Synchronous Rectifier in Forward Converter

9F-5, No. 3-2, Park Street, Nankang District, (NKSP), Taipei, Taiwan, 115, R.O.C. Tel:886-2-2655-8178 Fax:886-2-2655-8468

A. Rectifier Circuit
B. Rectifier Concept
C. Synchronous Rectifier

C -1 : RCD Clamp & Self - Driven SRs
C -2 : Active Clamp & Self - Driven SRs
C -3 : Control – Driven

D. Power Loss Comparisons
E. Efficiency Curve

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A. Rectifier Circuit

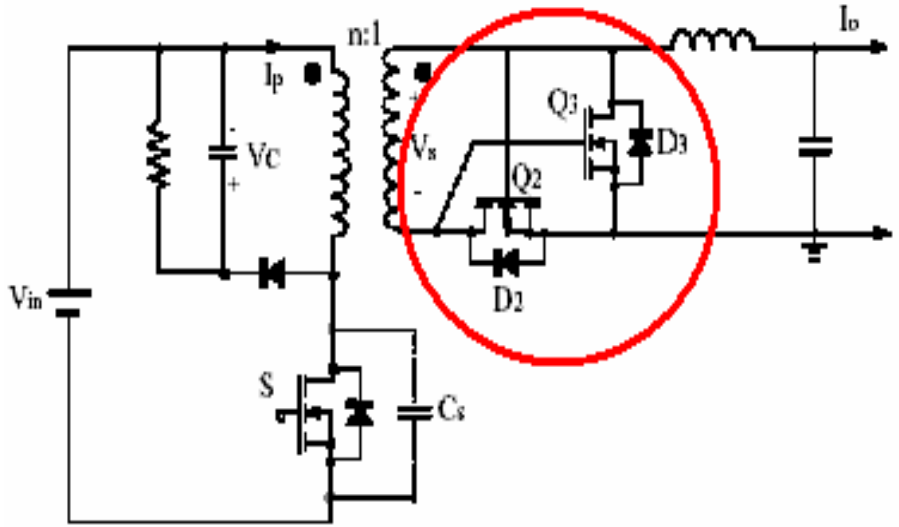

Fig1 : Forward Converter with MOSFET

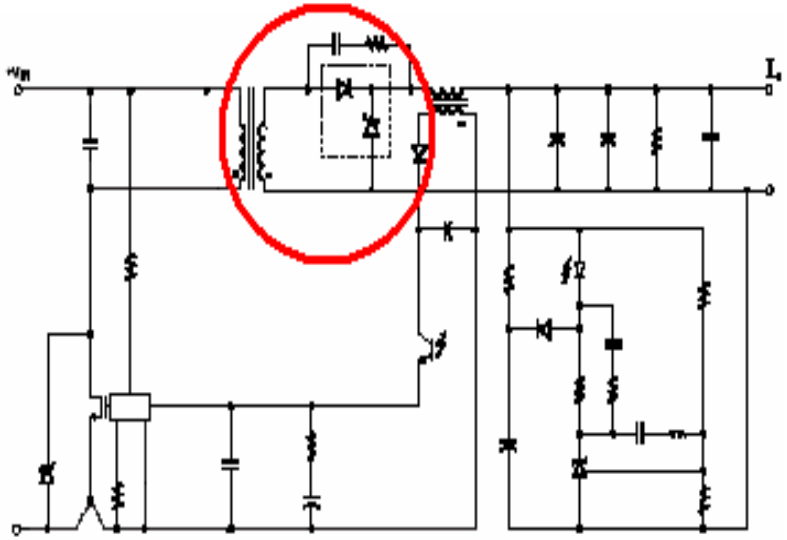

Fig2 : Forward Converter with Diode

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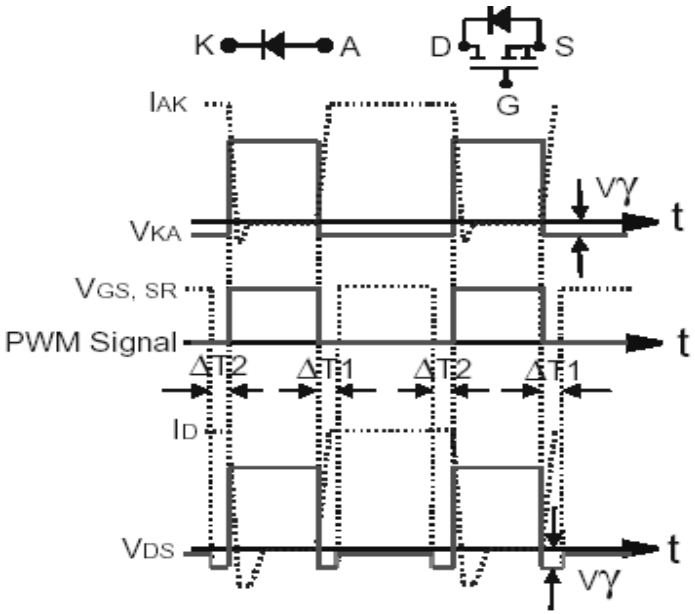
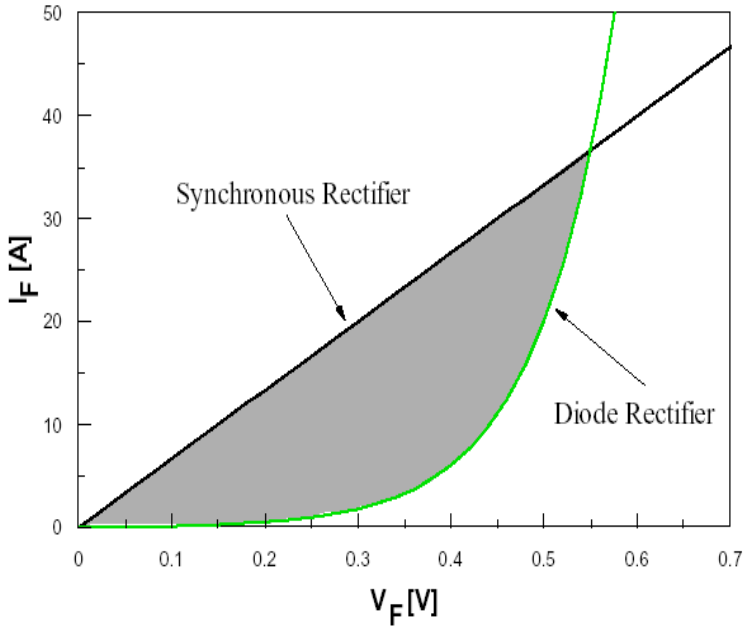
B. Rectifier Concept





The switching losses caused by the reverse recovery current of the body - diode will be dependent of the carried current in the instant in the which the voltage between anode and cathode reverses become negative

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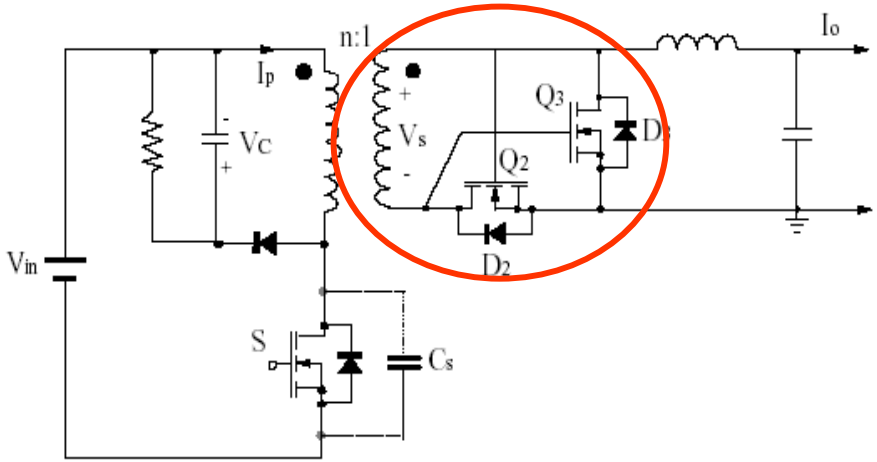
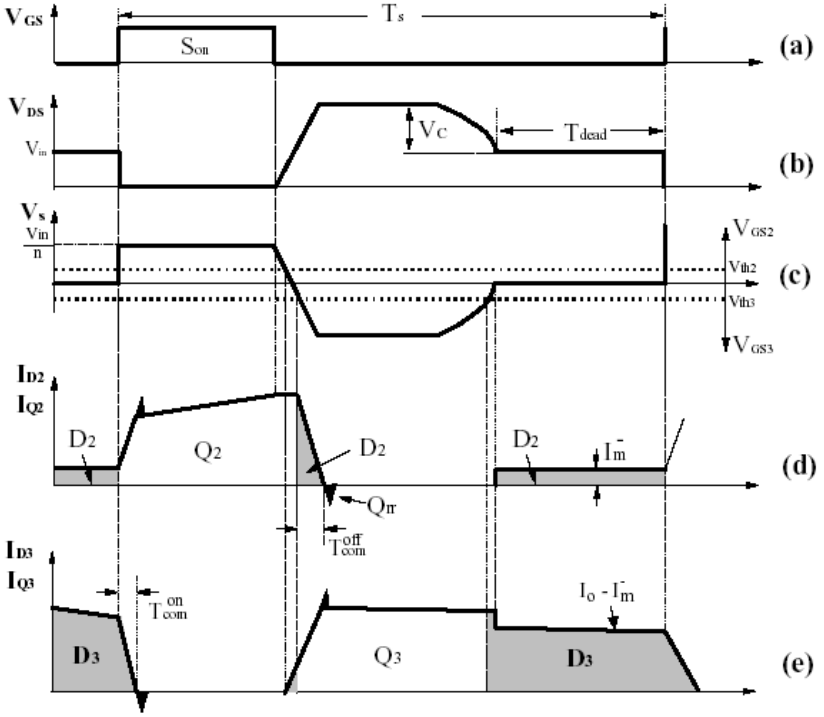
C. Synchronous Rectifier

C-1 RCD Clamp & Self – Driven SRs





(a) Gate –Driver signal
(b) Drain to Source voltage of primary switch
(c) Secondary winding voltage
(d) Current through SR2
(e) Current through SR3

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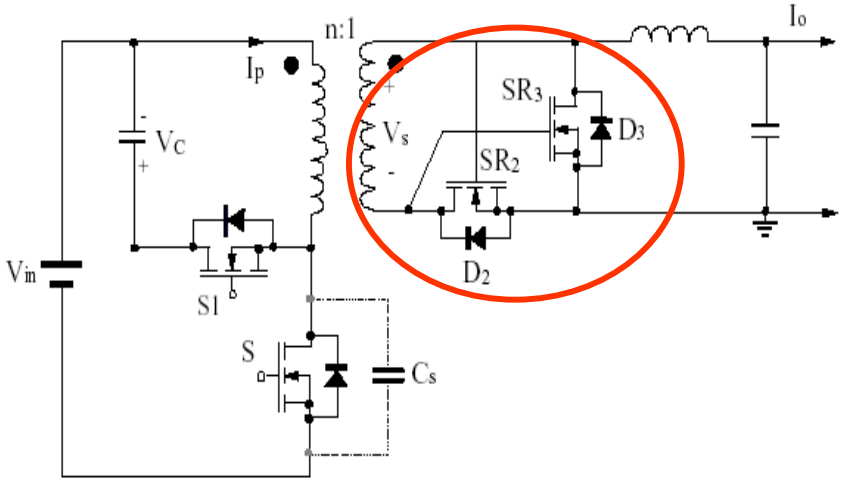
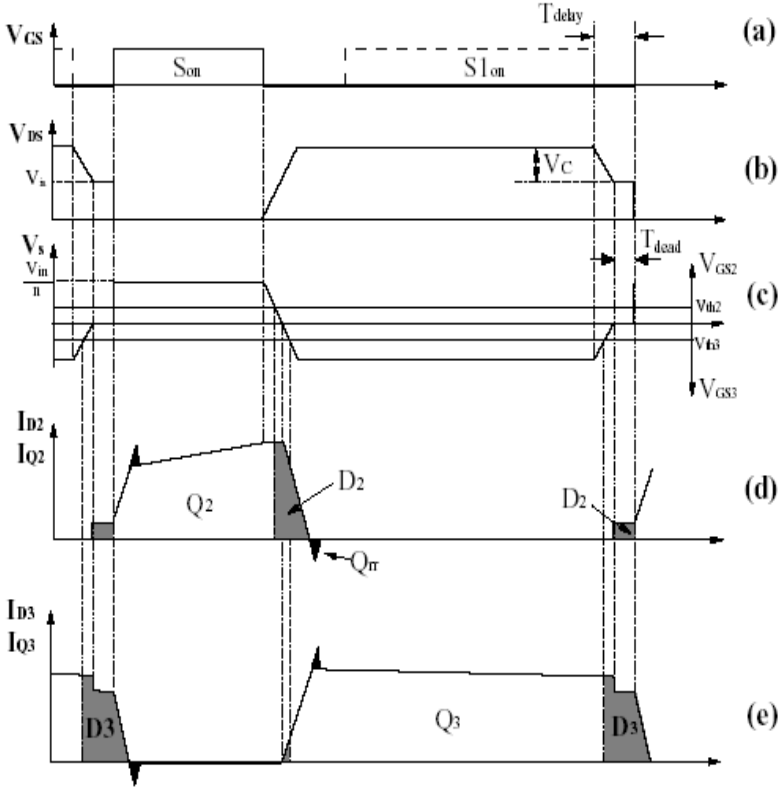
C. Synchronous Rectifier

C-2 Active Clamp & Self – Driven SRs



(a) Gate –Driver signal
(b) Drain to Source voltage of primary switch
(c) Secondary winding voltage
(d) Current through SR2
(e) Current through SR3



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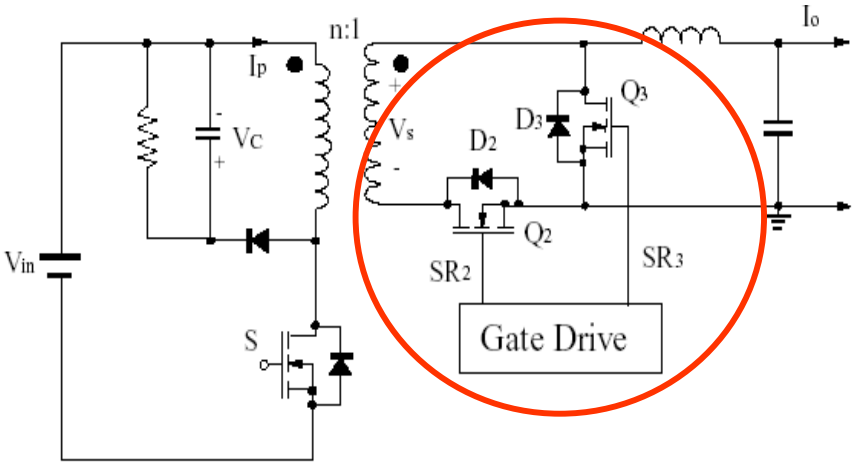
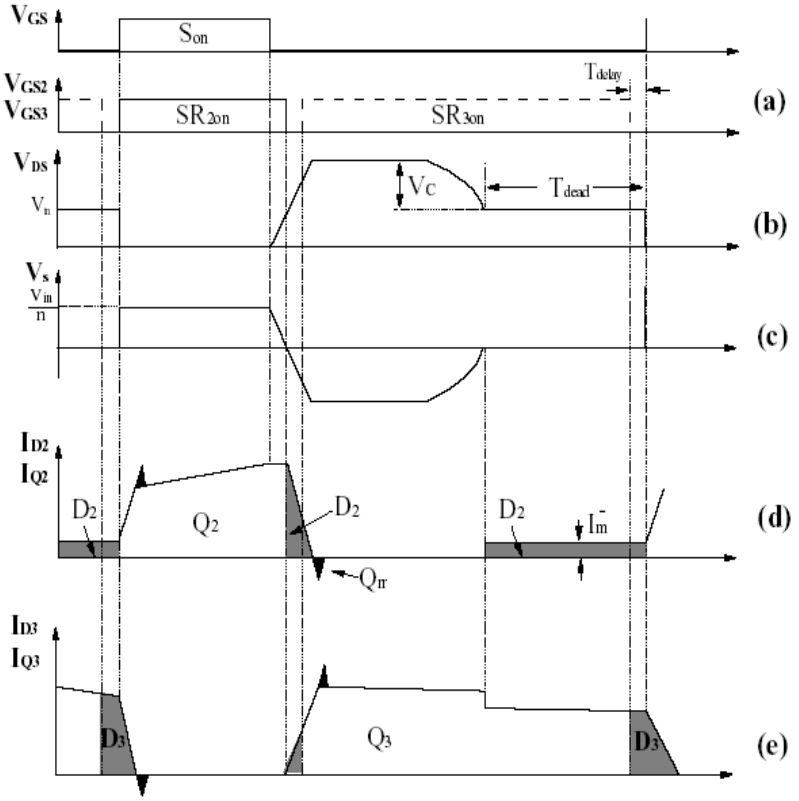
C. Synchronous Rectifier

C-3 Control – Driven SRs





(a) Gate –Driver signal
(b) Drain to Source voltage of primary switch
(c) Secondary winding voltage
(d) Current through SR2
(e) Current through SR3

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D. Power Loss Comparisons

$$\eta = \frac{P_o}{P_o + P_{loss} + P_{REC}}$$ → Converter efficiency

$$\eta_{SH} = \frac{P_o}{P_o + P_{loss} + P_{SH}}$$ → Converter Efficiency (For Schottky Rectifiers)

$$\eta_{SR} = \frac{P_o}{P_o + P_{loss} + P_{SR}}$$ → Converter Efficiency (For Synchronous Rectifiers)

P_O : Output Power
P_{SH} : Schottky Rectifiers Loss
P_{loss} : Total Loss ;
P_{SR} : Synchronous Rectifiers Loss

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D. Power Loss Comparisons

$$P_{SH} = V_{SH} I_o$$ → Schottky Power Loss

$$P_{SR}^{sd} = R_{DS(on)} I_o^2 (1 - D_{dead}) + V_D I_o D_{dead} + P_{gate} + P_{RREC}$$ → Self – Drivens SR Loss

$$P_{SR}^{cd} = R_{DS(on)} I_o^2 (1 - D_{dead}) + R_{DS(on)} (I_o - I_m^-)^2 (D_{dead} - D_{delay})$$ → Control – Drivens SR Loss

$$+ V_D I_m^- D_{dead} + V_D (I_o - I_m^-) D_{delay} + P_{gate} + P_{RREC}$$

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D. Power Loss Comparisons

$$\frac{1}{\eta_{SR}^{sd}} = \frac{1}{\eta_{SH}} - \frac{V_{SH}}{V_o}\left[1 - \frac{R_{DS(on)} I_o}{V_{SH}}(1 - D_{dead}) - \frac{V_D}{V_{SH}} D_{dead}\right] \longrightarrow$$

Efficiency
(RCD Self –Driven SRs)

$$\frac{1}{\eta_{SR}^{acl}} = \frac{1}{\eta_{SH}} - \frac{V_{SH}}{V_o}\left[1 - \frac{R_{DS(on)} I_o}{V_{SH}}\right] \longrightarrow$$

Efficiency
(Active Self –Driven SRs)

$$\frac{1}{\eta_{SR}^{cd}} = \frac{1}{\eta_{SH}} - \frac{V_{SH}}{V_o}\left[1 - \frac{R_{DS(on)} I_o}{V_{SH}}(1 - D_{dead}) - \frac{R_{DS(on)} I_o}{V_{SH}}\left(1 - \frac{\bar{I_m}}{I_o}\right)^2 (D_{dead} - D_{delay}) - \frac{V_D}{V_{SH}} \frac{\bar{I_m}}{I_o} D_{dead} - \frac{V_D}{V_{SH}}\left(1 - \frac{\bar{I_m}}{I_o}\right) D_{delay}\right] \longrightarrow$$

Efficiency
(Control –Driven SRs)

$V_D = V_{SH}$ = Body Diode Voltage ; D_{dead} = dead time duty cycle ; D_{delay} = delay time duty cycle

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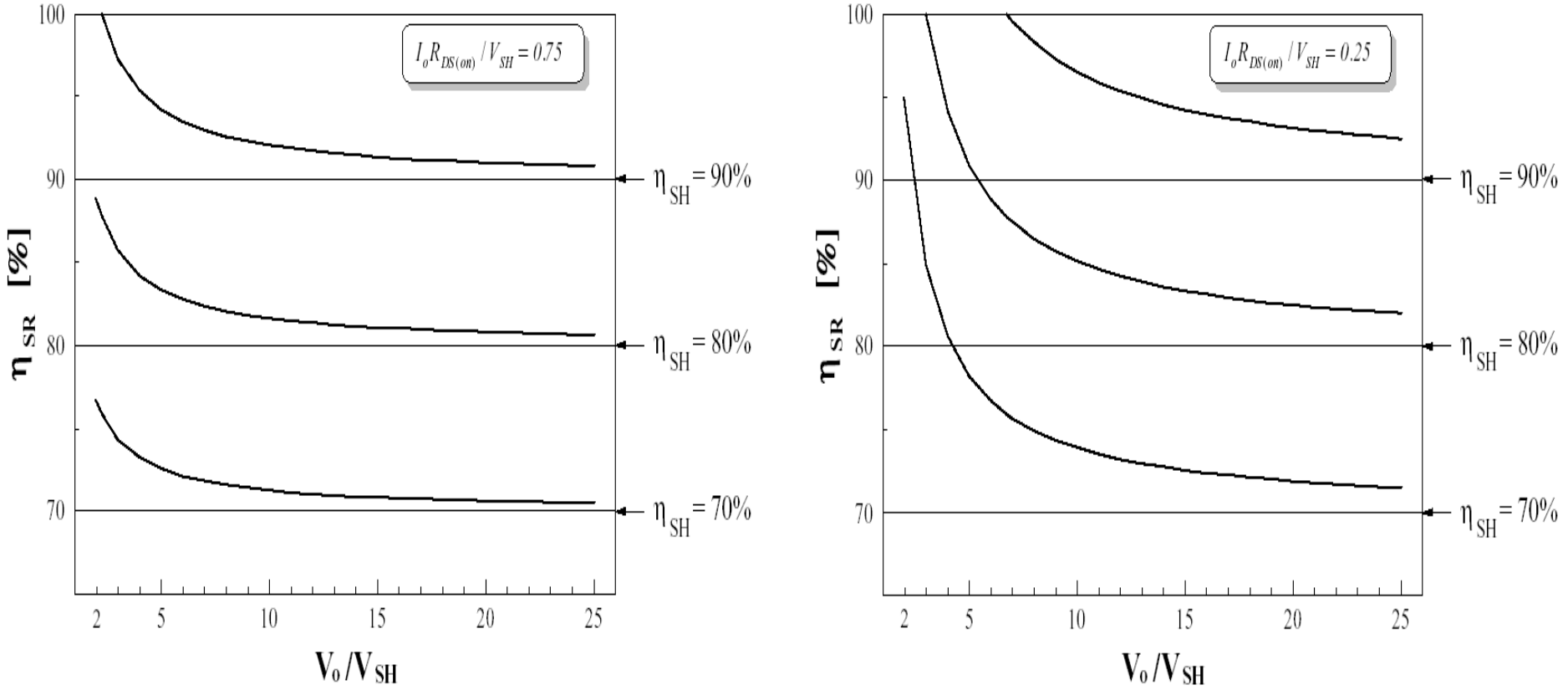
E. Efficiency Curve



$D_{delay} \approx 0$

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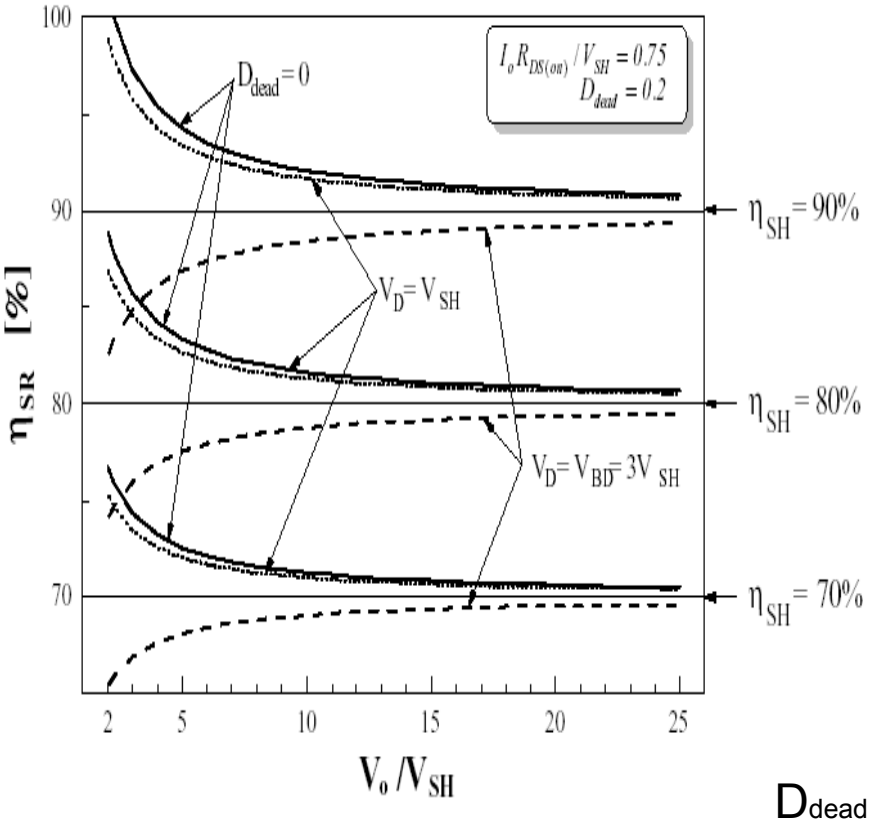
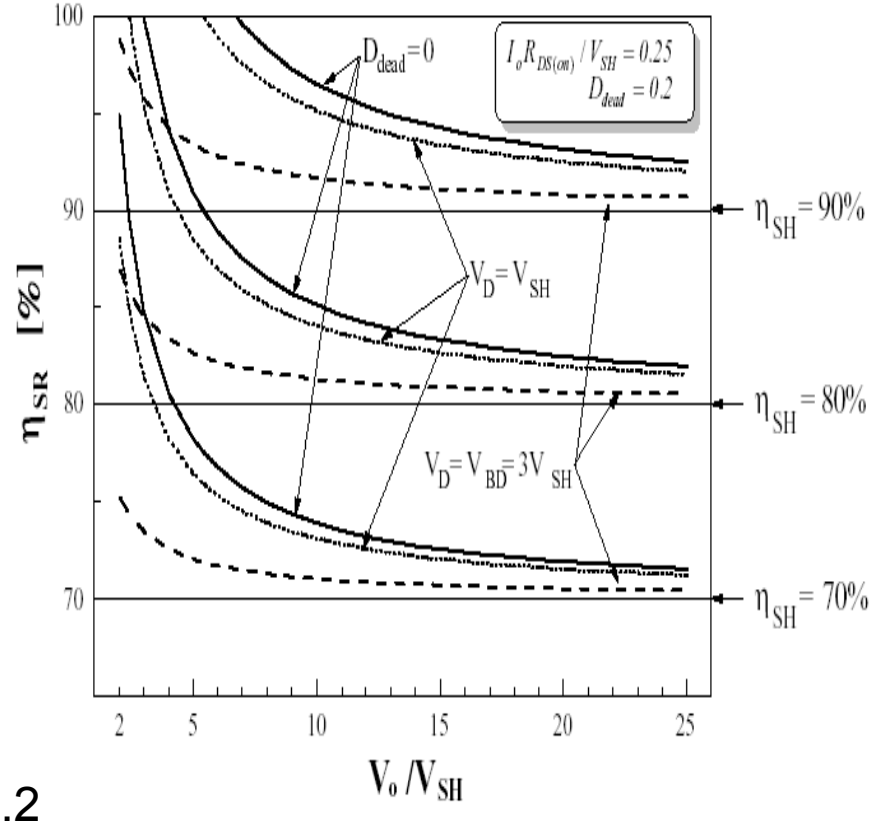
E. Efficiency Curve





$D_{dead} \approx 0.2$

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