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# Voltage-Source Parallel Resonant Class E Oscillator

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# Outline

1. Research Background
2. Proposed Circuit
3. Circuit Experiments
4. Conclusion

# Outline

# 1. Reserch Background

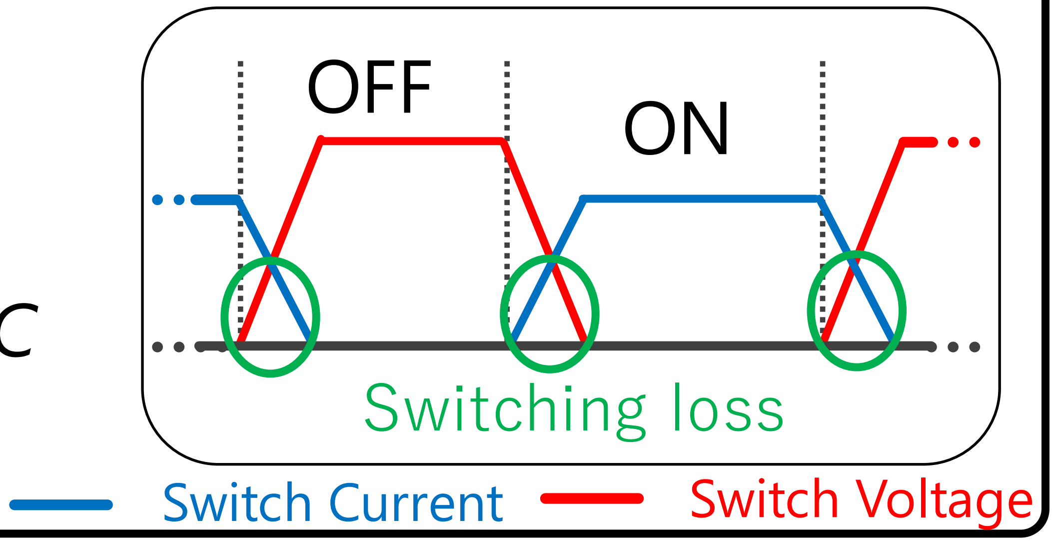
Demands

・Increasing the power density
→Downsizing

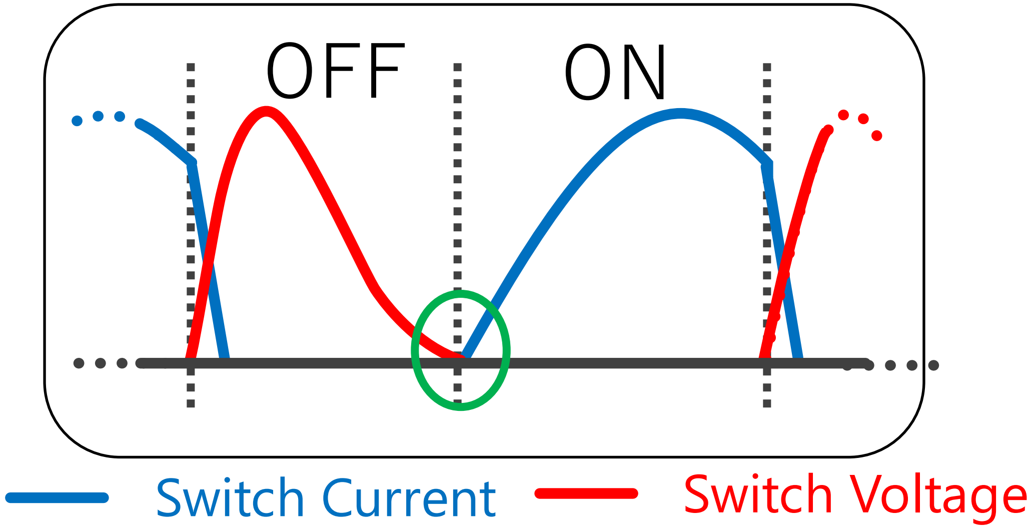
High frequency

・$X_L = 2\pi f L$ ・$X_C = 1/2\pi f C$

Downsizing




Class E switching condition



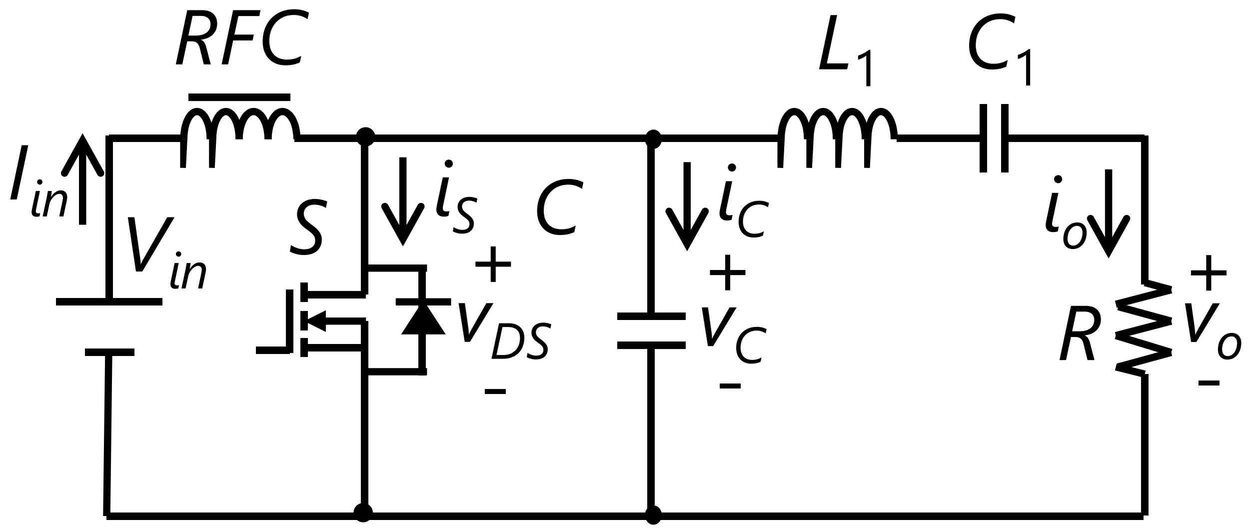

Minimizing Dissipated Power:

At the switching instant
- ZVS (Zero-Voltage Switching)
- ZVDS (Zero-Voltage Derivative Switching)
- ZCS (Zero-Current Switching)

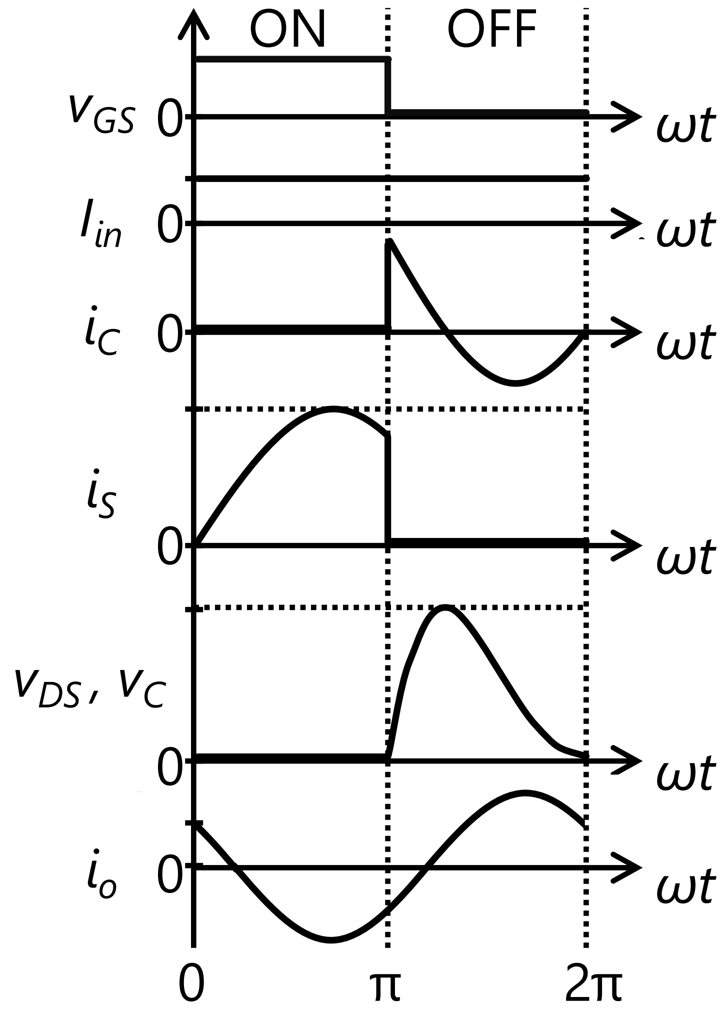
**Features**

- Low switching loss
- Low noise

# 1. Class E Amplifier[1]




Class E amplifier[1]



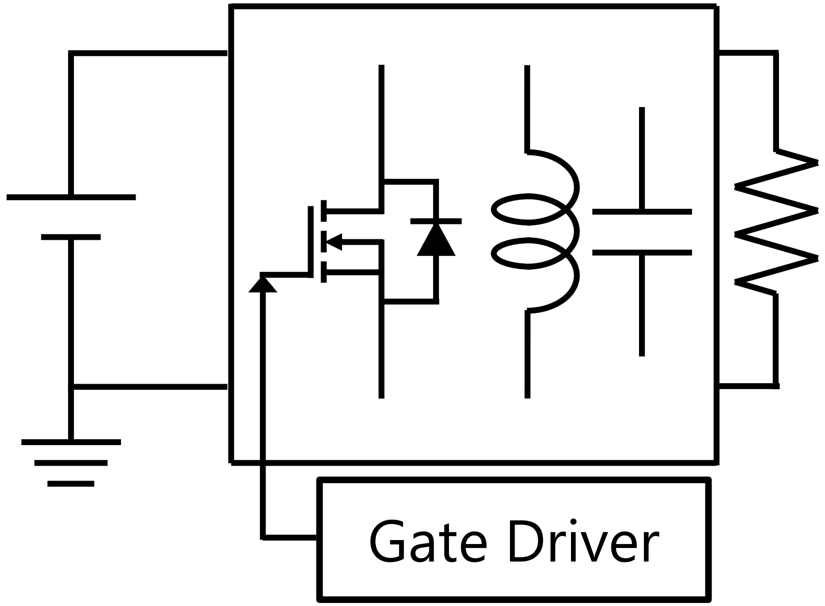

**<u>Featuers</u>**

- Achieving ZVS ,ZVDS and ZCS
  →High efficiency even at high operating frequency

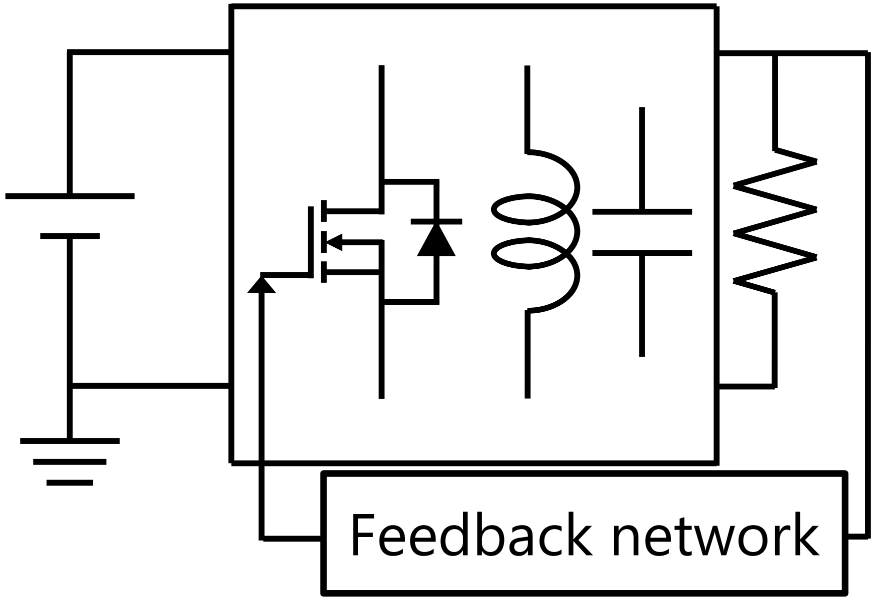

[1] N. O. Sokal et al., "Class E-A new class of high efficiency tuned single-ended switching power amplifiers," IEEE J. Solid-State Circuits,, vol. SC-10, pp. 168-176, June 1975.

# 1. Tuned Power Inverter and Oscillator[A]

Switching inverter




Switching oscillator




**Features**

- Switching device is driven by the gate driver

**Features**

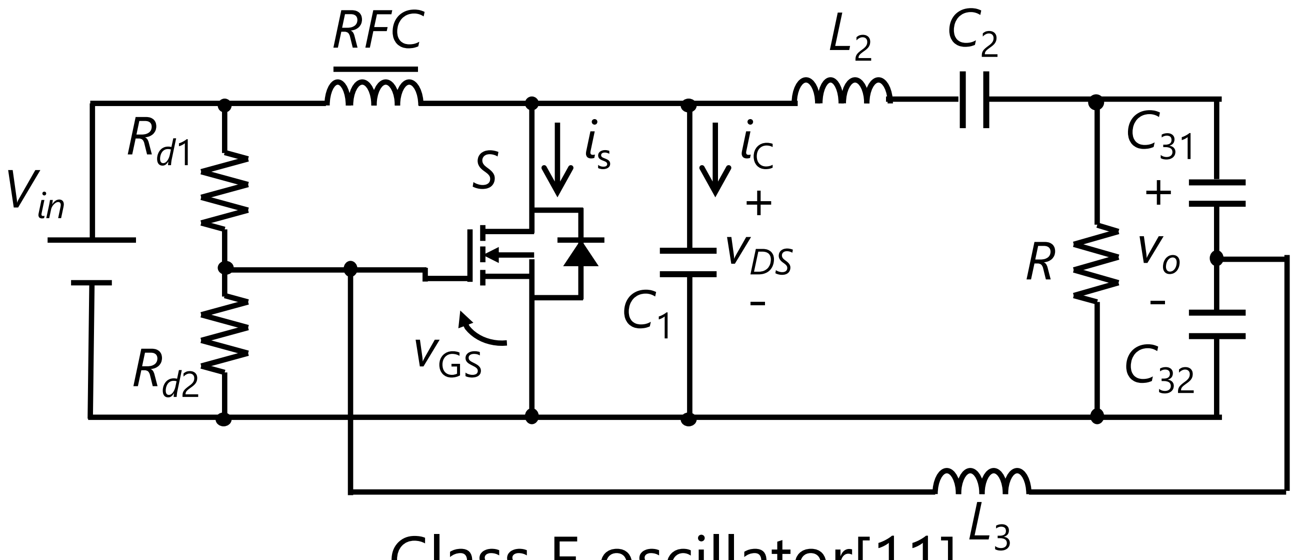
- Switching device is driven by the feedback voltage

**Point**

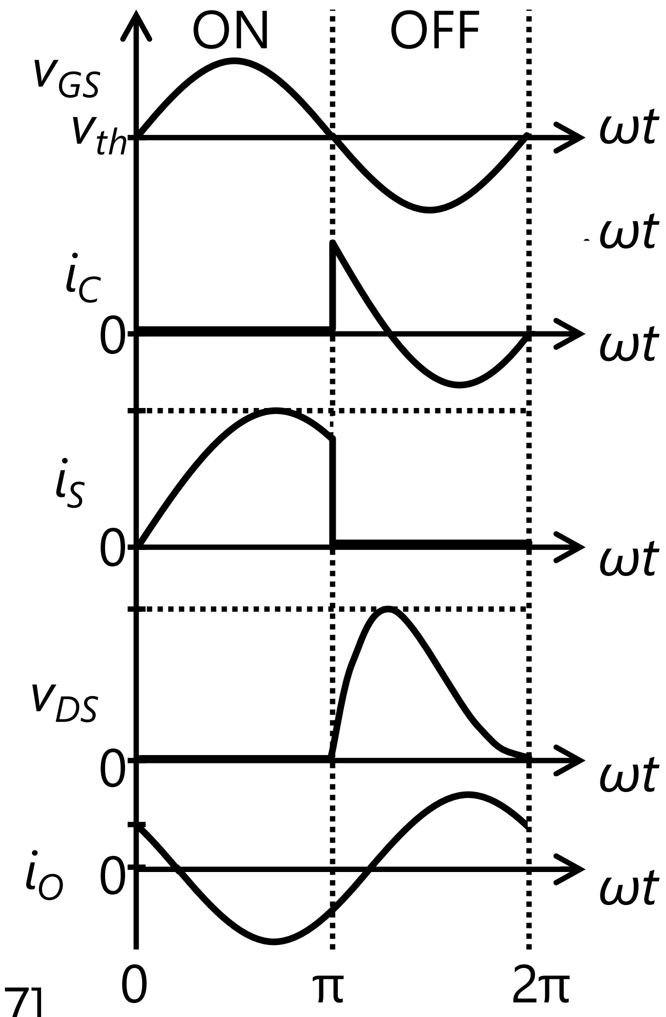
- Making a self-oscillation using the feedback mechanism

[A] Hiroo Sekiya, "Review of Tuned Power Oscillator,"2016 International Symposium on Nonlinear Theory and Its Applications,NOLTA2016, Yugawara, Japan, November 27th-30th, 2016

# 1. Class E Oscillator[11]




Class E oscillator[11]

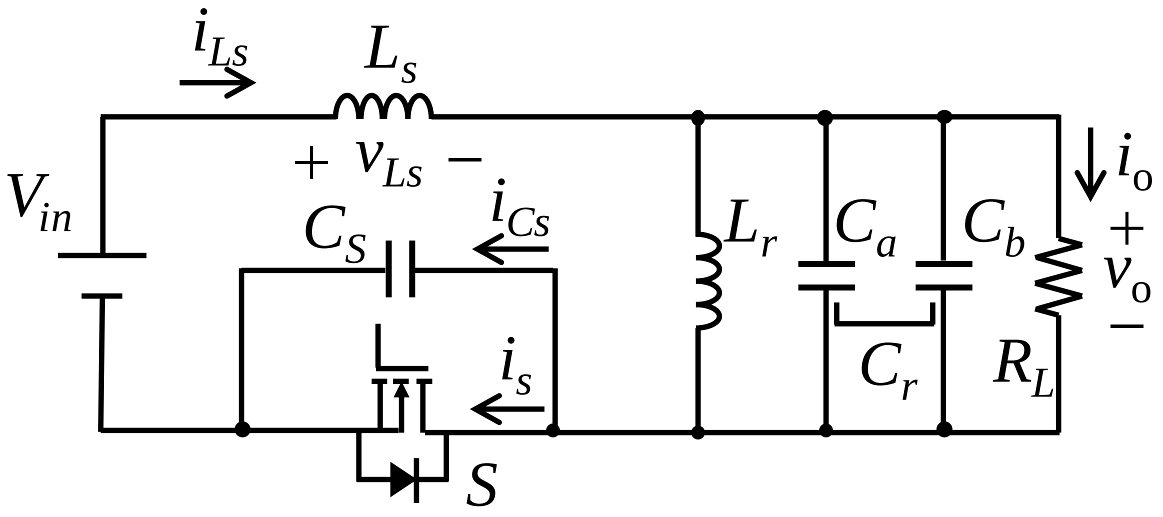



**Features**

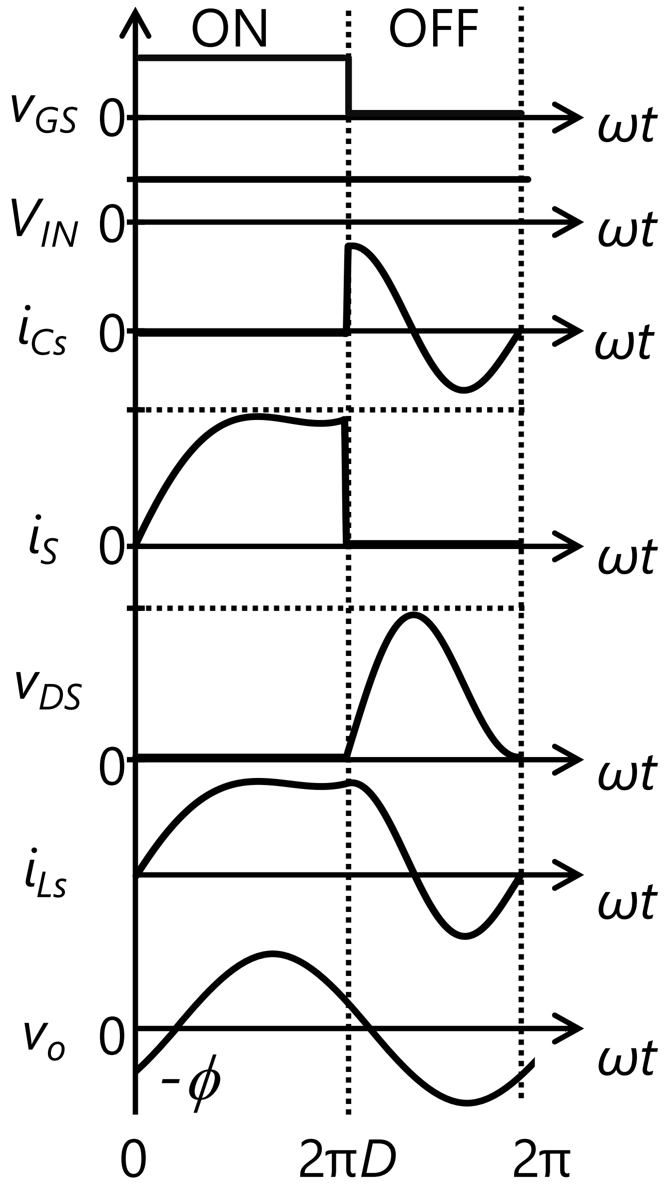
- Switching device driven by the feedback voltage from the ac output
- Achieving ZVS, ZVDS and ZCS
  →High efficiency even at high operating frequency
- Several types of Class E oscillators proposed
  →Class E/F[15], Parallel tuned class E[16], Load-independent class E[17]

[11]M. K. Kazimierczuk et al.,"Class-E MOSFET tuned power oscillator design procedure," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 52, no. 6, pp. 1138-1147, June 2005

# 1. Voltage-Source Parallel Resonant Class E Inverter [8]




Voltage-source parallel resonant class E inverter[8]




**<u>Featuers</u>**

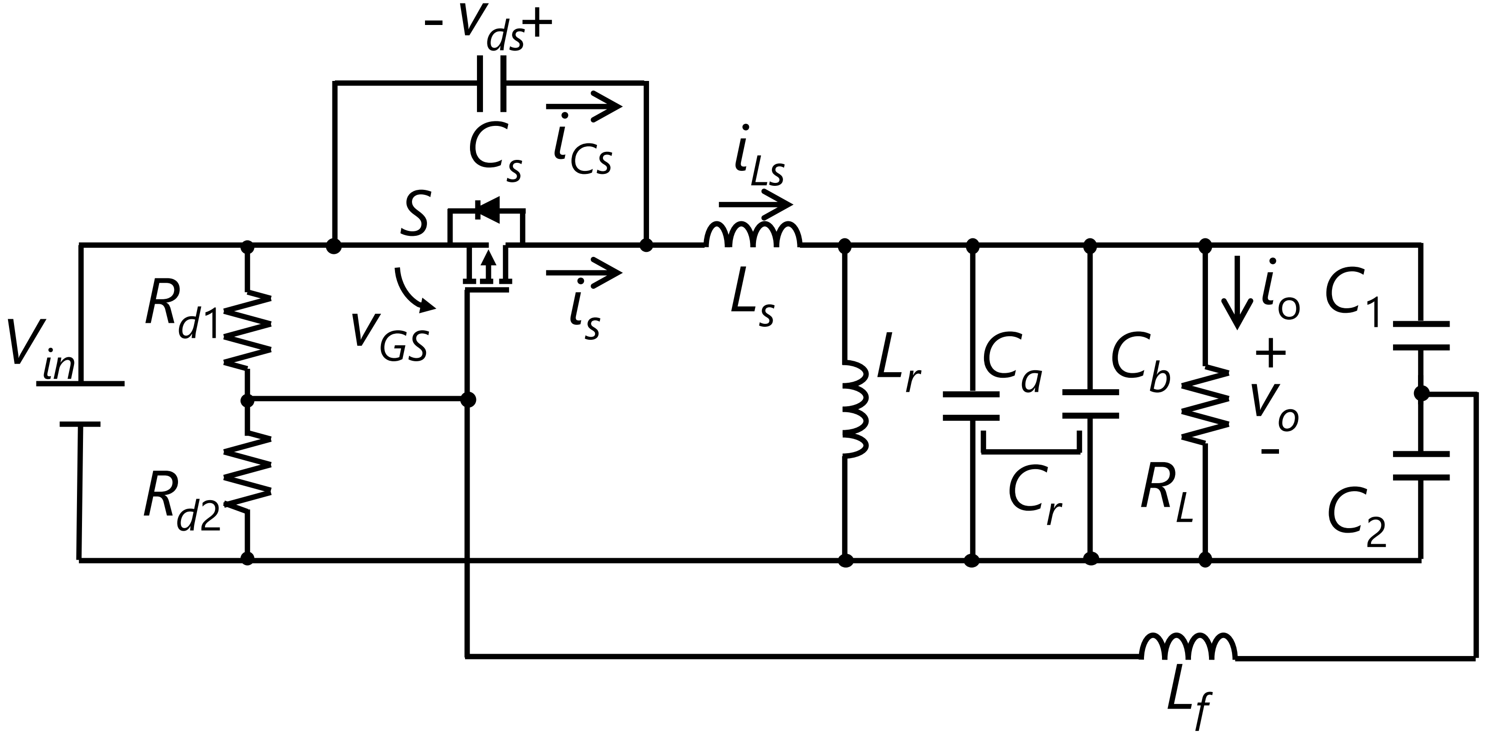
- $L_S$-$C_S$ resonant circuit
  →No choke inductor or dc blocking capacitor
- Parallel resonant tank
  →Robustness against load fluctuations
- Achieving ZVS and ZVDS
  →High efficiency even at high operating frequency

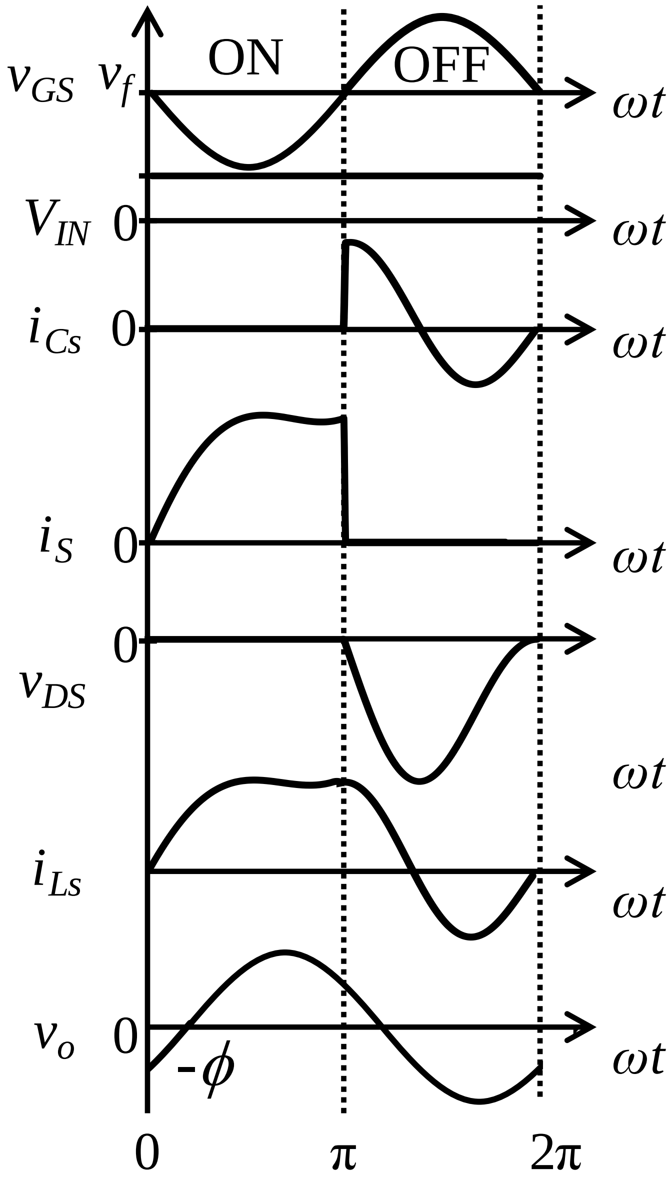
[8]A. Shigeno and H. Koizumi, "Voltage-Source Parallel Resonant Class E Inverter," in IEEE Transactions on Power Electronics, vol. 34, no. 10, pp. 9768-9778, Oct. 2019.

# Outline

1. Research Background
2. Conventional Circuits
3. Proposed Circuit
4. Circuit Experiments
5. Conclusion

# 2. Voltage-Source Parallel Resonant Class E Oscillator



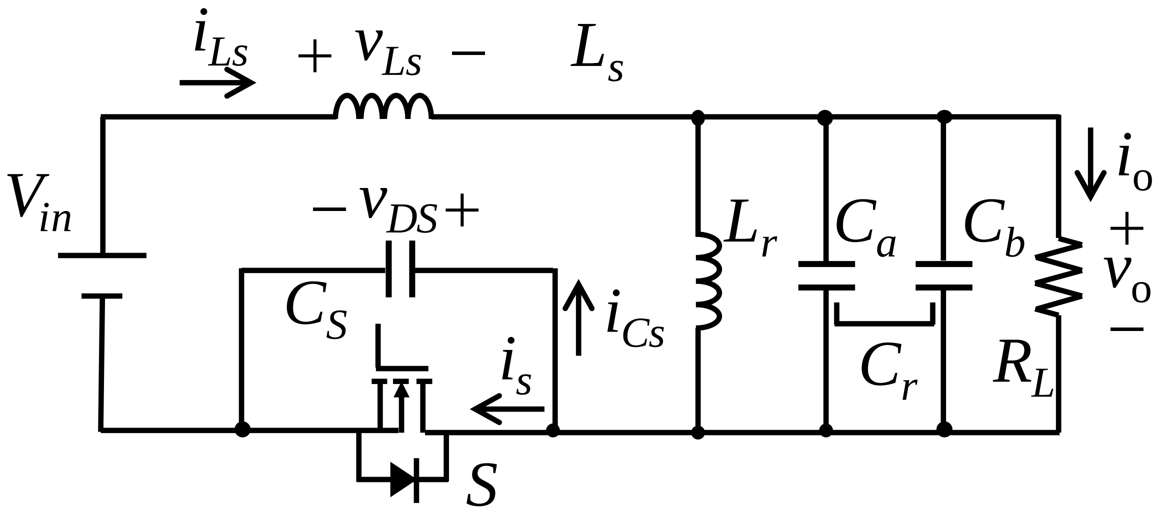




Voltage-source parallel resonant class E oscillator

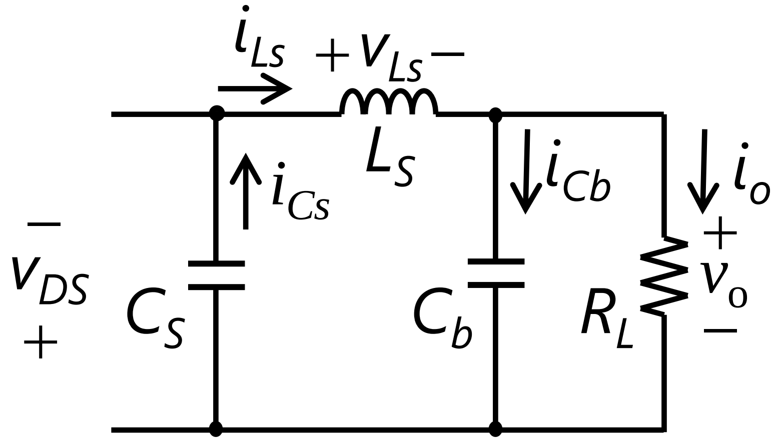
**Featuers**

- $L_S$-$C_S$ resonant circuit
  →no choke inductor or dc blocking capacitor
- Parallel resonant tank
- Achieving ZVS, ZVDS and ZCS
- P-ch power MOSFET

# 2. Design Method of the Feedback Network



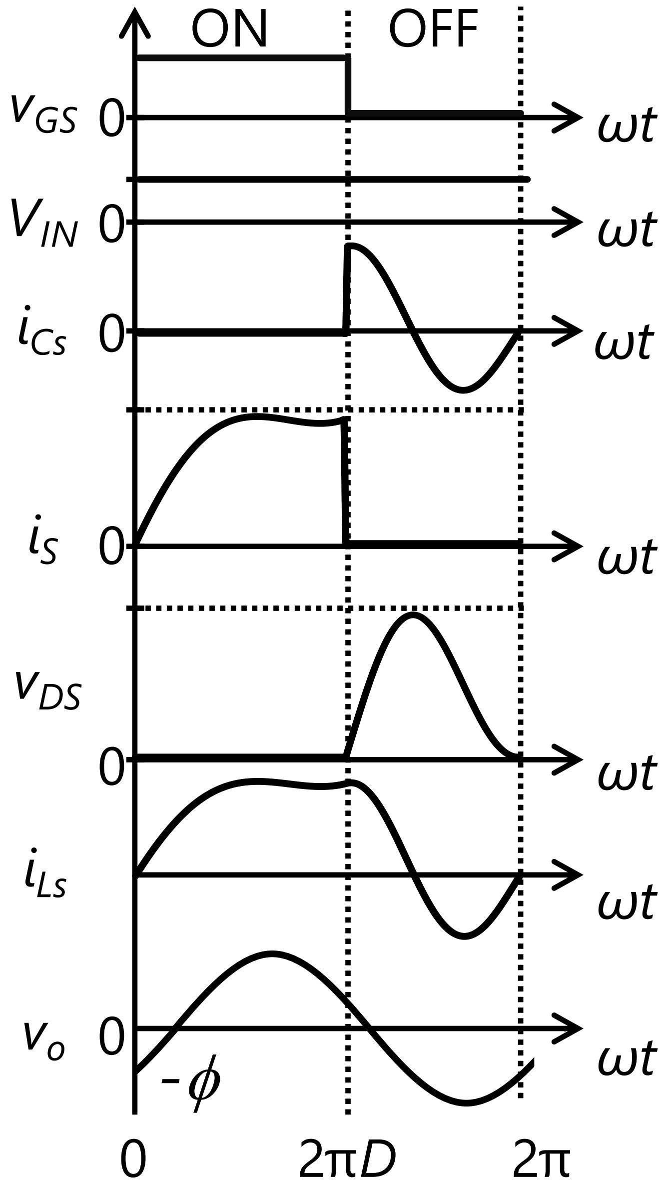

Voltage-source parallel resonant class E inverter[8]



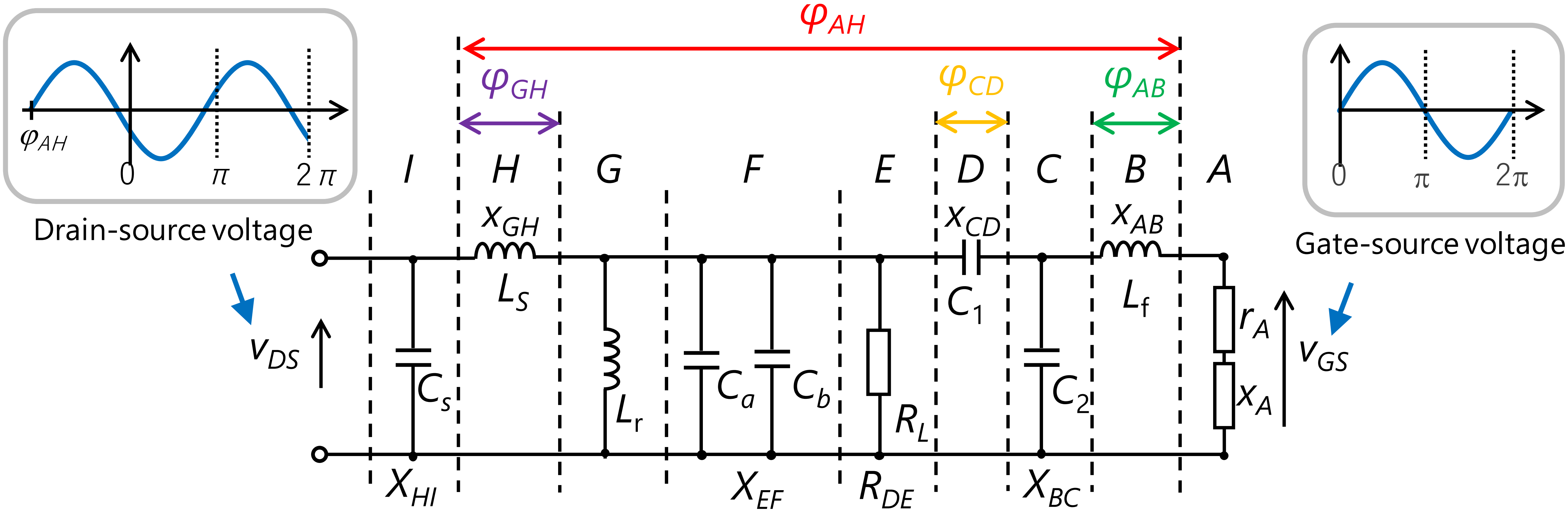

Equivalent circuit under fundamental frequency

$$
\begin{aligned}
v_{DS}(\omega t) &= -v_o(\omega t) - v_{LS}(\omega t) \\
&= -V_{DS}\sin(\omega t + \phi + \varphi) \\
&= V_{DS}\sin(\omega t + \theta)
\end{aligned}
$$

Phase shift from gate to drain under ZVS/ZDS condition



# 2. Design Method of the Feedback Network




Equivalent circuit of the Voltage-source parallel resonant class E oscillator

Phase shift from gate to drain under ZVS/ZDS condition

$$\varphi_{AH} = \varphi_{GH} + \varphi_{CD} + \varphi_{AB} = \theta$$

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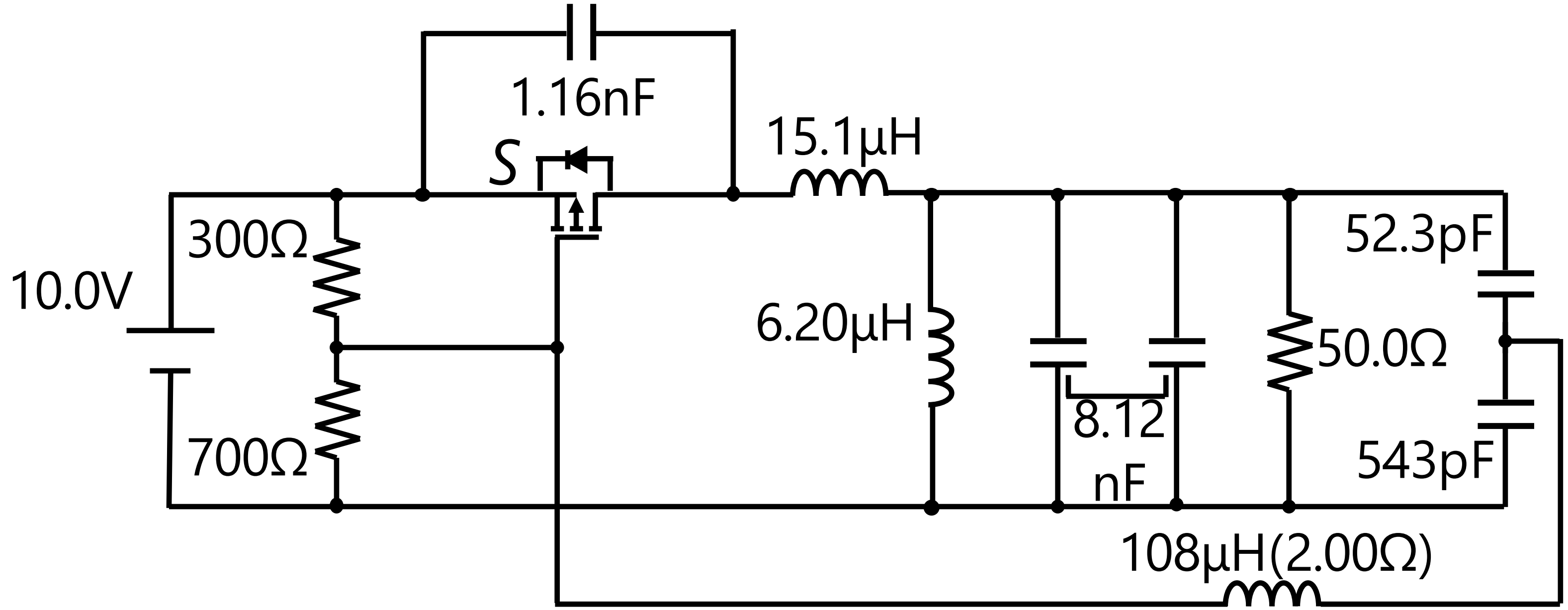
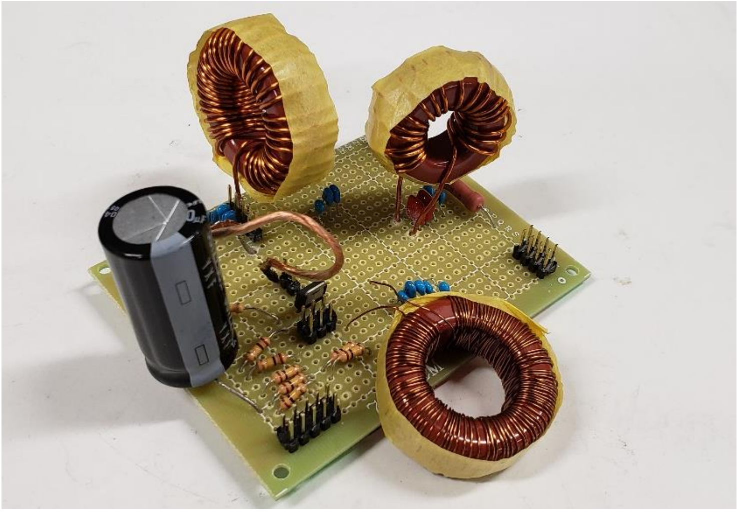
# 3. Parameters in Circuit Experiment

**Specifications**

- Oscillation frequency $f$ = 800 kHz
- On duty ratio $D$ = 0.5
- Loaded quality factor $Q$ = 2.00
- Input voltage $V_{in}$ = 10.0 V
- Load resistance $R_L$ = 50.0 Ω
- Output power $P_{out}$ = 1.00 W

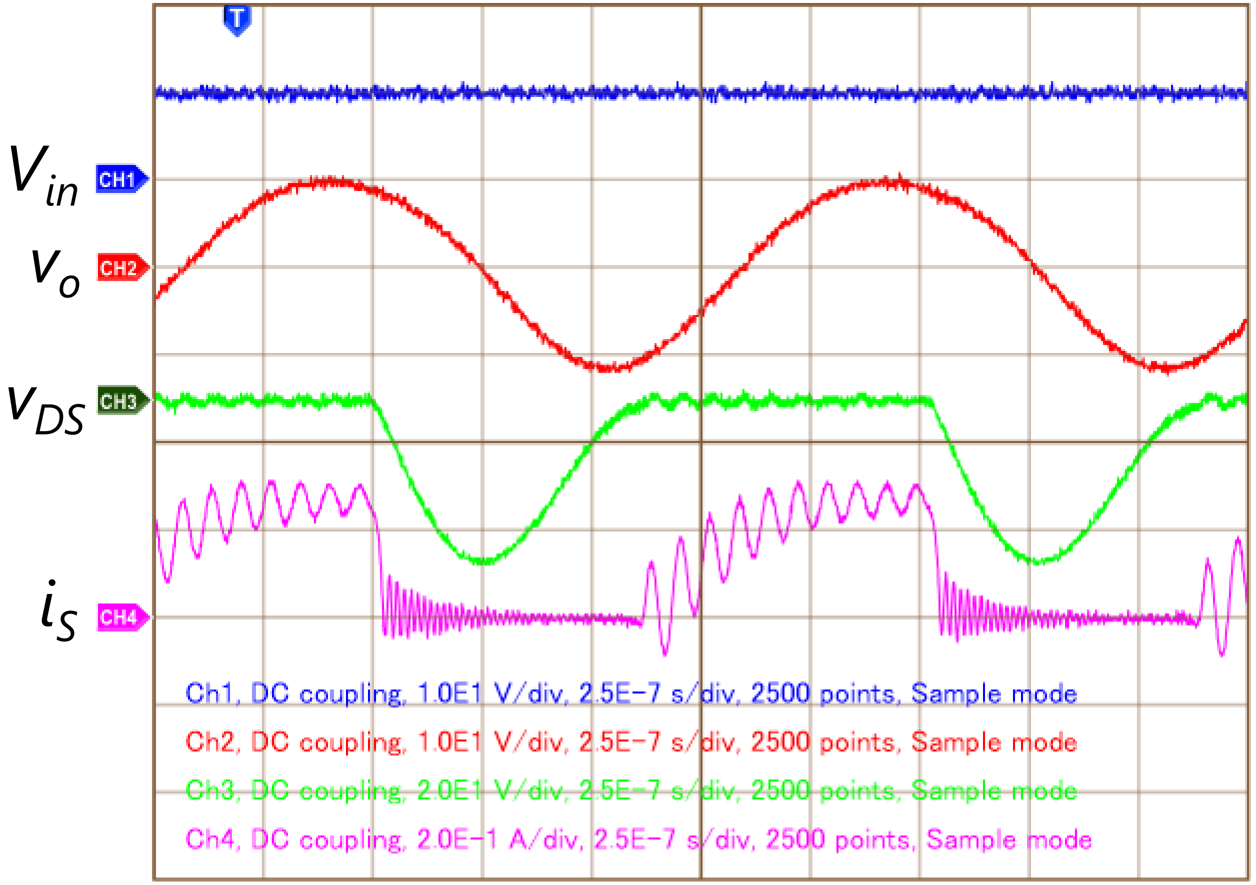


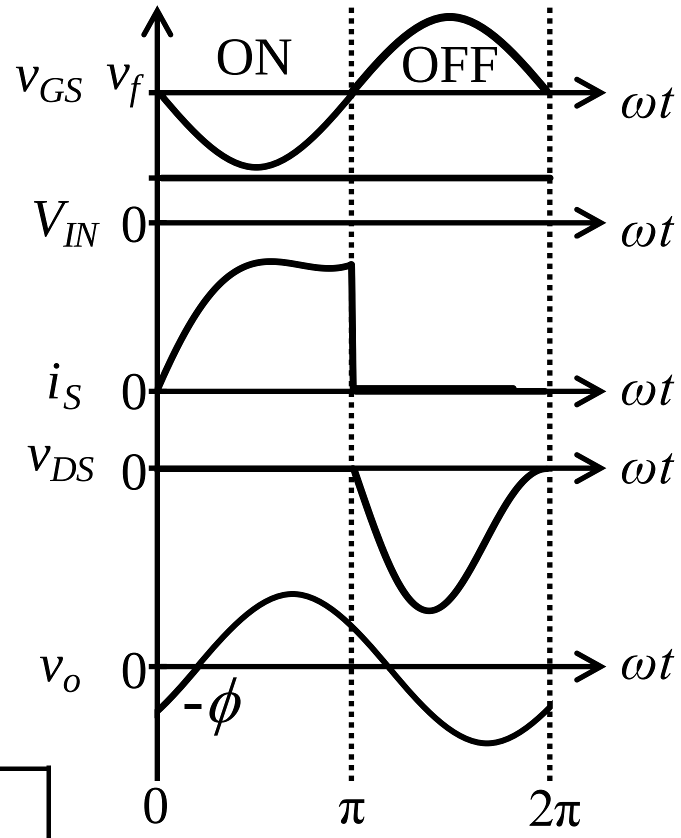

Proposed circuits

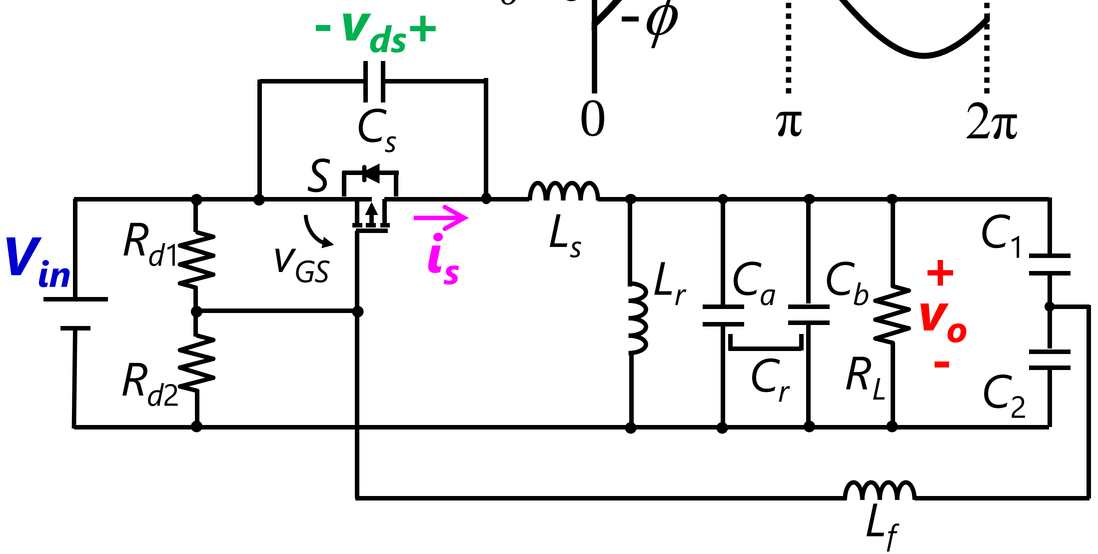


Experimental setup

# 3.Experimental results




Power conversion efficiency = 89.49%

Oscillation frequency = 786.4kHz

# Outline

1. Research Background

2. Proposed Circuit

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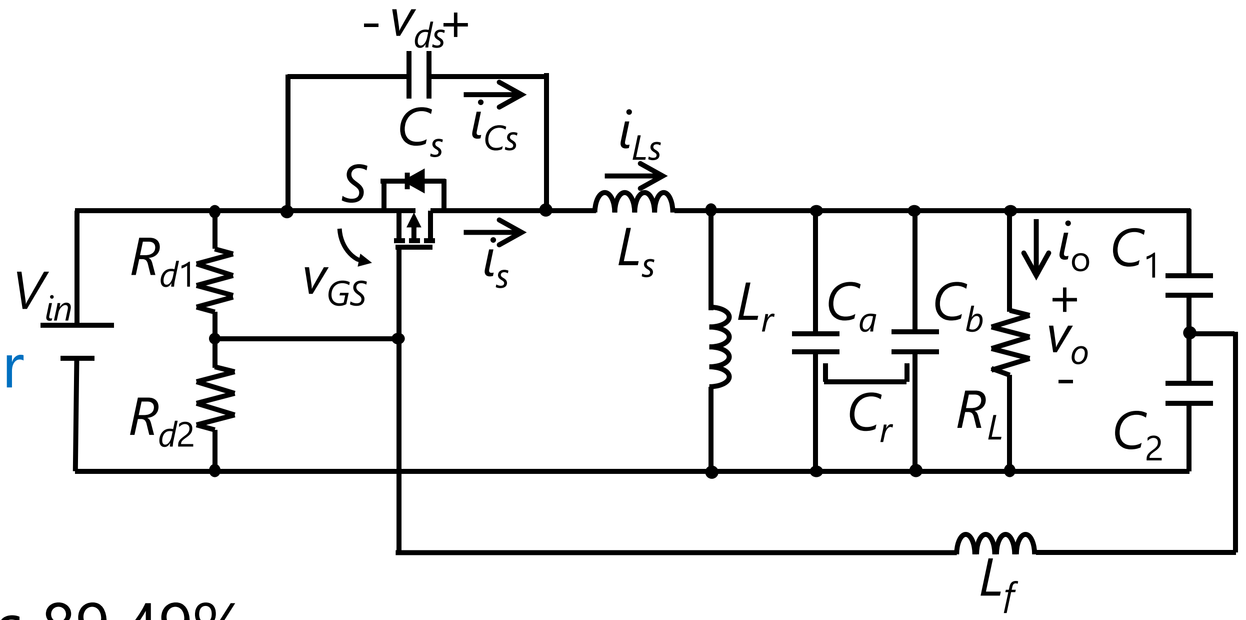
# 4. Conclusion

✓ Voltage-Source Parallel Resonant Class E Oscillator has been proposed

**<u>Featuers of the proposed oscillator</u>**

- Switching device driven by feedback voltage
- No choke inductor or blocking capacitor
- Parallel resonant tank




✓ Measured power conversion efficiency was 89.49% at the oscillation frequency 786.4kHz and output power 1.056W

## Thank You

If you have any questions, feel free to ask me “4320516@ed.tus.ac.jp”

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