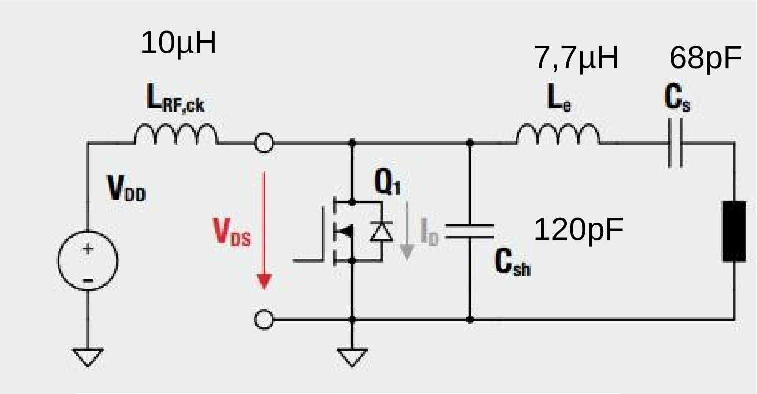


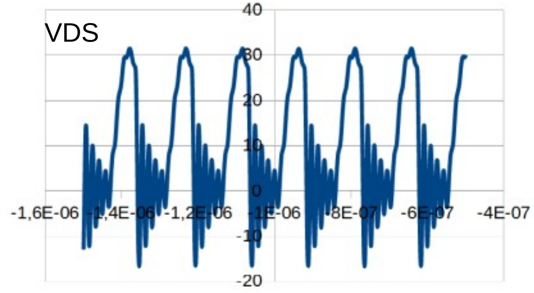
Montage générique

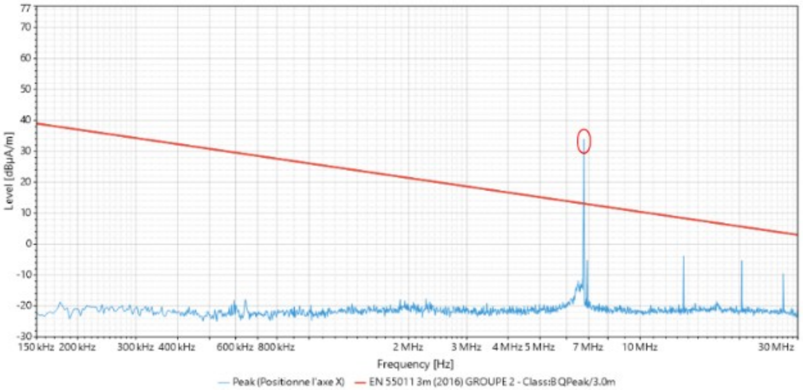


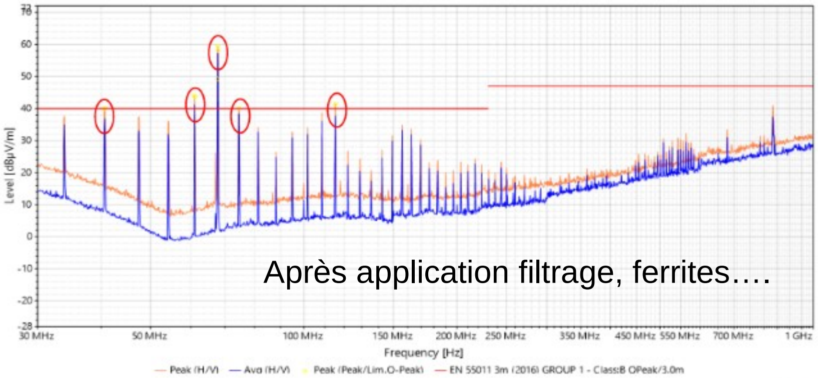
Retour d'expérience

Implant médical
Batterie 3,7V/200mAh
Charge 30mn max
Distance 5mm

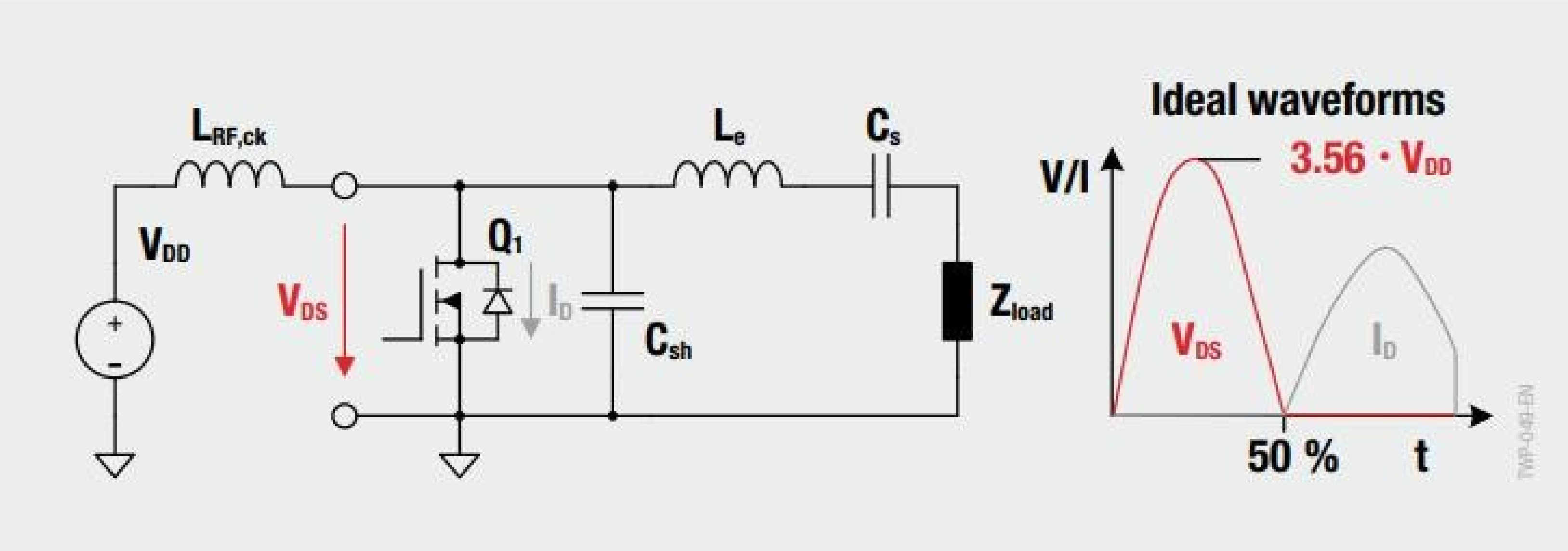








Classe E ZVS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V_DD
+
-
V_DS
Q_1
I_D
L_e
C_s
C_sh
Z_load
Ideal waveforms
V/I
3.56 · V_DD
V_DS
I_D
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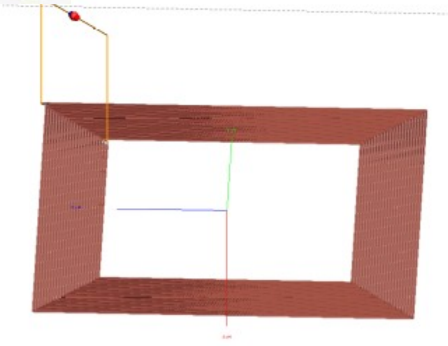
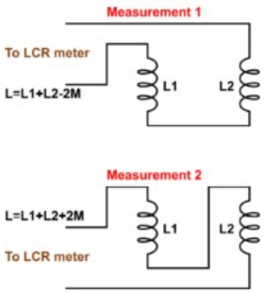
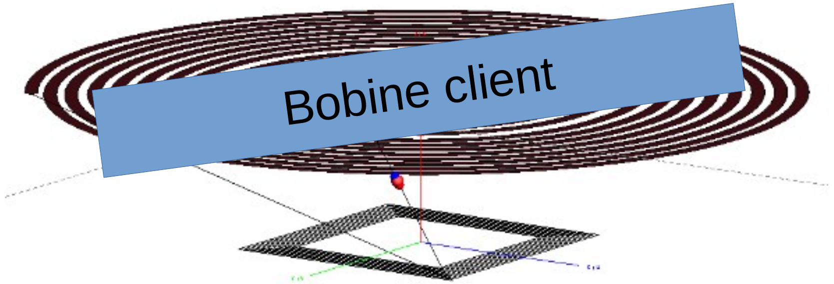
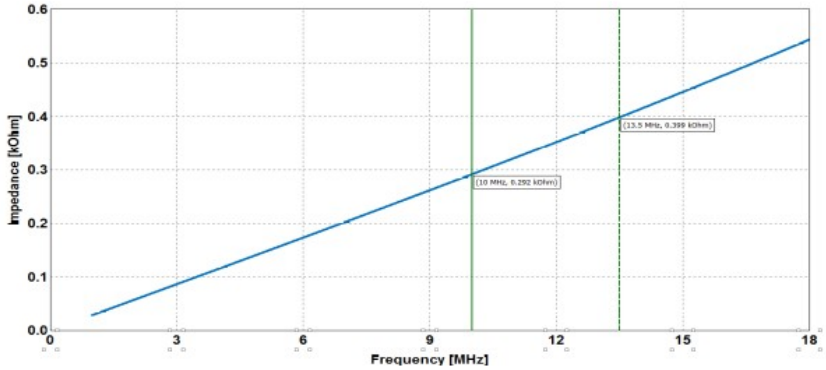
Simulation bobines

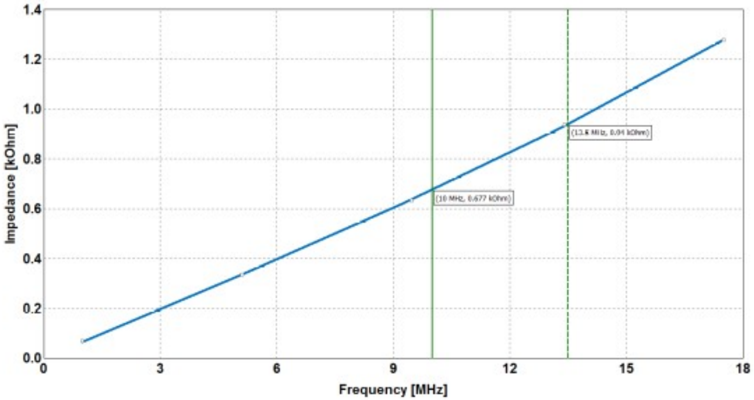
FEKO
Comprehensive Electromagnetic Solutions











Retour d'expérience

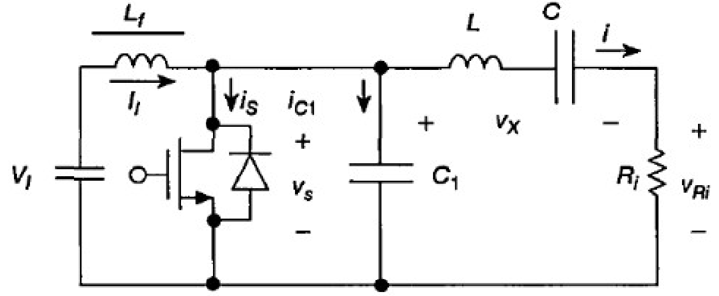


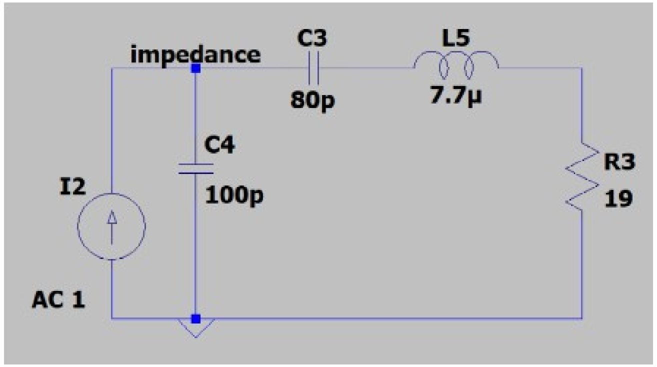
Figure 5. Convertisseur résonnant classe E commutation à tension nulle.

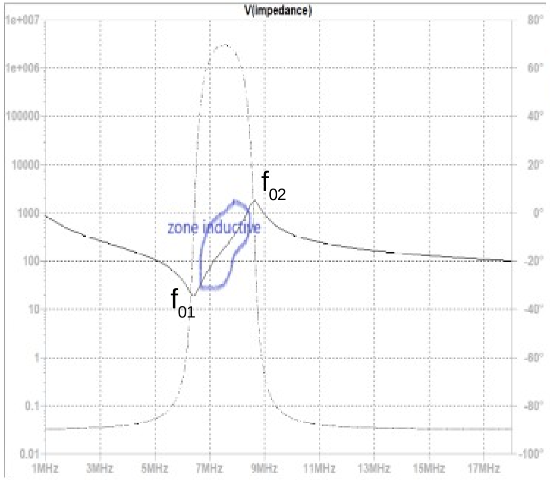
$$f_{01}=\frac{1}{2\pi\sqrt{LC}}$$

$$f_{01}=\frac{1}{2\pi\sqrt{LC}}\leq 0{,}9\times 6{,}78\,MHz$$

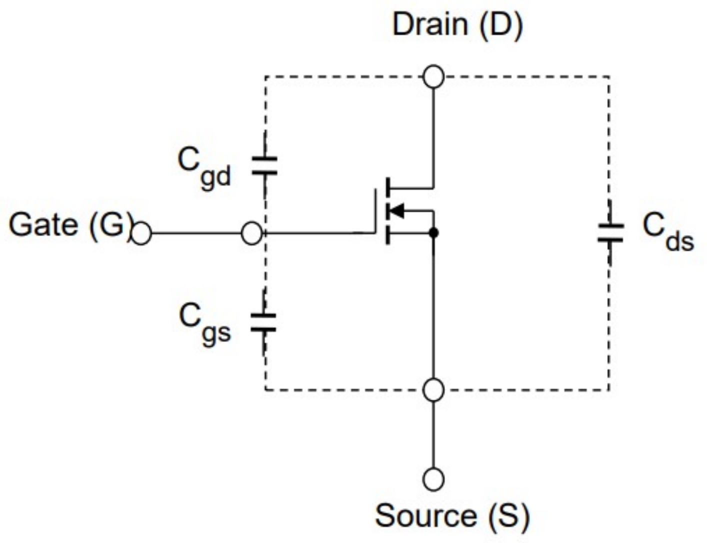
$$f_{02}=\frac{1}{2\pi\sqrt{L(CC1/(C1+C))}}$$

$$f_{02}=\frac{1}{2\pi\sqrt{L(CC1/(C1+C))}}\geq 1{,}2\times f$$





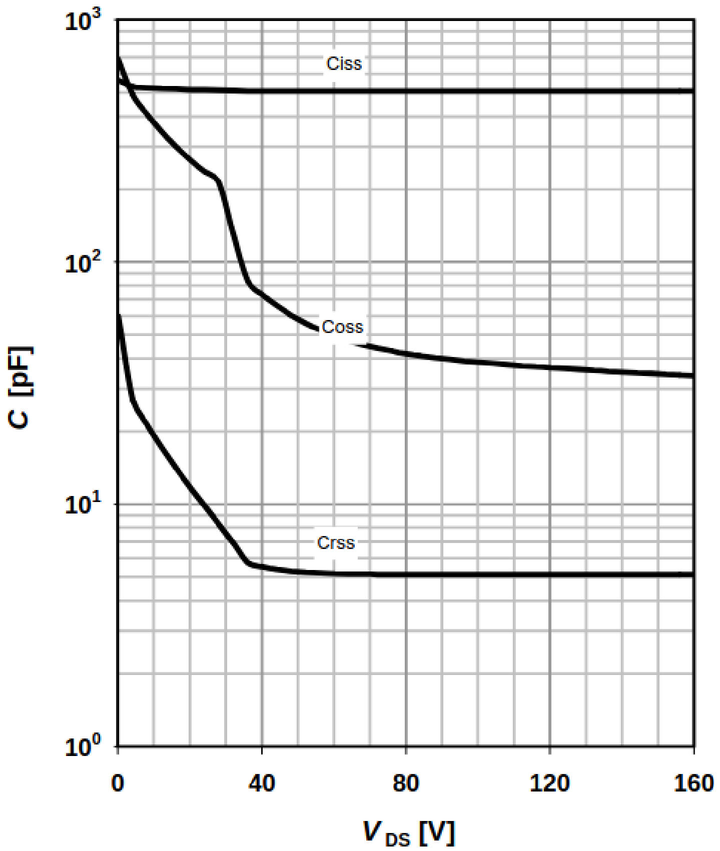
Capacité parasite



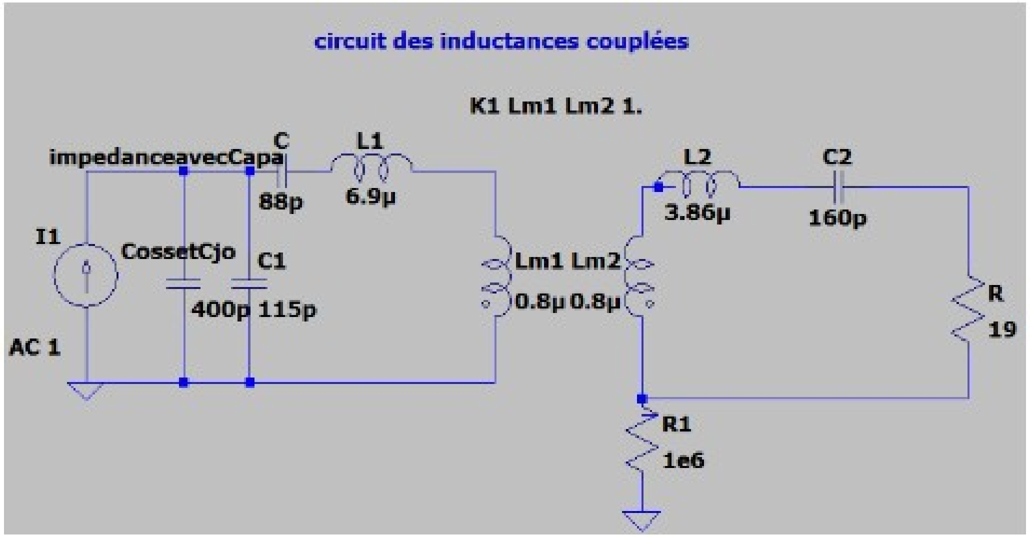
Input capacitance $(C_{iss}) = C_{gd} + C_{gs}$

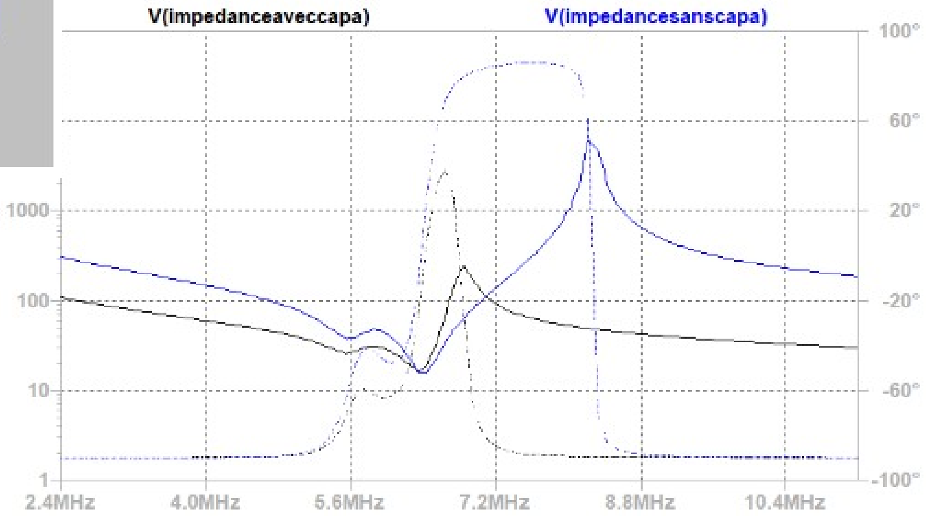
Output capacitance $(C_{oss}) = C_{ds} + C_{gd}$

Reverse transfer capacitance $(C_{rss}) = C_{gd}$



Capacité parasite

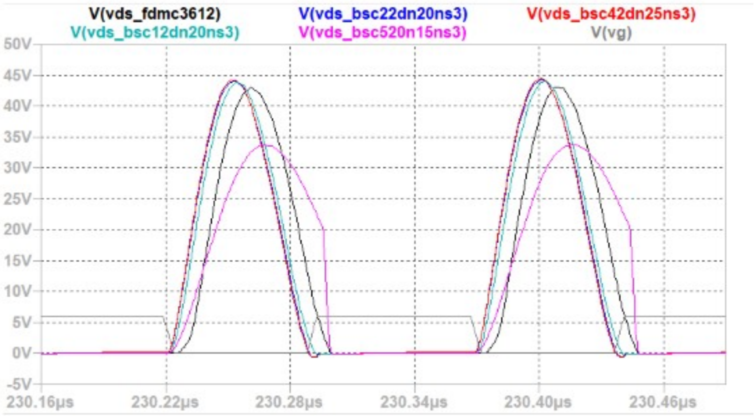




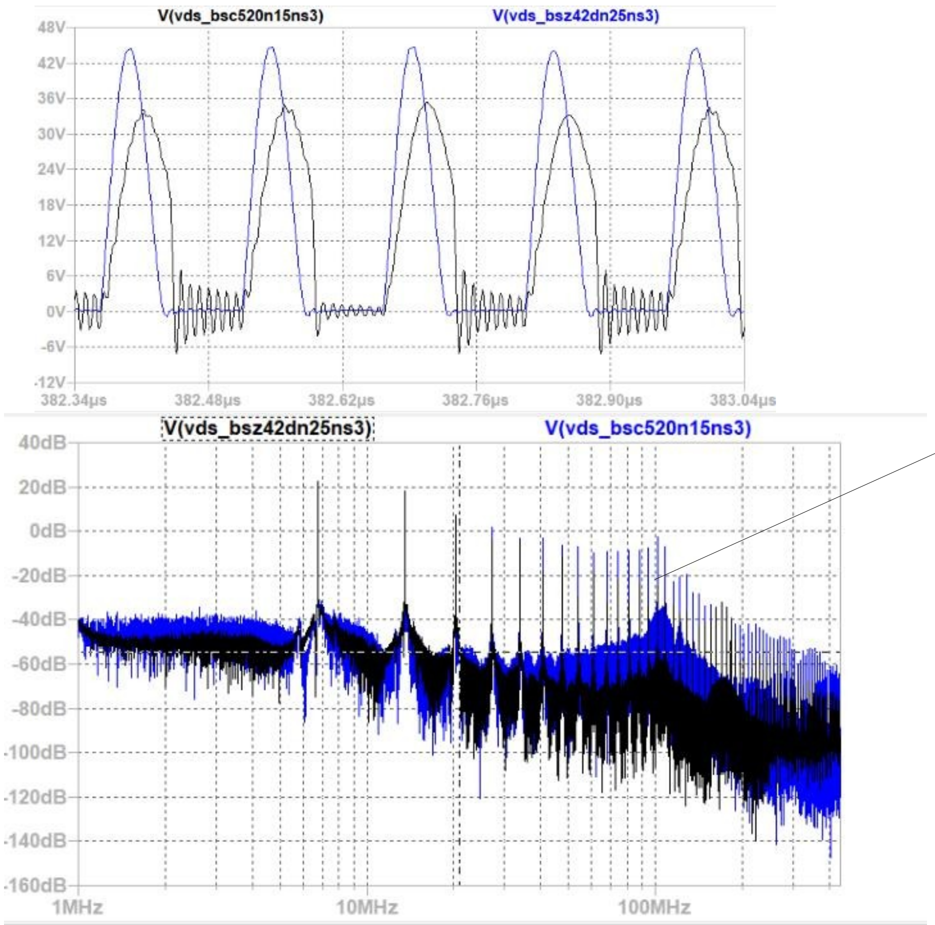
Principes

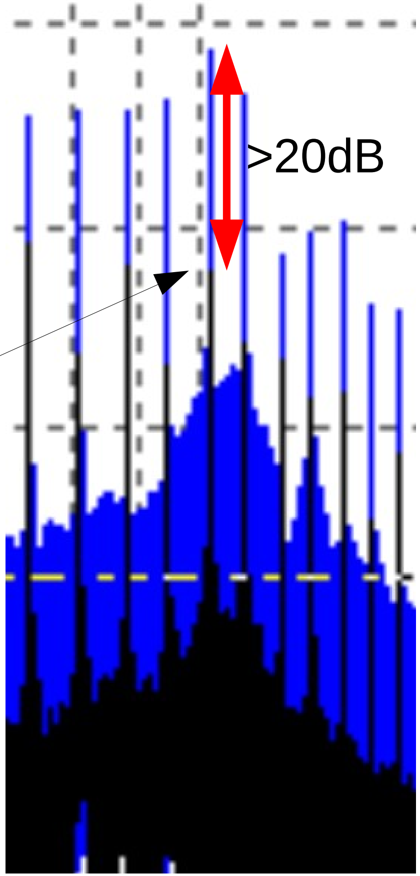
Influance du transistor

Mosfet	Cjo	Cgdmin	Cgdmax	Coss= cgd+cds	Tension max mosfet	ZVS	Courant de sortie
FDMC3612	180pF	17pF	600pF	30pF-460pF	100V	oui	200mA
BSC22DN20NS3	380pF	1pF	40pF	20pF-400pF	200V	oui	200mA
BSZ42DN25NS3	380pF	1pF	40pF	20pF-360pF	250V	oui	200mA
BSC12DN20NS3	680pF	2pF	70pF	35pF-600pF	200V	difficile	200mA
BSC520N15NS3	1nF	2pF	100pF	70pF-1000pF	150V	Difficile voir impossible	200mA



Influance du transistor

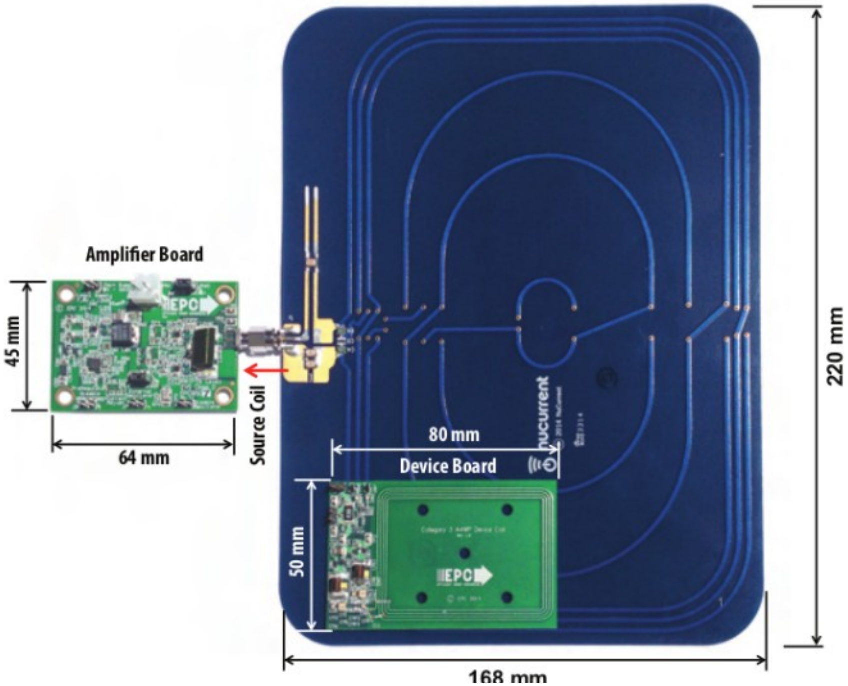




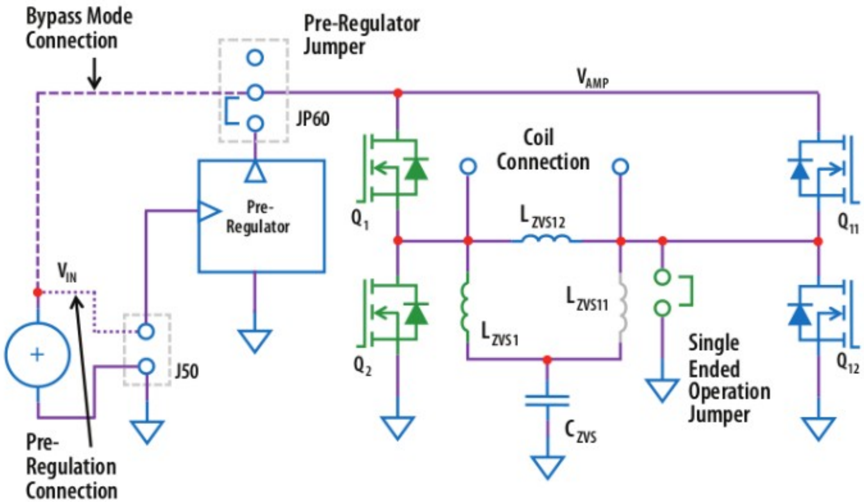
La démo

eGaN FETs and ICs (100 V–350 V) (enhancement-mode gallium nitrid)

Part Number	Configuration	V_{DS} max	V_{GS} max	Max $R_{DS(on)}$ (mΩ) @ 5 V_{GS}	Q_G typ (nC)	Q_{GS} typ (nC)	Q_{GD} typ (nC)	Q_{OSS} typ (nC)	Q_{RR} (nC)	C_{ISS} (pF)	C_{OSS} (pF)	C_{RSS} (pF)	I_D (A)	Pulsed I_D (A)	Max T_J (°C)	Package (mm)
EPC2038	Single withGate Diode	100	6	3300	0.044	0.02	0.004	0.134	0	7	1.6	0.02	0.5	0.5	150	BGA 0.9 x 0.9



Amplificateur diff Classe D
EPC2014C and EPC2038 (FET)
Max 30W transféré, multidivice



Place aux questions

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