90+

with

LLC/SRC + SR CM6900/1

and

Interleaved CRM PFC CM6565

Champion High Efficiency Solutions

- Typical DC/DC Converter efficiency
- Compare SRC/LLC
- Introduction of CM6900/6901
- Summary

Typical DC/DC Converter efficiency

Topology (Single Stage)	Power Stage			Controlled Section		
	Eff.	Soft Switching	Cost	High Power	Freq.(Hz)	Cost
Single Forward	85%	No	Low	No	50-150K Fixed Freq.	Low
Duel Forward	89%	No	Medium	Yes	50-150K Fixed Freq.	Low
Half-Bridge (non-Symmetric)	92%	Yes	Medium	Yes	50-150K Fixed Freq.	Low
Resonant Half-Bridge (LLC/No SR)	94%	Yes	Low	Possible Difficult	50-150K Variable	High
Resonant Half-Bridge (SRC/No SR)	94%	Yes	Low	Yes	50-200K Variable	High

How much efficiency can be improved by Champion LLC/SRC + SR CM6900/1

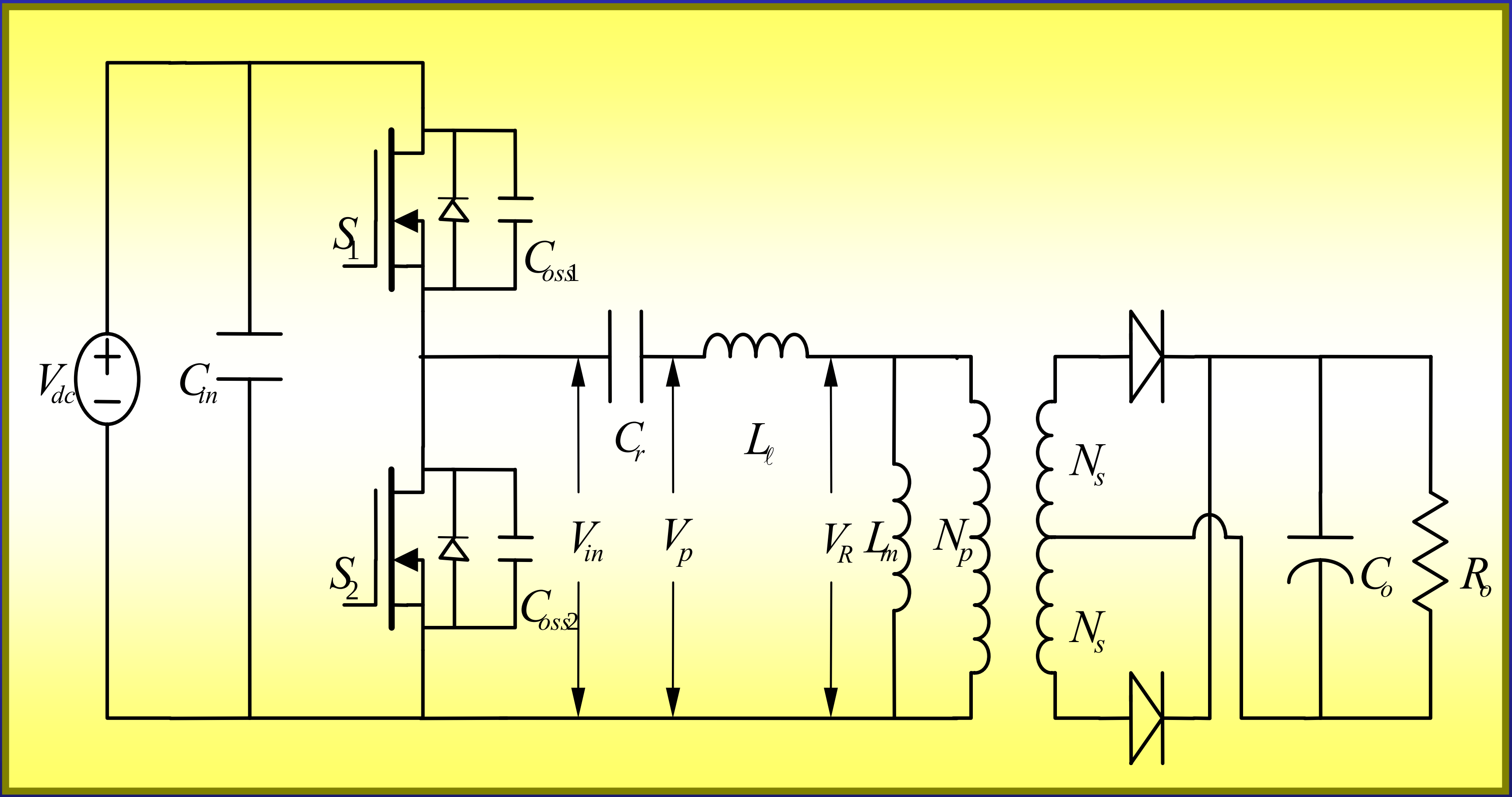
Item			Champion (SRC/LLC)	IMPROVE
LCD TV POWER CCM PFC Eff.=92%	DUAL Forward>80 %	LLC >86%	>88% (LLC)	2%
PC POWER(PFC) CCM PFC Eff.=92%	Single Forward>75 %	DUAL Forward>80%	>88%	>6%

Total Power Supply Efficiency Improvement with Hard Switching CCM PFC

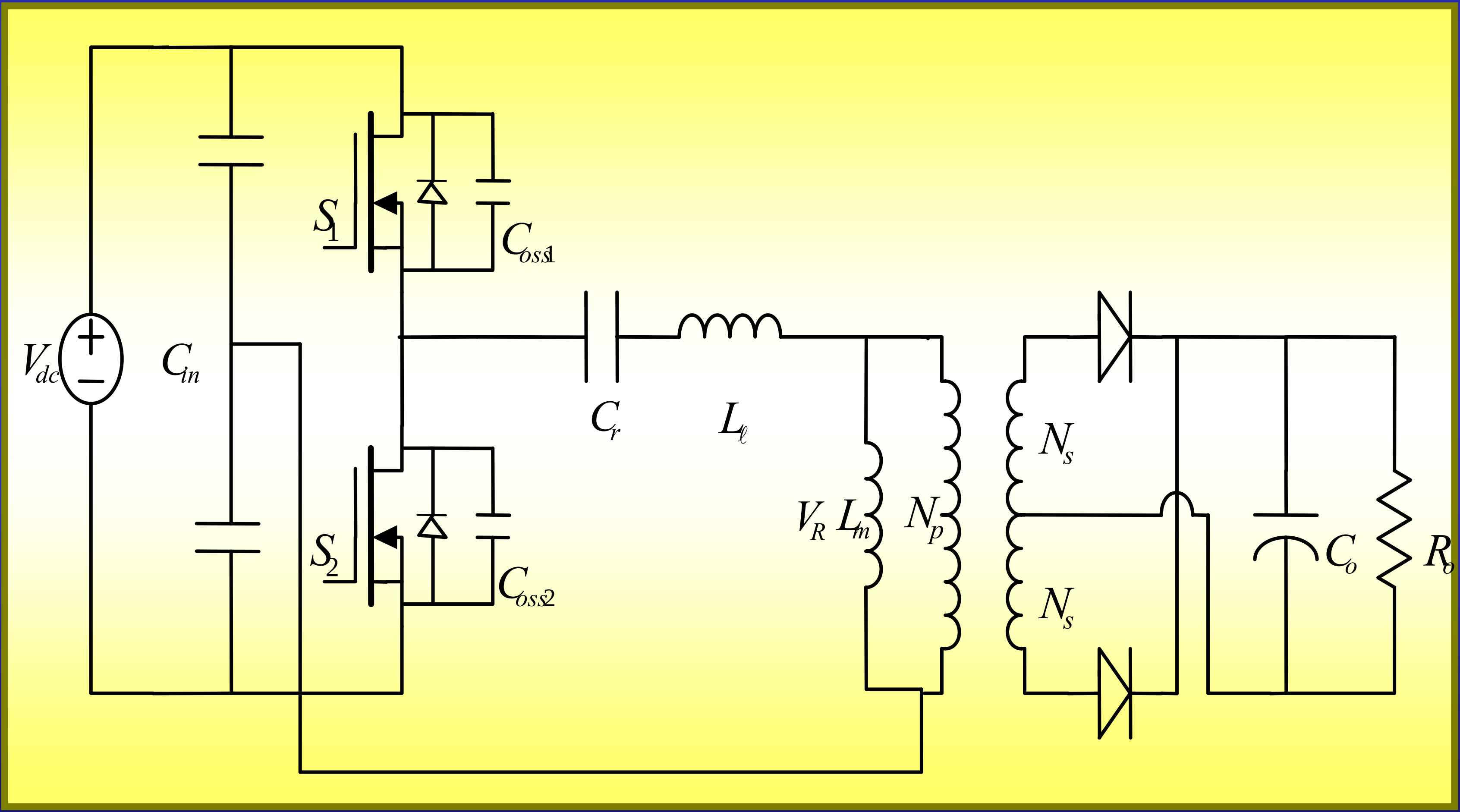
What kind of topology used by CM6900/1

- Half-Bridge class D < 500W
- Half-Bridge < 1KW
- Full-Bridge > 1KW

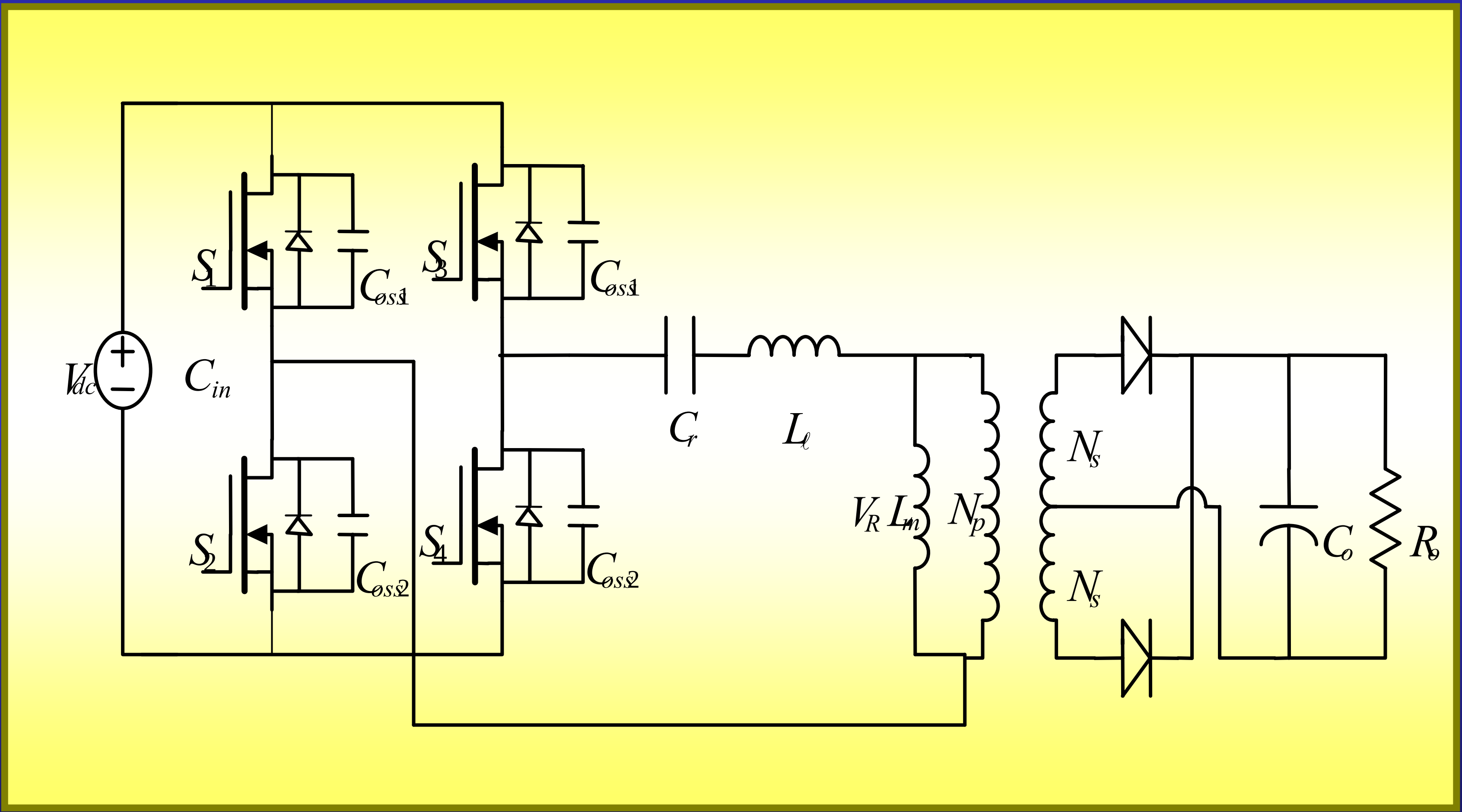
Half-Bridge Class D <500W



Half-Bridge <1KW



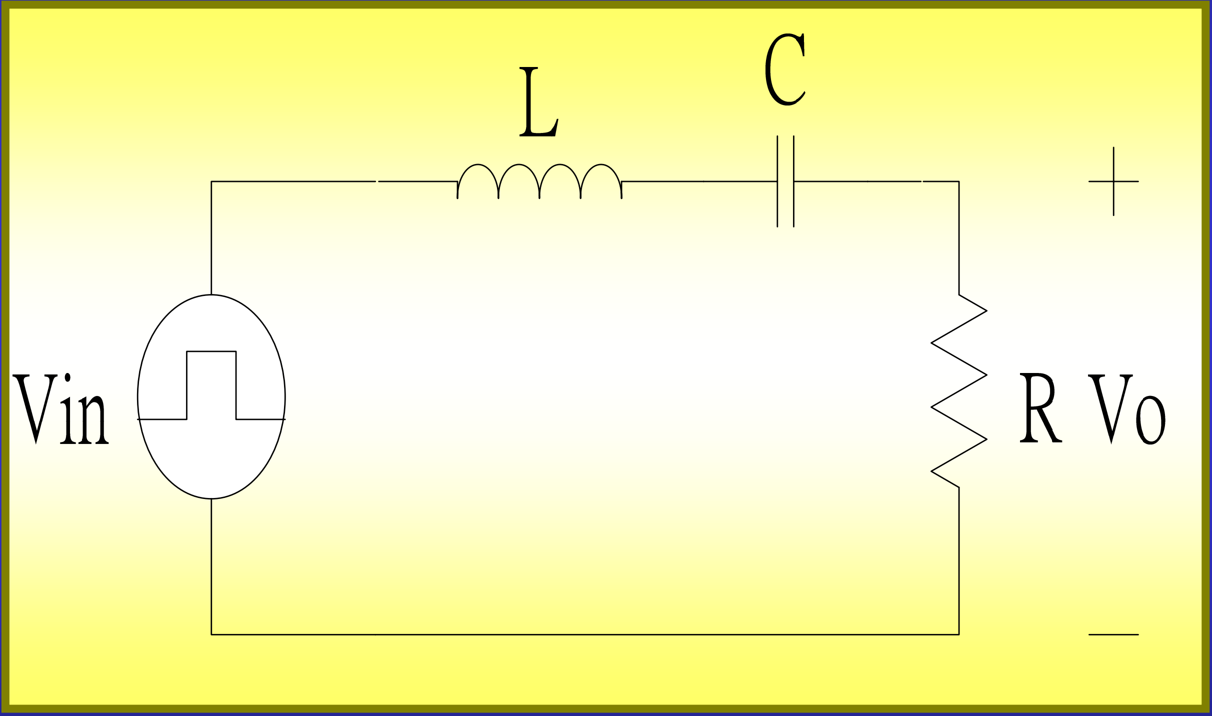
Full-Bridge > 1KW



What kind of Resonant type used by CM6900/1

- Mainly Series Resonant Converter (SRC and LLC)
- Output regulation is achieved by varying the switching frequency

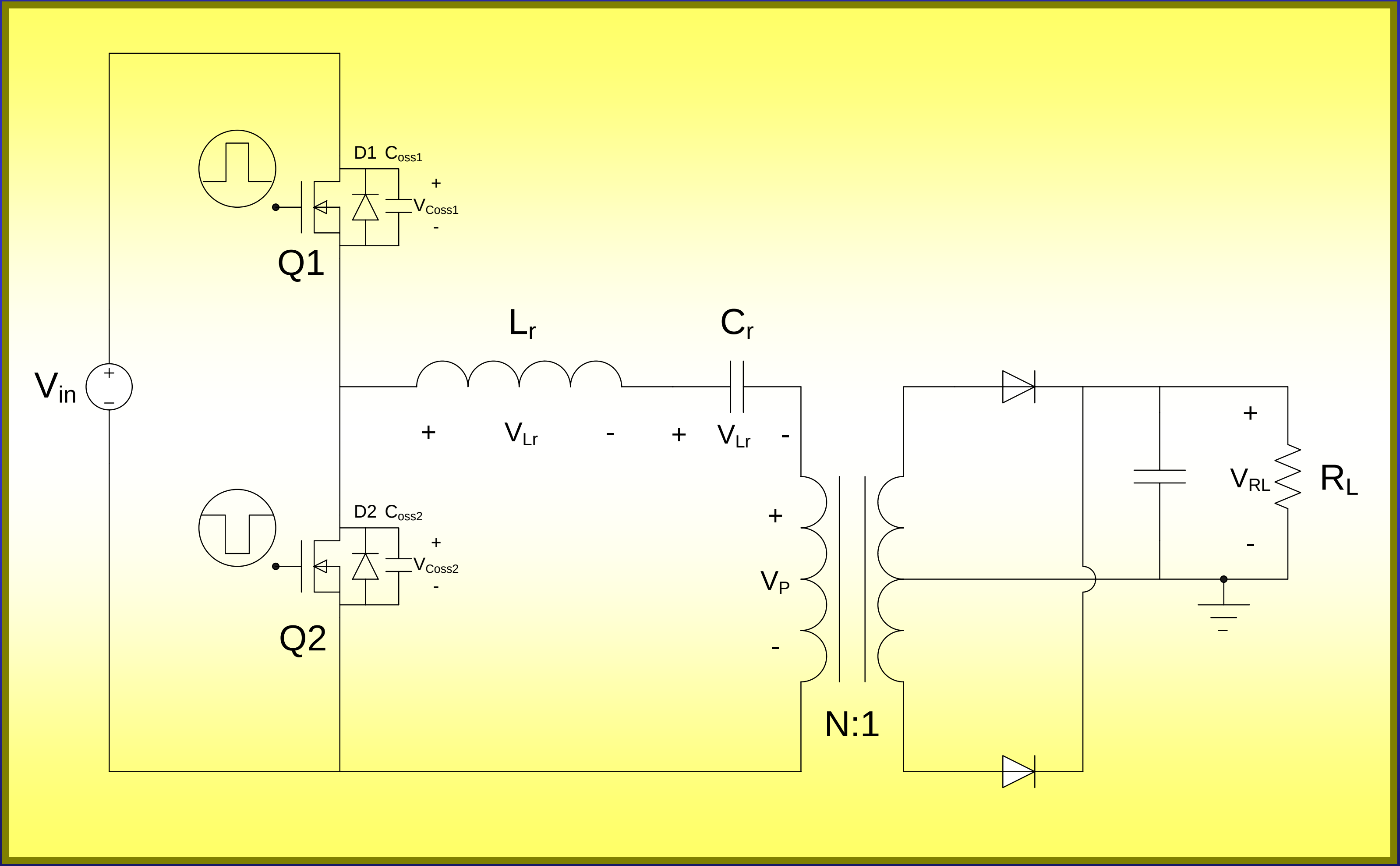
Series Resonant Circuit



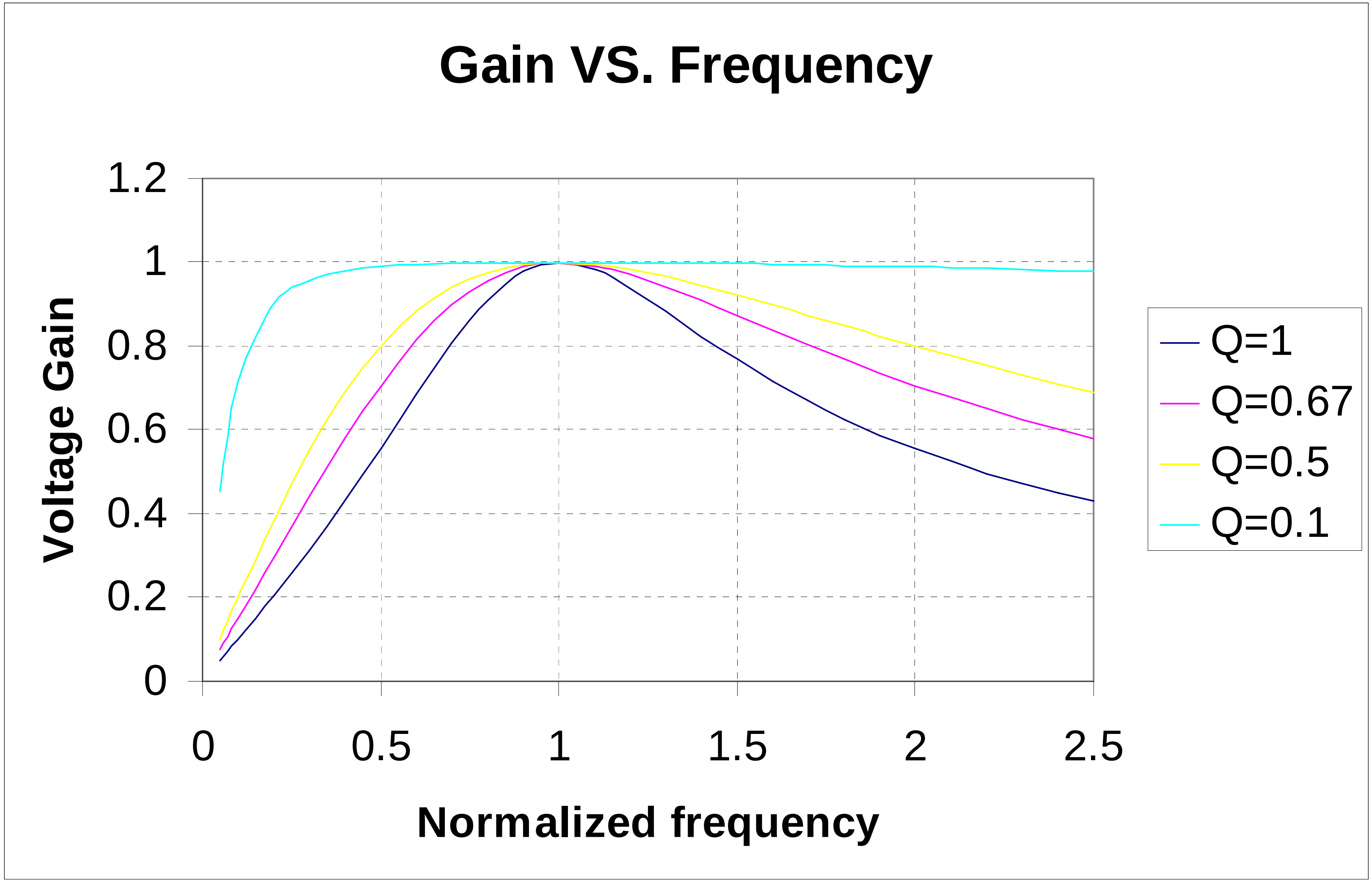
Compare SRC/LLC Design

- SRC Resonant Tank
- SRC Load Curve
- LLC Resonant Tank
- LLC Load Curve
- SRC/LLC Compare List

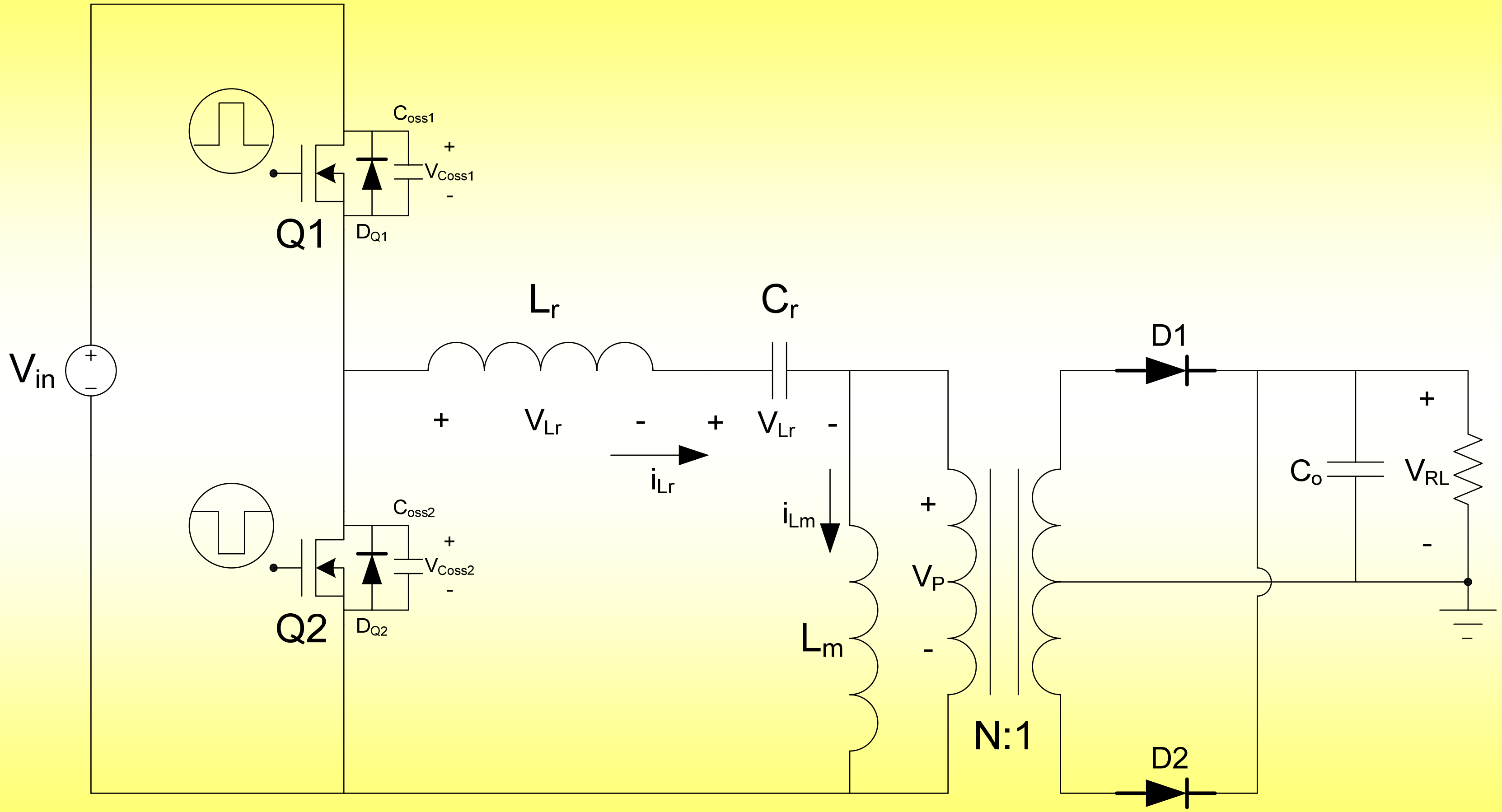
Typical SRC Resonant Tank



Typical SRC Load Curve



Typical LLC Resonant Tank



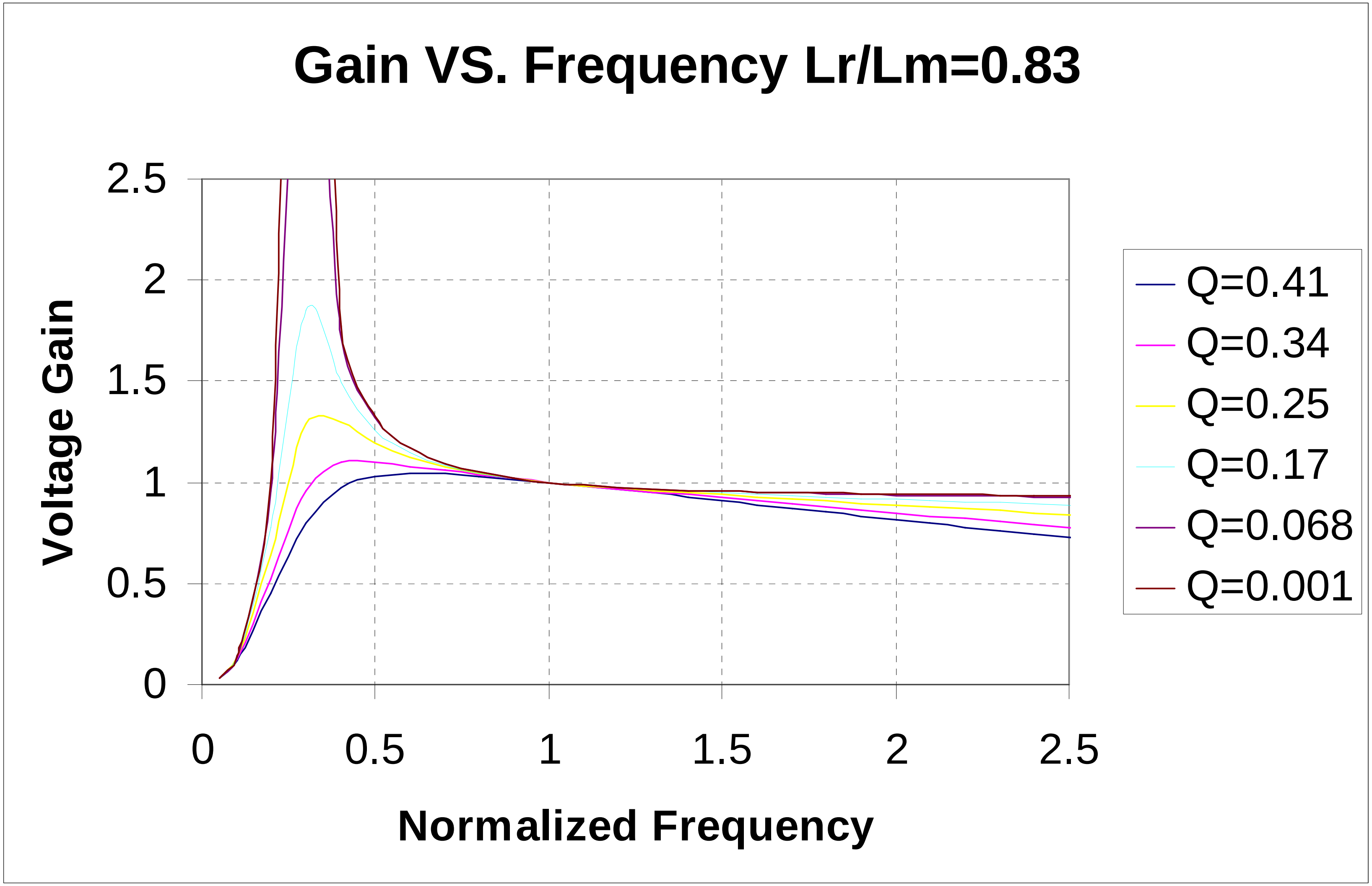
Champion Microelectronic

96+ LLC/SRC + SR CM6900/1

96+ Interleaved CRM PFC CM6565

Low Cost PFC + Stand By CM6807

Typical LLC Load Curve



Resonant Point of SRC/LLC

Item	SRC	LLC
L_r	External	Leakage
C_r	External	External
L_m	Mainly used for ZVS in light load	// with load which affects Resonant freq. Aid ZVS $f_{sw} < f_r$
R	Load	Load
f_r	$f_r = \frac{1}{2\pi\sqrt{L_r \cdot C_r}}$	$f_{r1} = \frac{1}{2\pi\sqrt{L_r \cdot C_r}}$ $f_{r2} = \frac{1}{2\pi\sqrt{(L_{eq} + L_r)\cdot C_r}}$ $L_{eq} = \frac{R^2 \times L_m}{R^2 + (\omega L_m)^2}$

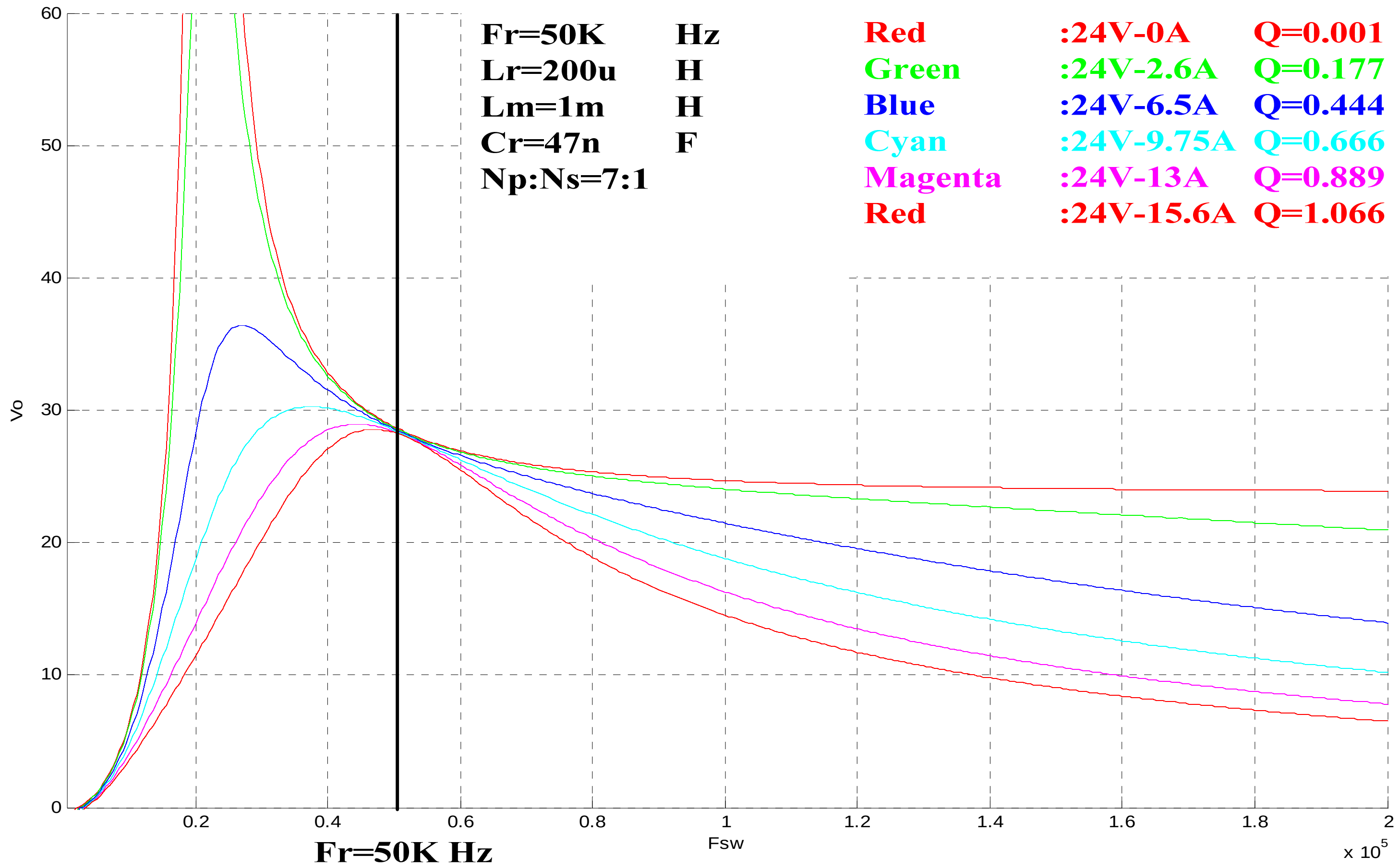
SRC/LLC Compare List

Item	SRC	LLC	Controller
Operating Freq.	$f_{sw} > f_r$	$f_{sw} > f_{r2}$	CM69000/CM6901
f_r	< 100Khz	> 100Khz	CM6900/CM6901
Load Reg.	Good	Better	Improved with CM6900/1
Light Load/No Load	Not Good	Not Good	Good with CM6900/1 Pat. FM+PWM Controlled
Synchroniz-ation	Easy (CCM)	Hard ($f_{sw} < f_{r1}$) but Easy with CM6900	CM6900/CM6901 Pat. Pending Synchronization
ZVS	Yes ((Related to magnetizing I+ Load)	Yes (Related to magnetizing I only when $f_{sw} < f_{r1}$	
Resonant pt.	Single/not related to load	Duel/ related to load	
Design	Easy	Easy for low power	
Power	>1KW	Harder for higher power	
Efficiency	>94%	>94%	Increased with CM6900/1
Lr	External	Leakage	
Main Xformer	Standard	Special Bobbin	

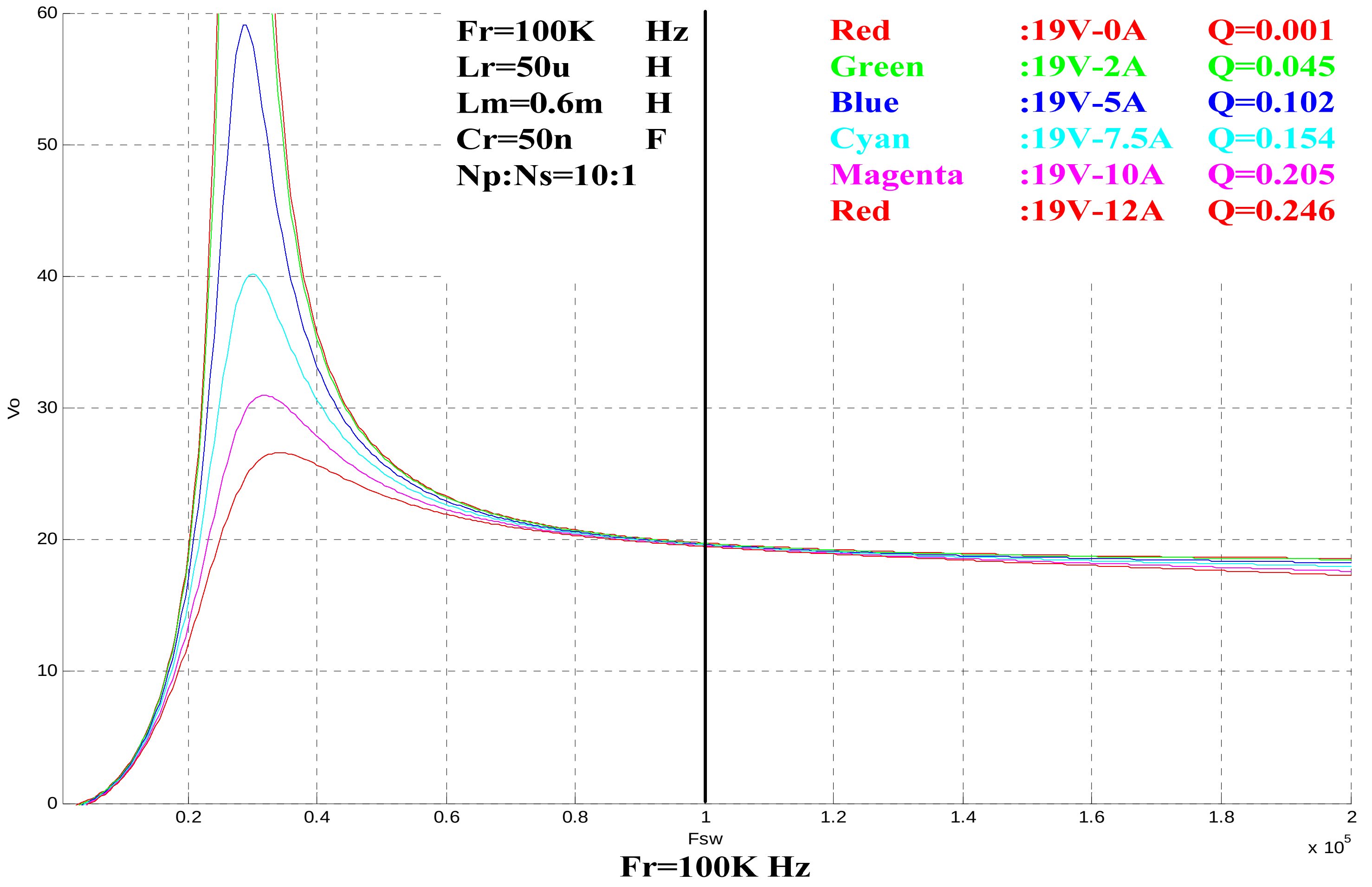
When use SRC or LLC?

- 24V/13A SRC Load Curve (300W)
- 19V/10A LLC Load Curve (200W)
- Compare SRC/LLC Design

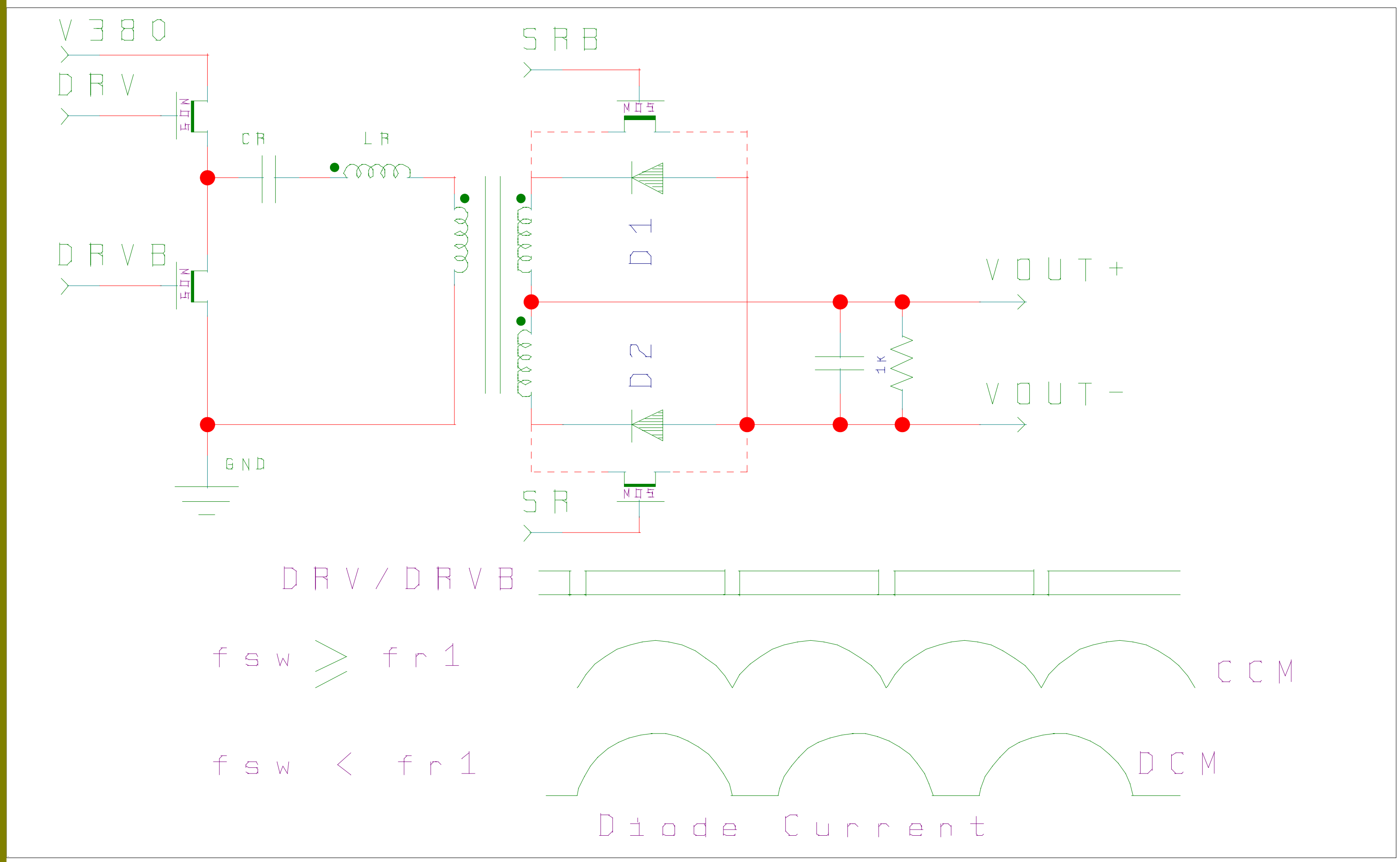
24V/13A SRC Load Curve



19V/10A LLC Load Curve



Why Synchronous Rectification is Difficult in LLC ?



Summary SRC/LLC + SR Design

- SRC-Simple design due to single resonant point
- LLC-Complicated Design due to double resonant points
- SRC-High power, no need to increase resonant freq.
- LLC-Low power, provide gain < f_{r1}, help hold-up issue
- Under same power SRC f_{sw} is lower, switching loss is lower
- SRC-Easy to implement SR rectification, higher efficiency.
- LLC-Complicated to implement SR rectification without using CM6901 (Pat. pending scheme).
- SRC-Transformer is easy to design. Loss is low.
- LLC-Transformer is complicated to design, required special bobbin.
- SRC- high Q design
- LLC- low Q design

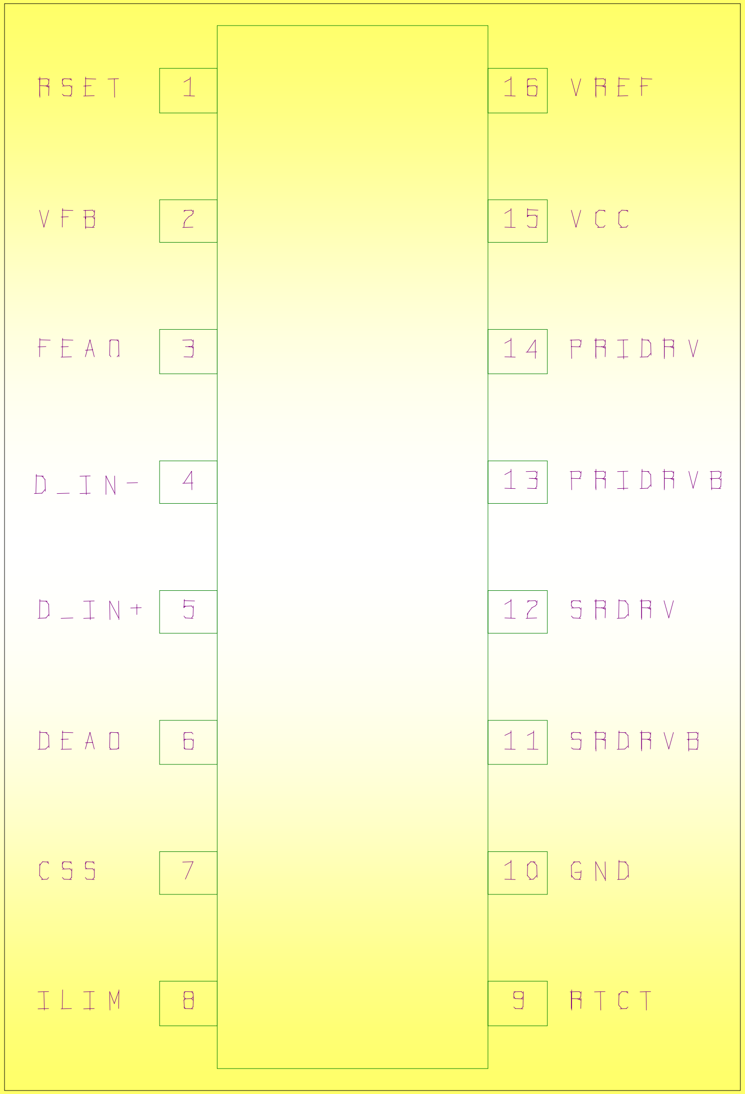
Introduction of CM6900/1

- CM6900/6901 Features
- CM6900/6901 Pin Assign
- CM6900/6901 Pin Description
- CM6900/6901 Block Diagram
- CM6900/6901 Parameter design

CM6900/1 Features

- Resonant controller (Primary or Secondary); start-up current < 200uA
- FM /PWM control mode
- Build-in synchronous drives with pwm-ing capability for LLC operation
- Wide frequency range operation with adjustable dead time
- Soft-start with shutdown function
- Build-in OCP/OVP function
- UVLO=13V with 3V Hysteresis
- Auto-Restart during OCP/OVP

CM6900/1 Pin Assign



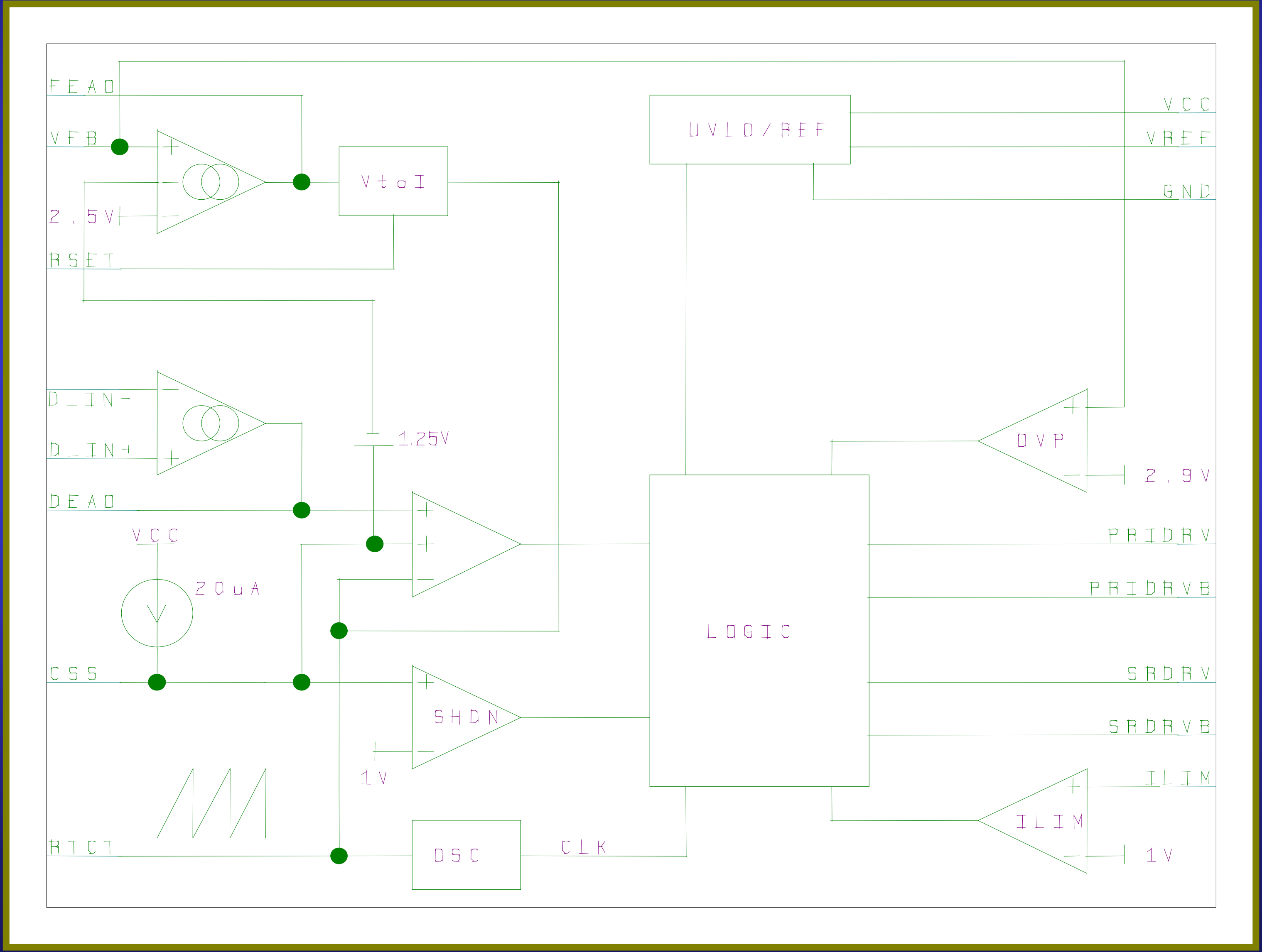
CM6900/1 Pin Description

Pin No.	Symbol	Description	Operating Voltage			
			Min.	Typ.	Max.	Unit
1	RSET	External resistor which convert FEAO voltage signal into current signal for frequency modulation.	0		5.5	V
2	VFB	Non-inverting input into resonant error amplifier and OVP input.	0	2.5	3	V
3	FEAO	Resonant error amplifier output and compensation node for frequency modulation control.	0		5.5	V
4	D_IN-	Inverting input into PWM error amplifier.	0		5	V
5	D_IN+	Non-inverting input into PWM error amplifier.	0		5	V
6	DEAO	PWM error amplifier output and compensation node for PWM control.	0		4.5	V
7	CSS	Soft start for FM/PWM operation with 1V enable threshold. Also, use for auto-restart operation during current limit.	0		5.5	V
8	ILIM	Input to current comparator with 1V threshold.	0	1	1.25	V

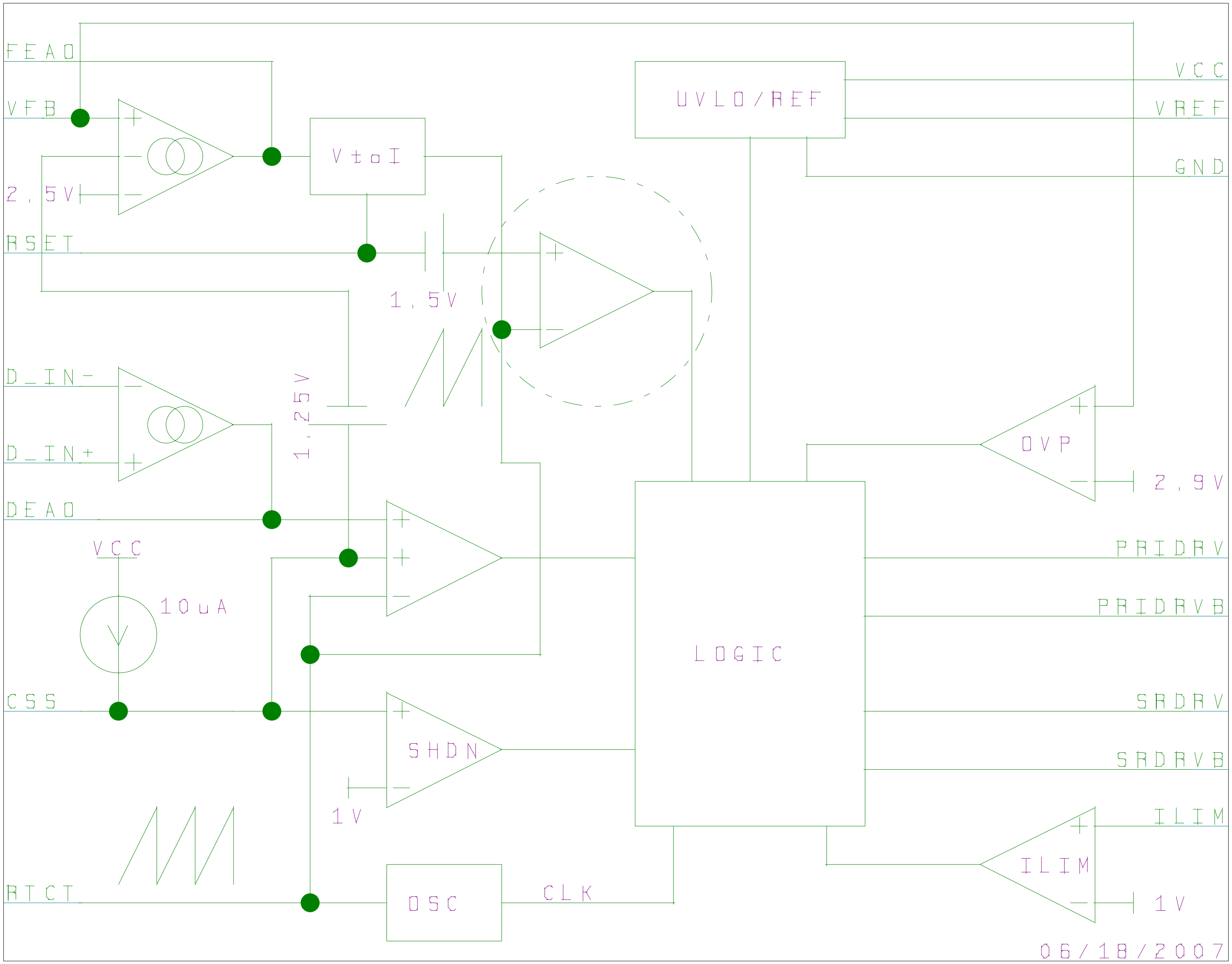
CM6900/1 Pin Description

Pin No.	Symbol	Description	Operating Voltage			
			Min.	Typ.	Max.	Unit
9	RTCT	Oscillator timing components which set the minimum frequency.	1.2		3	V
10	GND	Ground				
11	SDRVB	Synchronous MOSFET driver output.	-0.3		VCC	V
12	SDRV	Synchronous MOSFET driver output.	-0.3		VCC	V
13	PRIDRV	Primary side MOSFET driver output.	-0.3		VCC	V
14	PRIDRVB	Primary side MOSFET driver output.	-0.3		VCC	V
15	VCC	Positive supply for the IC	10	15	17.5	V
16	VREF	Buffered output for the 7.5V voltage reference		7.5		V

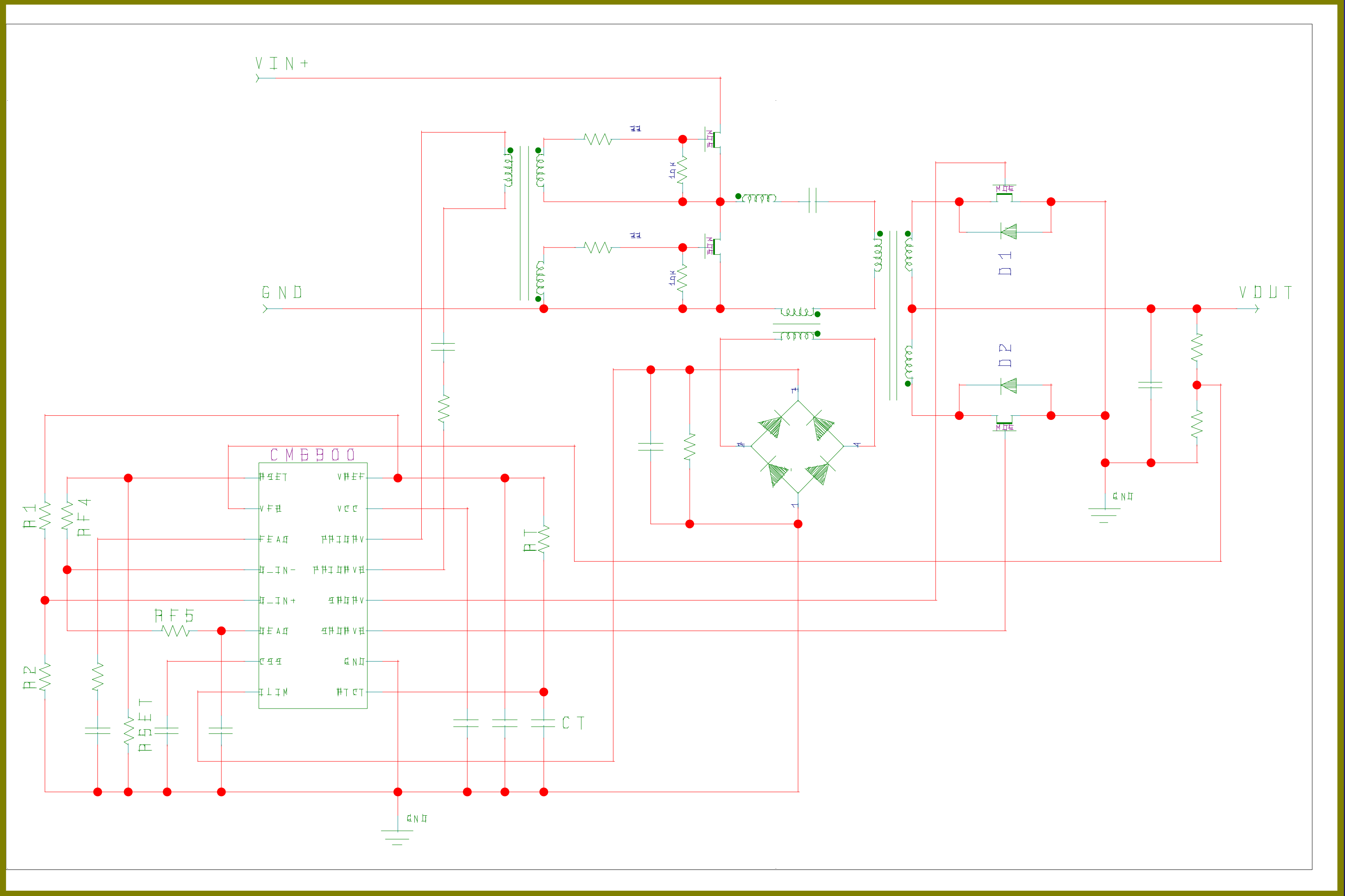
CM6900 Block Diagram



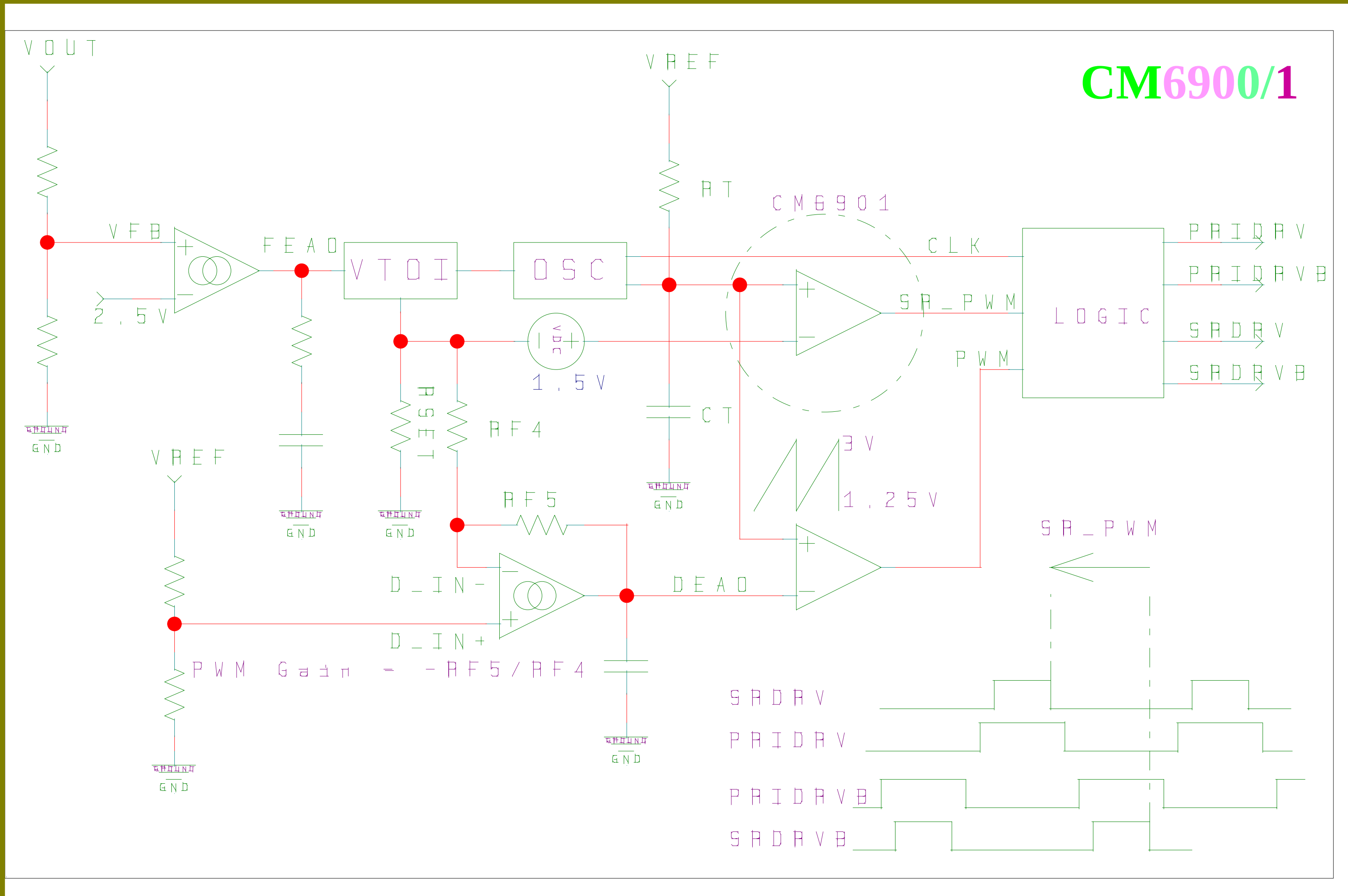
CM6901 Block Diagram



CM6900/1 Application Circuit



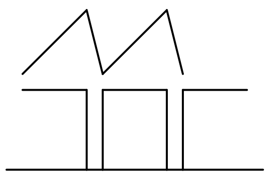
FM+PWM+SR

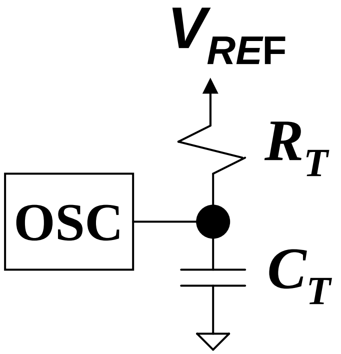

CM6900/1
VOUT
VFB
2.5V
FEAO
VTOI
OSC
VREF
RT
CM6901
CLK
LOGIC
PRIDRV
PRIDRVB
SRDRV
SRDRVB
SR_PWM
PWM
1.5V
RSET
RF4
CT
3V
1.25V
RF5
D_IN-
D_IN+
DEAO
PWM Gain = -RF5/RF4
GND

Important design parameters for proper operation SR in LLC Configuration

- Select C_T for desired dead time.

$$t_{Dead} = 850 * C_T$$





- Select R_T for minimum frequency.

$$f_{RTCT(\min)} = \frac{1}{0.33 * R_T * C_T + 850 * C_T}$$

$$f_{SW} = 0.5 * f_{RTCT}$$

CM6900/1

Important design parameters for proper operation SR in LLC Configuration

- Select resistor R_{SET} value at $V(R_{SET})$ value of 1.5V so that f_{sw} is at f_{r1} for maximum SR pulse width.

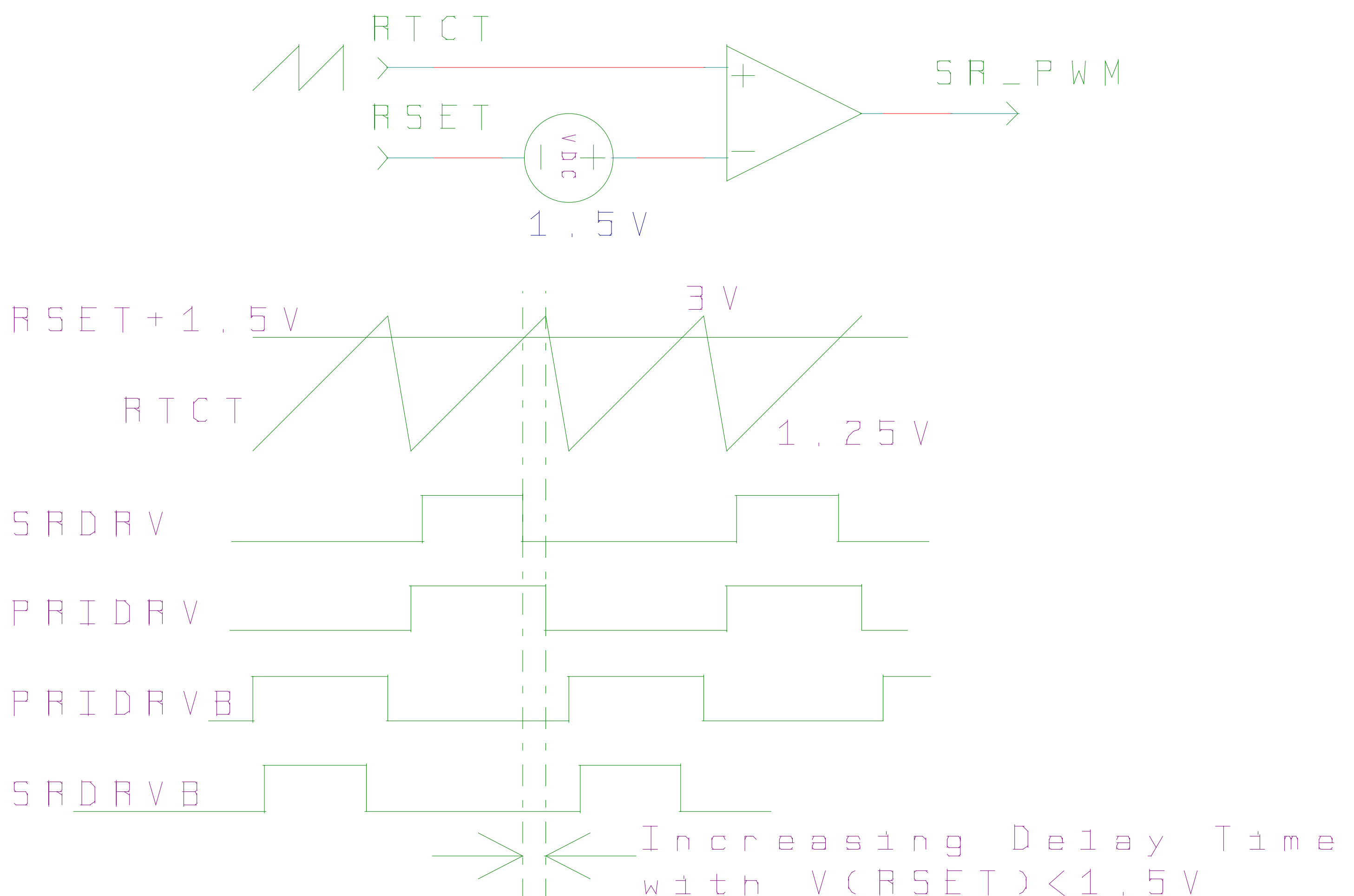
$$f_{RTCT} = \frac{1}{t_{Ramp} + t_{Dead}}$$

For LLC with CM6901 Only!

$$t_{Ramp} = R_T * C_T * \ln\left(\frac{V_{REF} + R_T * I_{CHG} - 1.25}{V_{REF} + R_T * I_{CHG} - 3.0}\right); I_{CHG} = 4 * \frac{V(R_{SET})}{R_{SET}}$$

- PWMing of SR will happen when $V(R_{SET}) < 1.5V$.

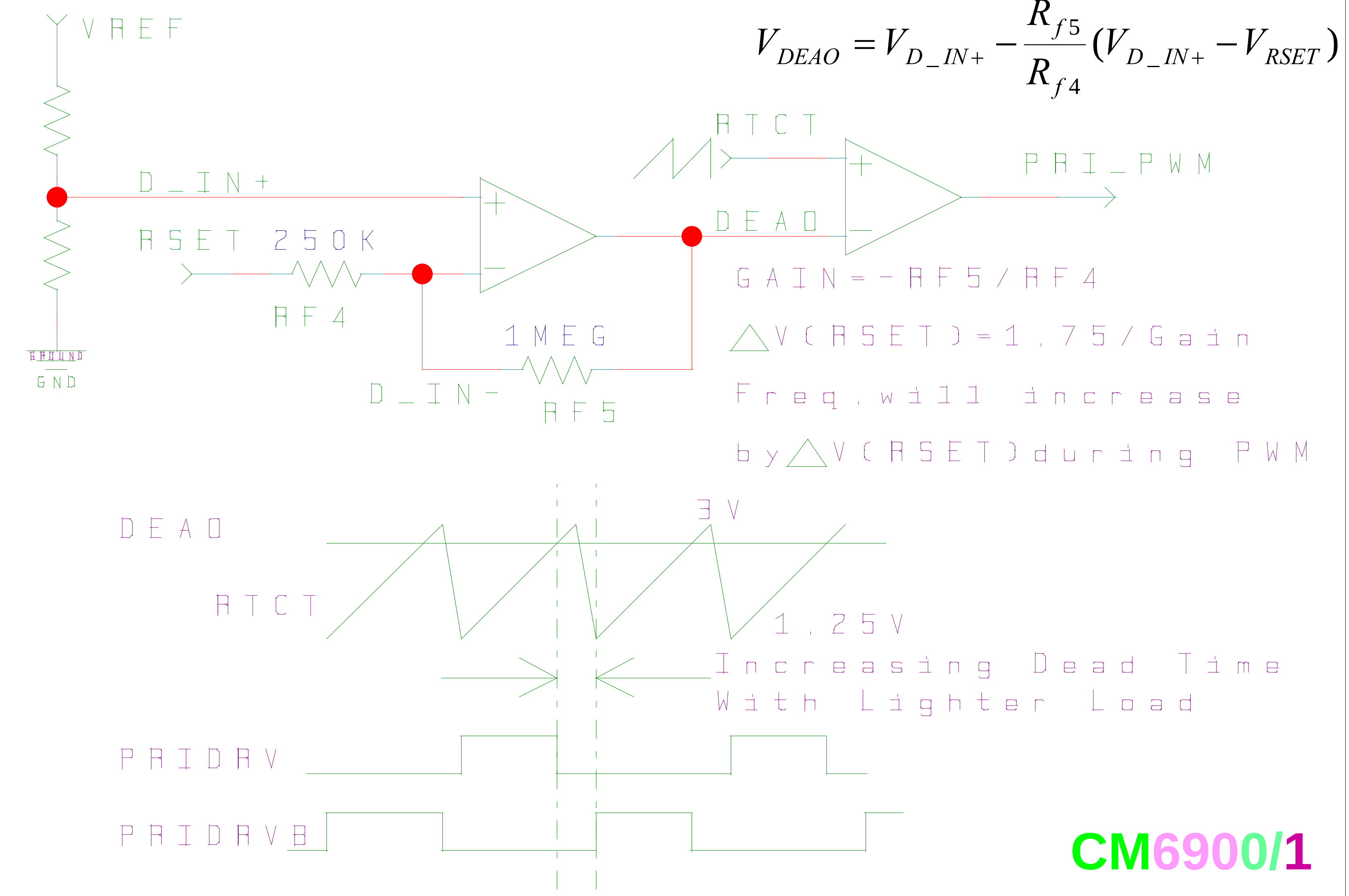
Timing Diagram for PWMing of SR



For LLC with CM6901 Only!

Timing Diagram for PWMing at Light Load

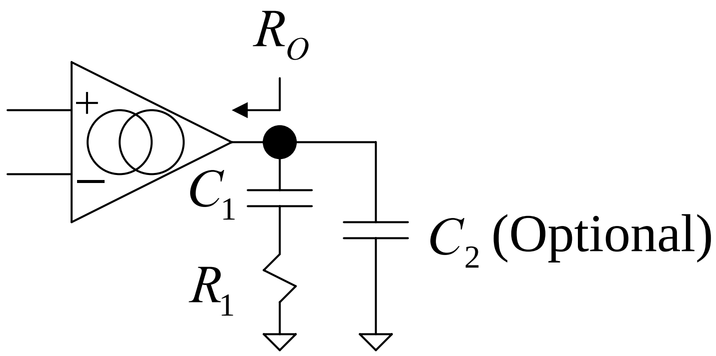
$$V_{DEAO} = V_{D\_IN+} - \frac{R_{f5}}{R_{f4}}(V_{D\_IN+} - V_{RSET})$$



CM6900/1

Compensation using Gm based amplifier

- Gm amplifier



$$P_1 = \frac{1}{2\pi R_O C_1}$$

$$R_O \approx 5Meg$$

$$P_2 = \frac{1}{2\pi R_1 C_2}$$

$$C_1 >> C_2$$

$$f_u = \frac{Gm}{2\pi C_1}$$

$$Z_1 = \frac{1}{2\pi R_1 C_1}$$

$$Gm = 135\mu Moh$$

$$Av(s) = \frac{Ao(1 + R_1 C_2 S)}{(1 + R_o C_1 S)}$$

CM6900/1

Loop-gain

$$T = \frac{1}{(1+R_L C_{out})} * \frac{A_o(1+R_1 C_2 S)}{(1+R_o C_1 S)} * \frac{1}{\sqrt{\left(1+\lambda-\frac{\lambda}{f_n^2}\right)^2 + Q^2\left(f_n - \frac{1}{f_n}\right)^2}} * \beta$$

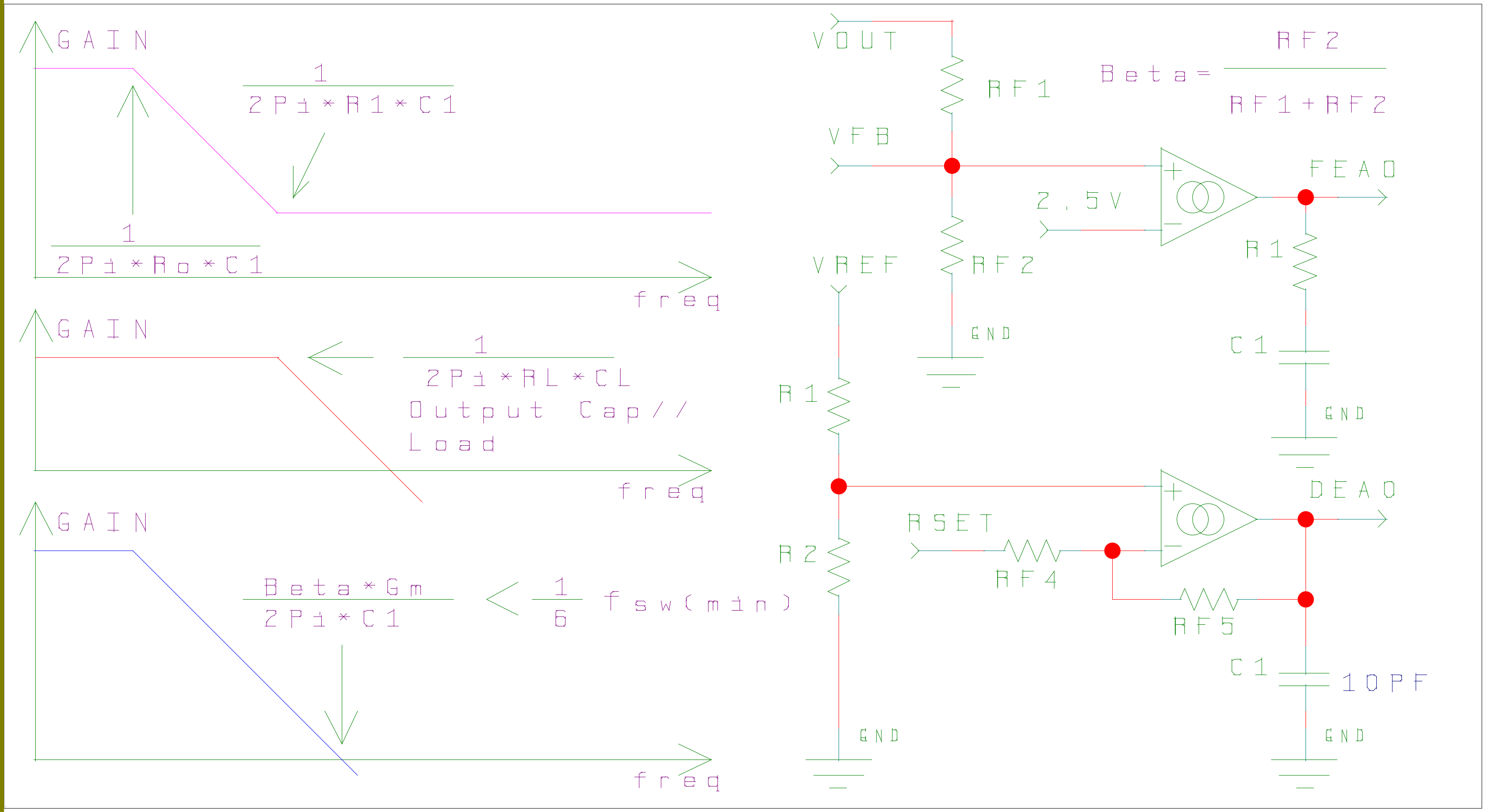
$$\lambda = \frac{L_r}{L_m} \qquad f_n = \frac{f_{sw}}{f_r} \qquad \beta = \frac{R_{f2}}{R_{f1}+R_{f2}}$$

$$Q = \frac{Z_O}{N^2 R_{eff}} \qquad R_{eff} = \frac{8}{\pi^2} R_L \qquad Z_O = \sqrt{\frac{L_r}{C_r}}$$

If $(1+R_L C_{out} S) = (1+R_1 C_2 S)$, then

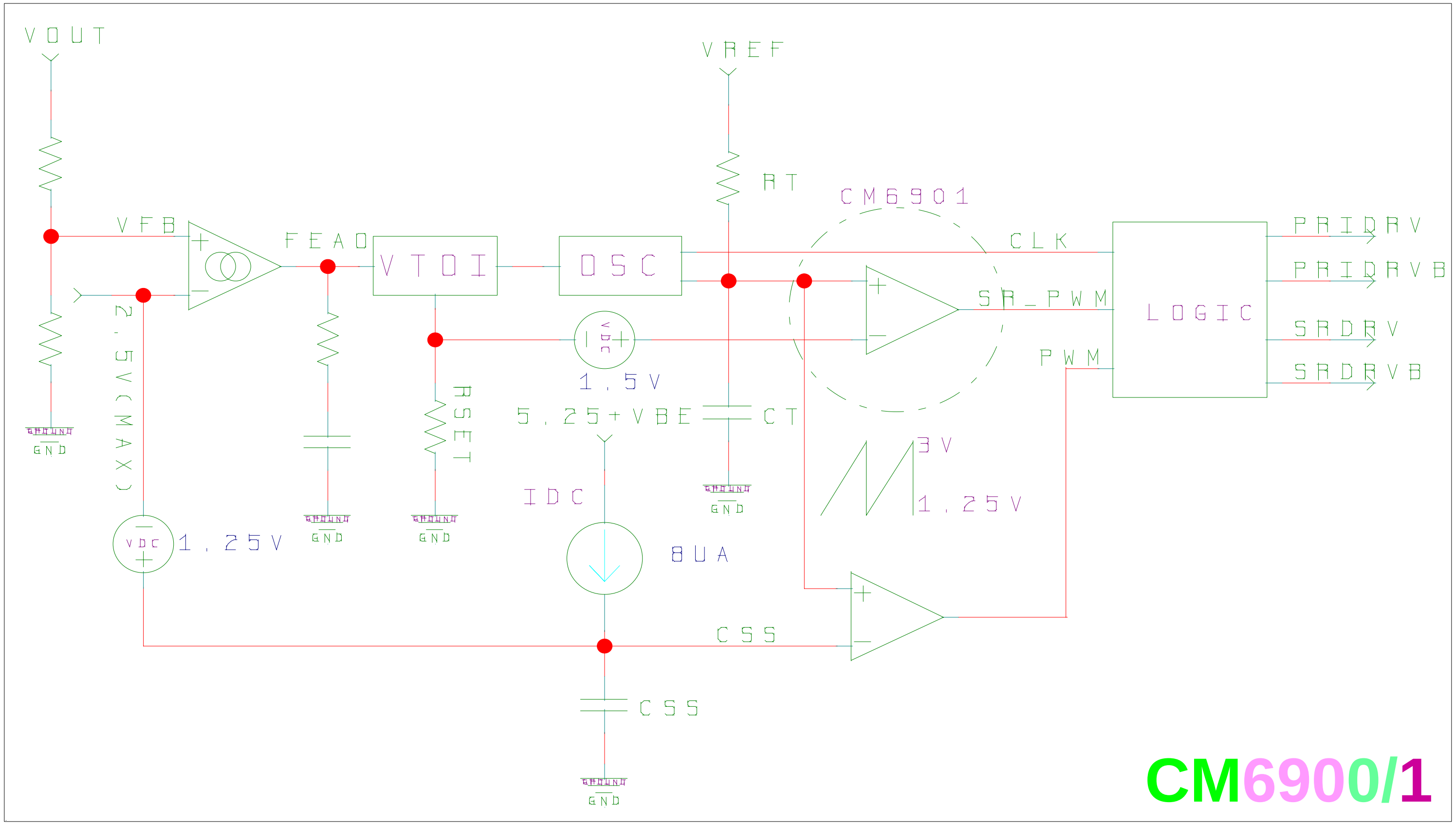
$$BW \approx \beta * \frac{G_m}{2\pi C_1}$$

Graphical Analysis



Soft Start Function

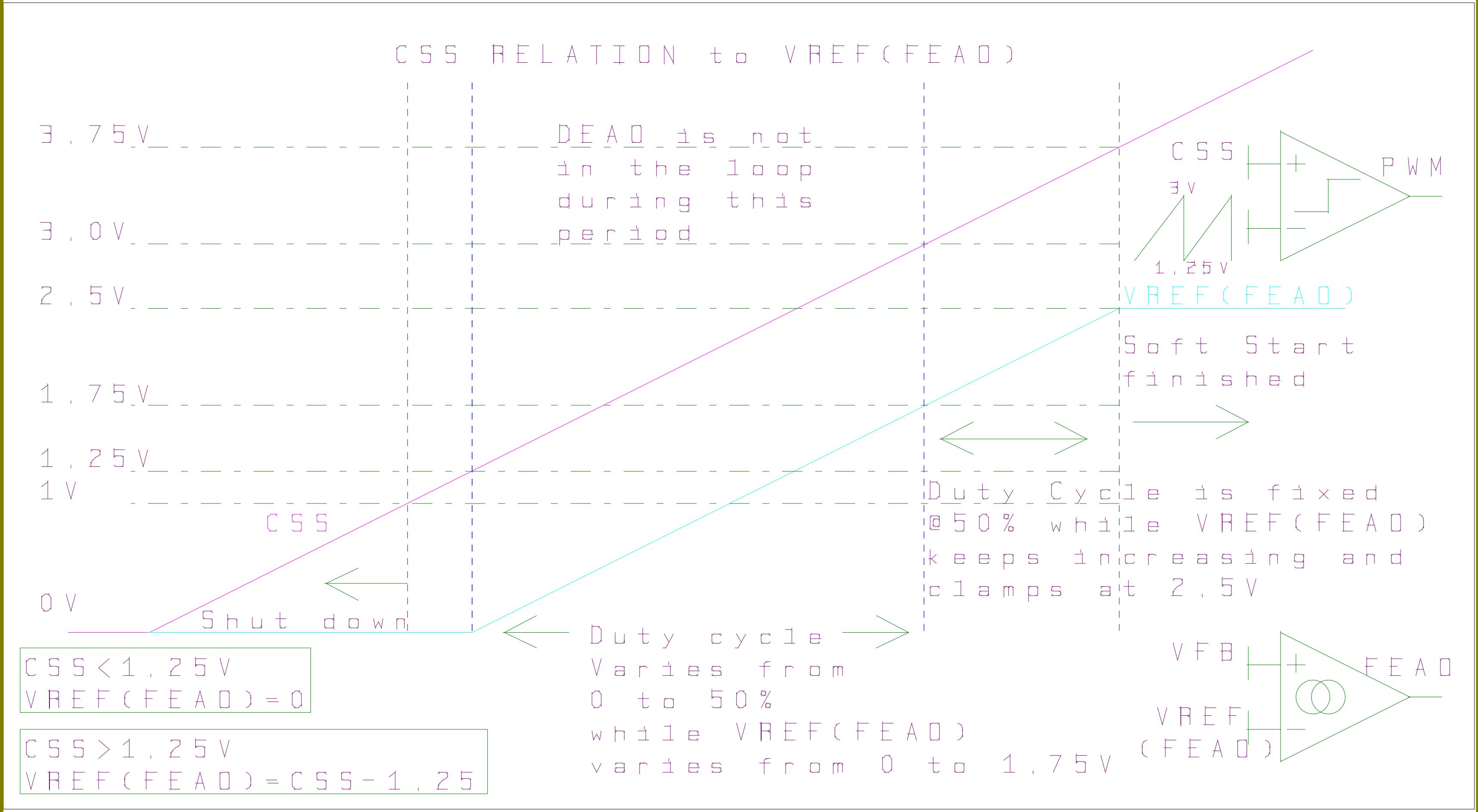
- SS begins when CSS > 1.25V
- Closed-loop FM; open-loop PWM



CM6900/1

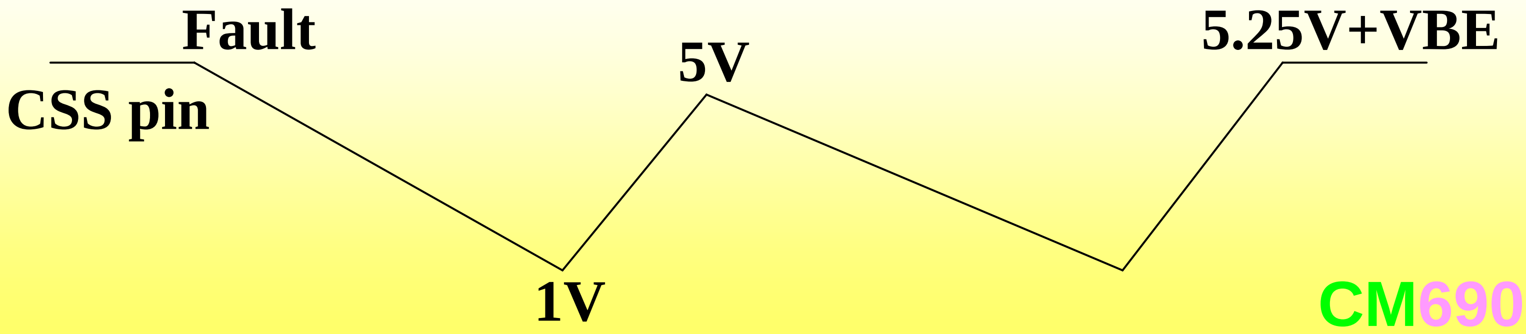
Soft Start Timing Diagram

CM6900/1



Auto Retry During OVP or I Limit

- Output drivers are disable immediately.
- Soft-start pin is discharged slowly.
- Output drivers are enable again when Soft-Start pin is below 1V and soft-start cycle begins again.



Why use CM6900/1?

- Competitors
- Power stage compare

Power stage compare

Brand Function	Champion CM6900/6901	ST L6599	ON-SEMI NCP1396	Philips TEA1610T
Load Regulation	best	good	poor	poor
Efficiency	>95%	>93%	>93%	>93%
Improve Efficiency	>2%			