Power Electronics
Flyback Converter Circuit

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Abstract - This report focuses on the design and analysis of flyback converters through direct experiments, aiming to understand their operating principles and losses. The flyback converter is a type of isolated buck-boost converter that can have an output voltage higher or lower than the input voltage. It is known for its low cost, simple design, high efficiency, and low power loss. Similar to buck-boost converters, flyback converters utilize MOSFETs and diodes for switching operations. The report includes experimental investigations on controlling the voltage using a transformer, which is a key feature of the flyback converter. The relationship between input and output voltages is explored, and the experimental values are compared to theoretical values using oscilloscope measurements. The report also covers the analysis of magnetization inductance generated by the transformer and presents the output waveforms of each component through PSIM simulation. Overall, the report provides insights into the design and performance of flyback converters, shedding light on their practical implementation and efficiency.

I. Introduction

A flyback converter is a type of insulated buck-boost converter capable of generating output voltages that can be either lower or higher than the input voltage. It finds application in low-power DC-to-DC conversion and serves as an auxiliary power supply or battery charger. For instance, flyback converters are commonly employed as auxiliary power supplies in electronic devices, communication systems, small appliances, and mobile devices. They can also be utilized in battery charging systems, where they convert the input voltage to provide the necessary voltage for charging or even feed back excess energy generated by the battery to the grid.

In comparison to buck-boost converters, flyback converters employ a simplified circuit design by utilizing a single switch. This configuration reduces the complexity and cost of the circuit. Unlike buck-boost converters, which rely on inductors for voltage conversion, flyback converters utilize transformers to store and control energy. The transformer plays a crucial role in the flyback converter by facilitating the conversion between input and output voltages. It enables energy transfer by accumulating and releasing magnetic energy. Typically, transformers in flyback converters consist of coils and iron cores, which provide magnetic inductance for energy storage.

The advantages of flyback converters lie in their simple circuit design, low component count, cost-effectiveness, and high conversion efficiency, resulting in reduced power losses. These factors make them an attractive choice for various applications, particularly in scenarios requiring efficient and affordable power conversion.

In summary, a flyback converter is an insulated buck-boost converter capable of generating variable output voltages. It offers advantages such as a simple circuit design, low component count, cost-effectiveness, and high conversion efficiency. The transformer used in flyback converters plays a crucial role in voltage conversion and energy transfer.

Through this experiment, we aim to understand the structure and operation principle of the flyback converter. We will investigate the variation of the output voltage by controlling the Duty(D) cycle and observe the changes in response to different frequencies. Additionally, we will analyze the losses that occur during the switching processes of the MOSFET, equivalent series resistance (ESR), and the transformer.

By conducting this experiment, we expect to gain insights into the underlying causes of these losses and further enhance our understanding of the flyback converter's performance.

II. Principle of Flyback Converter Operation

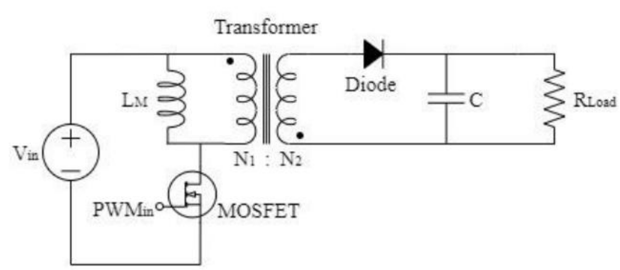


Figure 1. Circuit of Flyback converter

1) Understanding Flyback Converter Components

Components	Dual Op-amp	PWM modulator	Gate Driver	MOSFET	Transformer
Device	TLE207X	TL494	TC1426	IRF830	MID-FLYLT
Quantity	1EA	1 EA	1 EA	1 EA	1 EA

Table 1. Flyback Converter Components

Table 1 illustrates the major components of the flyback converter, which can be divided into five elements. The Dual Op-amp serves as a Voltage Divider to reduce the voltage input to the PWM modulator. The PWM modulator generates a pulse signal and amplifies the output voltage to the Gate Driver. The MOSFET is responsible for the switching operation. As mentioned earlier, the Transformer performs voltage conversion by utilizing the winding ratio.

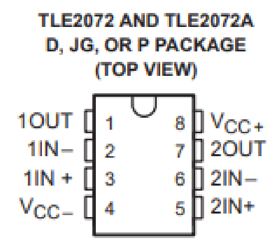


Figure 2. Pinout of TLE2072

The TLE2072 is a dual op-amp integrated circuit that combines two independent operational amplifiers on a single chip. Each op-amp is designed to amplify and manipulate input signals.

In our experiment, we utilized a specific model of TLE2072 with two input pins and two output pins. This integrated circuit operates at a low voltage and serves as a voltage divider. By using the op-amps, it divides the voltage and provides the desired output voltage (3.5[V]) for the PWM generator.

Dual op-amps, like the TLE2072, find wide application in various electronic circuits for input signal processing. Their versatility and independent operation greatly simplify circuit design and implementation, leading to efficient performance.

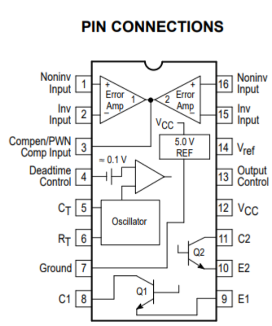


Figure 3. Pinout of TL494

The TL494 is a PWM generator that converts a DC voltage, which passes through a Voltage Divider, into a pulse waveform. It consists of several key components, including an error amplifier, a comparator, an error measurement circuit, an internal oscillator, and an output driver.

The error amplifier in the TL494 measures the difference or error between the comparison signal and the reference voltage. This error signal is then fed back to the control circuit for further processing.

The comparator in the TL494 compares the input signal with the reference signal and generates a pulse width modulated signal based on this comparison. The pulse width modulated signal determines the Duty cycle(D) or the on-time of the pulse waveform.

The error measurement circuit processes the error signal received from the error amplifier and provides feedback to ensure accurate control and regulation of the output.

The internal oscillator of the TL494 generates a reference frequency, which is utilized by the comparator for its operation. This reference frequency helps determine the timing and frequency characteristics of the pulse waveform.

Finally, the output driver of the TL494 generates the PWM output signal based on the input signals and controls the output of the switching power supply or inverter accordingly.

PWM generators, such as the TL494, produce pulse waveforms that are divided into on-state and off-state periods. The duty ratio refers to the ratio of the on-state duration to the total period of the pulse waveform and plays a crucial role in controlling the output voltage or power level.

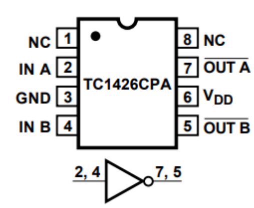


Figure 4. Pinout of TC1426

The TC1426 amplifies and outputs the voltage received from the PWM generator to the Gate Driver element. The purpose of amplifying the voltage is to exceed the threshold voltage of the MOSFET. The voltage of 5[V] received from the PWM generator is boosted to 12[V] when passing through the gate driver, and the phase is switched accordingly. The TC1426 is designed to support high-speed, high-current, and low-voltage gate driving. This feature enables effective control of the gates of MOSFETs or IGBTs and ensures reliable operation in circuits such as switching power supplies and inverters.

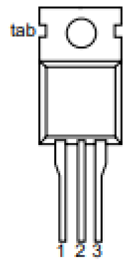


Figure 5. Pinout of IRF830

The IRF830 is an N-channel MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) known for its powerful switching capabilities in high voltage and high current applications. It has three pins: pin 1 for the gate, pin 2 for the drain, and pin 3 for the source, as shown in Figure 5.

With its suitability for high voltage and high current applications, the IRF830 finds wide usage in various fields including automotive electronics, inverters, switching power supplies, and motor control.

Featuring the basic structure of a MOSFET, the IRF830 consists of an insulating gate with a canadle in the case. It controls the flow of current by adjusting the gate voltage.

The IRF830 is characterized by its low resistance and capability to handle high voltages. These attributes ensure efficient switching behavior and reliable performance.

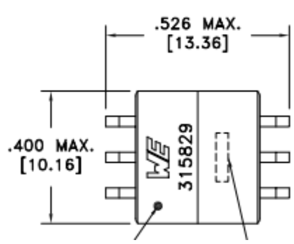


Figure 6. Pinout of MID-FLYLT

The MID-FLYLT is a family of power transformers consisting of specific models with an input voltage range of 36V to 72V and a frequency range of 50kHz to 200kHz. These transformers are designed specifically for high-frequency switching applications.

The MID-FLYLT power transformers find their primary applications in high-frequency systems such as switching power supplies, inverters, and chargers. They play a crucial role in converting the input voltage to the desired output voltage. Additionally, their design is optimized for high-speed switching, ensuring minimal power loss and efficient energy conversion.

Manufactured using high-quality materials and advanced manufacturing techniques, the MID-FLYLT power transformers are known for their reliability and consistent performance across a wide frequency range.

Transformers are fundamental components in power conversion systems, responsible for converting and transferring electrical energy. They operate based on the principle of converting electrical energy into magnetic energy using electromagnetic fields and then re-converting it back into electrical energy.

By incorporating the MID-FLYLT power transformer into your design, you can expect efficient power conversion, reliable performance, and compatibility with high-frequency applications.

2) Understanding Flyback Converter Operation

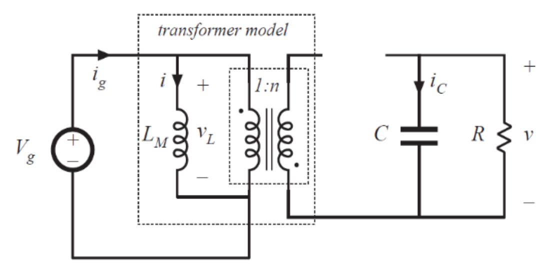


Figure 7. Operation of Flyback Converter: On State

On source side of the transformer, small ripple approximation leads to

$$v_L = V_g$$

$$i_c = -\frac{V}{R}$$

$$i_g = I$$

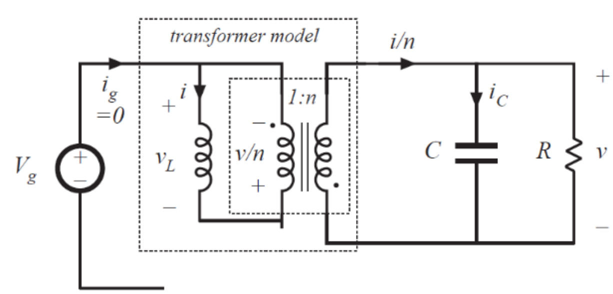


Figure 8. Operation of Flyback Converter: Off State

On source side of the transformer, small ripple approximation leads to

$$v_L = -\frac{V}{n}$$

$$i_c = \frac{1}{n} - \frac{V}{R}$$

$$i_g = 0$$

As mentioned in the previous lab, all converters operate in Continuous Conduction Mode (CCM) and steady state conditions. This implies that the amount of charge accumulated in the inductor during the on-time of the duty cycle must be equal to the amount of charge discharged from the inductor during the off-time of the duty cycle.

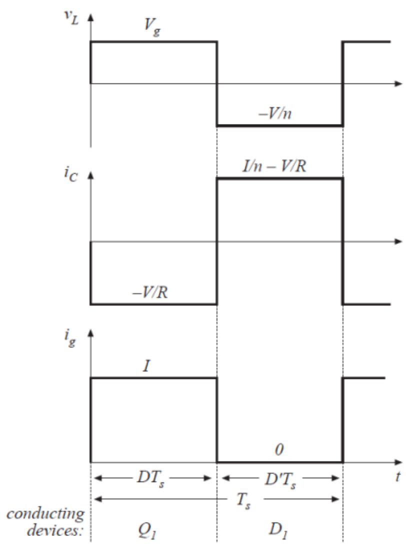


Figure 9. Characteristic curve of V_L, i_c, i_g

Through volt-second balance,

$$\langle v_L \rangle = D(V_g) + (1 - D) \times \left(-\frac{V}{n}\right) = 0$$

Conversion ratio is

$$M(D) = \frac{V}{V_g} = n \times \frac{D}{1 - D}$$

Through charge balance,

$$\langle i_c \rangle = D\left(-\frac{V}{R}\right) + (1 - D) \times \left(\frac{I}{n} - \frac{V}{R}\right) = 0$$

DC components of manetizing current is

$$I = \frac{nV}{(1 - D) \times R}$$

Ripple current I_{Lm} is

$$\frac{di_{Lm}}{dt} = \frac{V_g}{L_m}$$

$$di_{Lm} = \frac{V_g}{L_m}$$

$$\Delta i_{Lm} = \frac{V_g}{L_m} DT$$

DC components of source current is

$$I_g = \langle i_g \rangle = D(I) + (1 - D)(0)$$

3) Discussion Problems

① **In a Flyback converter shown in Fig. 1, $V_{in} = 48\,[V]$, $V_{out} = 5\,[V]$, $n = 1/6$, and the magnetizing inductance $L_m = 150[\mu H]$. This converter is operating in equivalent CCM with a switching frequency $f = 200\,[kHz]$ and supplying an output load $P_{out} = 30\,[W]$. Assuming this converter to be lossless, calculate the input and output waveforms.**

We drew the wave forms required by the problem below through simulation of the PSIM program with the experimental conditions shown in problem.

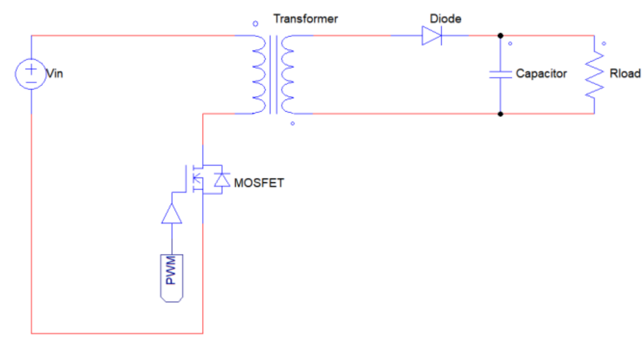


Figure 10. Circuit of Flyback Converter (PSIM)

$$V_o = n \times \left(\frac{D}{1 - D}\right) \times V_{in},$$

$$5 = \frac{1}{6} \times \left(\frac{D}{1 - D}\right) \times 48, \qquad D \cong 0.3846$$

$$T = \frac{1}{f}, \qquad \frac{D}{f} = \frac{0.3846}{200 \times 10^3}, \qquad T = 5[\mu S]$$

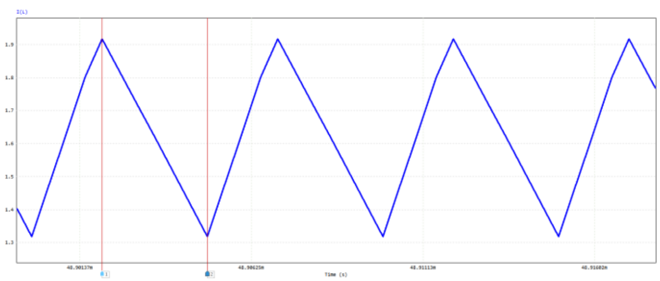
$$P_{out} = \frac{V_{out}^2}{R_{Load}}, \qquad R_{load} = \frac{25}{30}[\Omega] \cong 0.8333[\Omega]$$

$$I_{Lm} = \frac{n \times V_{out}}{(1-D) \times R} = 1.625[\mathrm{A}]$$

$$\Delta i_{Lm} = \frac{V_{in}}{L_m} \times DT = \frac{48}{150 \times 10^{-6}} \times 0.3846 \times 5 \cong 0.6154[\mathrm{A}]$$

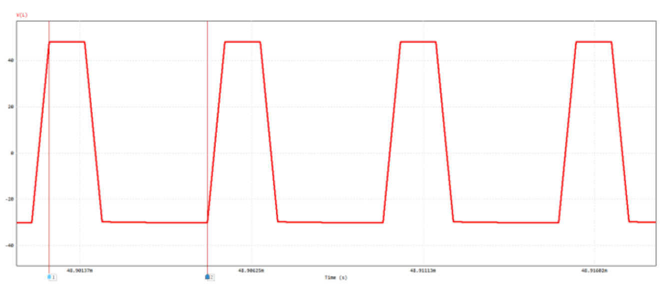
$$I_{Lm,max} = I_{Lm} + \frac{\Delta i_{Lm}}{2} = 1.9327[\mathrm{A}]$$

$$I_{Lm,min} = I_{Lm} - \frac{\Delta i_{Lm}}{2} = 1.3173[\mathrm{A}]$$



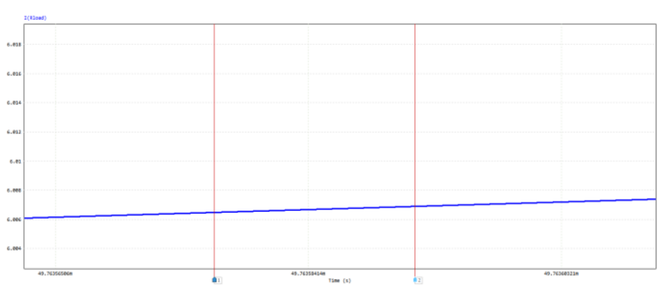
	X1	X2	Δ	Average
Time	4.89020e-02	4.89050e-02	3.00000e-06	
I(L)	1.91768e+00	1.31755e+00	-6.00130e-01	1.61829e+00

Figure 11. Waveform of I_{Lm}



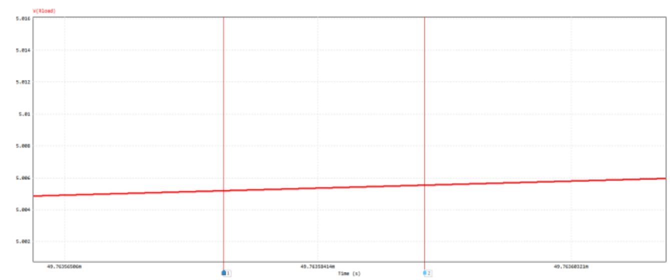
	X1	X2	Δ	Average
Time	4.89005e-02	4.89050e-02	4.50000e-06	
V(L)	4.80000e+01	-3.01884e+01	-7.81884e+01	-8.32068e+00

Figure 12. Waveform of V_{Lm}



	X1	X2	Δ	Average
Time	4.97636e-02	4.97636e-02	1.50838e-08	
I(Rload)	6.00648e+00	6.00689e+00	4.10330e-04	6.01118e+00

Figure 13. Waveform of I_{out}



	X1	X2	Δ	Average
Time	4.97636e-02	4.97636e-02	1.50838e-08	
V(Rload)	5.00520e+00	5.00554e+00	3.41928e-04	5.00912e+00

Figure 14. Waveform of V_{out}

② **In Problems 2 through 5, consider a Flyback converter with $V_{in} = 30[\mathrm{V}]$, $N_1 = 30$ turns, and $N_2 = 15$ turns. The self-inductance of winding at 1 is $50[\mu\mathrm{H}]$, and $f = 200[k\mathrm{Hz}]$. The output voltage is regulated at $V_{out} = 9[\mathrm{V}]$. Calculate and draw the waveforms of inductor current, input current, output current and the ripple current in the output capacitor, If the load is $30[\mathrm{W}]$.**

$$n = \frac{N_2}{N_1} = 0.5,$$

$$V_o = n \times \left(\frac{D}{1-D}\right) \times V_{in} = 0.5 \times \left(\frac{D}{1-D}\right) \times 30[\mathrm{V}]$$

$$D = 0.375$$

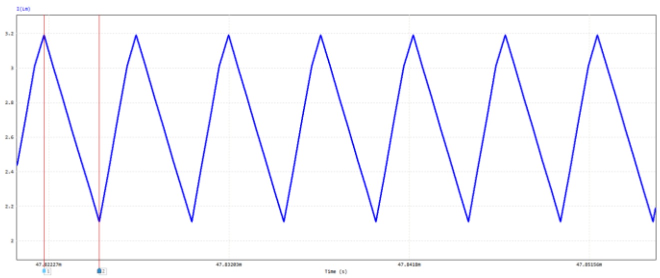
$$\Delta i_m = \frac{V_{in}}{L_m} \times DT = \frac{30[\mathrm{V}]}{50[\mu\mathrm{H}]} \times \frac{0.375}{200[k\mathrm{Hz}]} = 1.125[\mathrm{A}]$$

$$P_{out} = \frac{V_{out}^2}{R_{Load}}, \qquad R_{Load} = \frac{V_{out}^2}{P_{out}} = \frac{9^2[\mathrm{V}]}{30[\mathrm{W}]} = 2.7[\Omega]$$

$$I_{Lm} = \frac{n \times V_{out}}{(1-D) \times R} = \frac{0.5 \times 9[\mathrm{V}]}{(1-0.375) \times 2.7[\Omega]} = 2.667[\mathrm{A}]$$

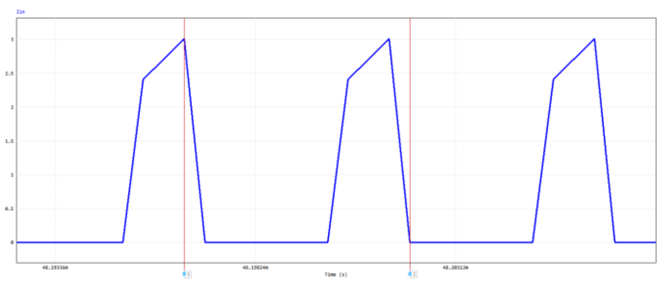
$$\Delta i_{L_m} = \frac{V_{in}}{L_m} \times DT = \frac{30[\mathrm{V}]}{50[\mu\mathrm{H}]} \times \frac{0.375}{200[k\mathrm{Hz}]} = 1.125[\mathrm{A}]$$

$$I_{out} = \frac{P_{out}}{V_{out}} = \frac{30[\mathrm{W}]}{9[\mathrm{V}]} = 3.333[\mathrm{A}]$$



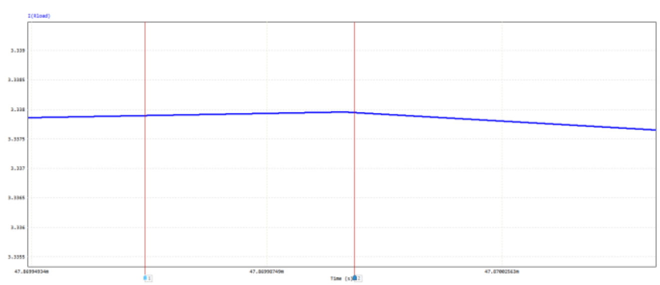
⋮	X1	X2	Δ	Average
Time	4.78220e-02	4.78250e-02	3.00000e-06	
I(Lm)	3.18974e+00	2.10965e+00	-1.08009e+00	2.64997e+00

Figure 15. Waveform of I_{Lm}



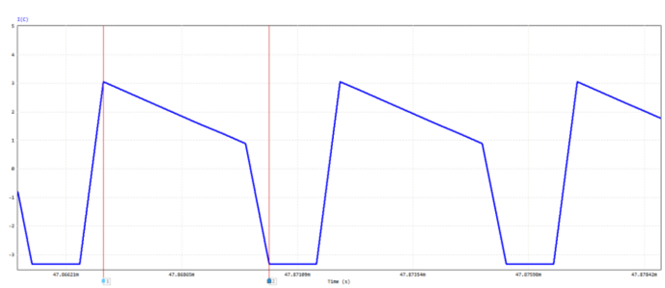
⋮	X1	X2	Δ	Average
Time	4.81965e-02	4.82020e-02	5.50000e-06	
Iin	3.00965e+00	4.79616e-06	-3.00964e+00	8.75801e-01

Figure 16. Waveform of I_{in}



⋮	X1	X2	Δ	Average
Time	4.78700e-02	4.78700e-02	3.40641e-08	
I(Rload)	3.33790e+00	3.33795e+00	5.26986e-05	3.33694e+00

Figure 17. Waveform of I_{out}



⋮	X1	X2	Δ	Average
Time	4.78670e-02	4.78705e-02	3.50000e-06	
I(C)	3.05235e+00	-3.33487e+00	-6.38723e+00	1.51027e+00

Figure 18. Waveform of I_C

III. RESULT

In this section, Input-Output results are presented.
In Lab Guidance, the following values were given.

$$f = 120[kHz], \quad n = 1, \quad V_{out} = 2.5[V]$$
$$R_{Load} = 200[\Omega], \quad V_{in} = 5[V], \quad L_M = 150[\mu H],$$
$$C = 1{,}800[\mu F], \quad \Delta V_{out} \le 0.1\% \cdot V_{out}$$

We need to find value of L and C are suitable for the design of Flyback Converter before start experiment.

Flyback Converter's transfer function is below,

$$V_{out} = V_{in}\left(\frac{D}{1-D}\right)\left(\frac{N_2}{N_1}\right)$$

$$\rightarrow 2.5[V] = 5[V] \cdot \left(\frac{D}{1-D}\right) \cdot 1 \rightarrow D = \frac{1}{3} \approx 0.3333$$

To operate CCM,

$$i_{L_m,min} = I_{L_m} - \frac{\Delta i_{L_m}}{2} = \frac{V_s D}{(1-D)^2 R}\left(\frac{N_2}{N_1}\right)^2 - \frac{V_s DT}{2L_m} \ge 0$$

$$L_m \ge \frac{V_s DT}{2} \cdot \frac{(1-D)^2 R}{V_s D} \cdot \left(\frac{N_1}{N_2}\right)^2$$

$$L_m \ge \frac{\left(1-\frac{1}{3}\right)^2 \cdot 200[\Omega]}{2 \cdot 120[kHz]} \cdot (1)^2 = 370.37[\mu H]$$

Ripple must be maximum for C to be minimum.
Since maximum ripple is 0.1%,

Equation about ripples is below,

$$|\Delta Q| = \left(\frac{V_o}{R}\right) DT = C\Delta V_o$$

$$\Delta V_o = \frac{V_o DT}{RC} = \frac{V_o D}{RCf} \rightarrow \frac{\Delta V_o}{V_o} = \frac{DT}{RC} = \frac{D}{RCf} \le 0.1\%$$

$$C \ge= \frac{\frac{1}{3}}{200[\Omega] \cdot \left(\frac{1}{1000}\right) \cdot 120[kHz]} = 13.88[\mu F]$$

We choose

$$L_M = 150[\mu H], \quad C = 1{,}800[\mu F]$$

We can say capacitance is suitable, but Inductance is hard to say it's suitable. It's covered in more detail in Observation.

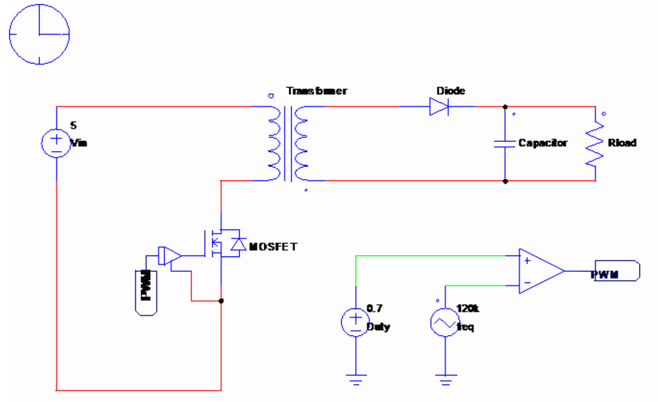


Figure 19. PSIM Simulation Circuit

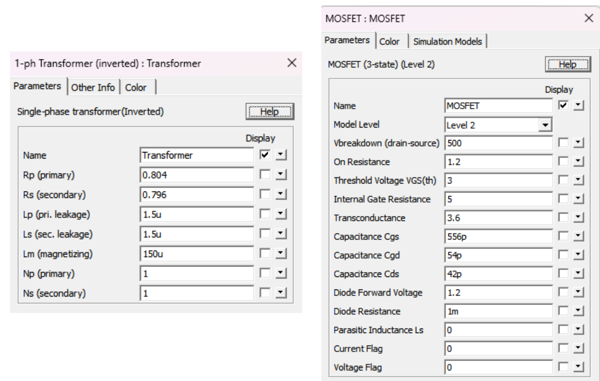


Figure 20. PSIM Simulation Condition(from spec sheet)

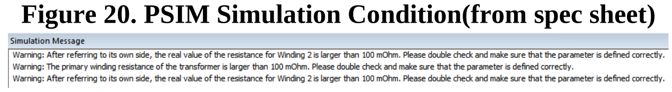


Figure 21. PSIM Simulation Warning Messages

We created simulations in the PSIM program as shown in Figure 18. Although a specific sheet provided by the device manufacturer was found and entered directly into the PSIM circuit, the exact simulation value was not obtained because the primary and secondary resistance supported by the PSIM program were only supported below 100[Ω].

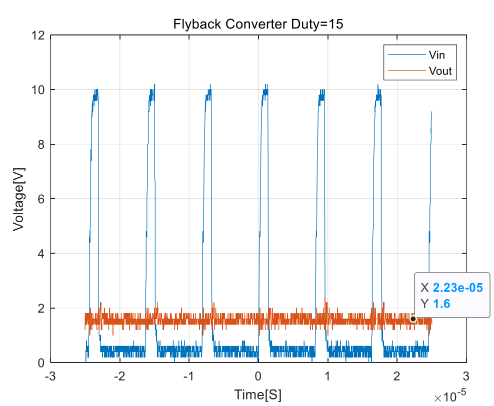


Figure 22(a). Output Voltage Curve
$(D = 0.15, f = 120[kHz])$

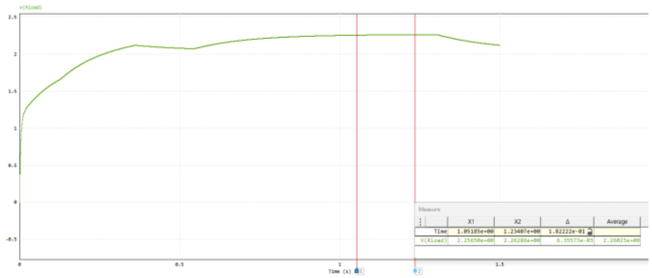


Figure 22(b). Output Voltage Curve (PSIM)
$(\boldsymbol{D} = \mathbf{0.15}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

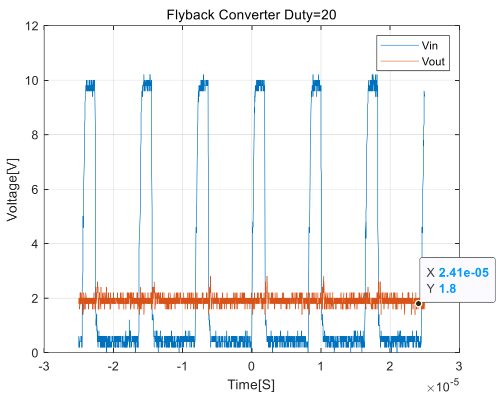


Figure 23(a). Output Voltage Curve
$(\boldsymbol{D} = \mathbf{0.2}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

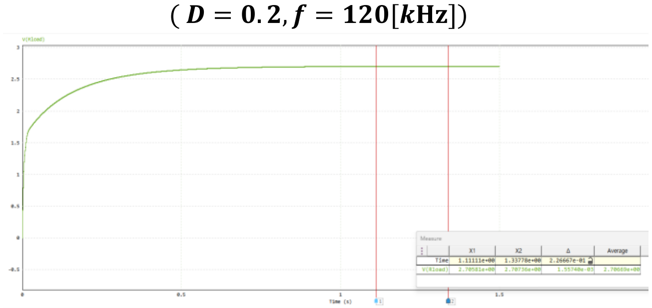


Figure 23(b). Output Voltage Curve (PSIM)
$(\boldsymbol{D} = \mathbf{0.2}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

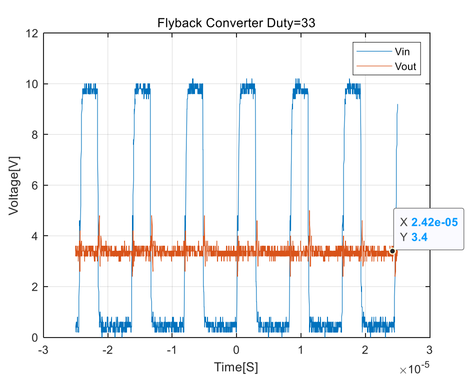


Figure 24(a). Output Voltage Curve
$(\boldsymbol{D} = \mathbf{0.33}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

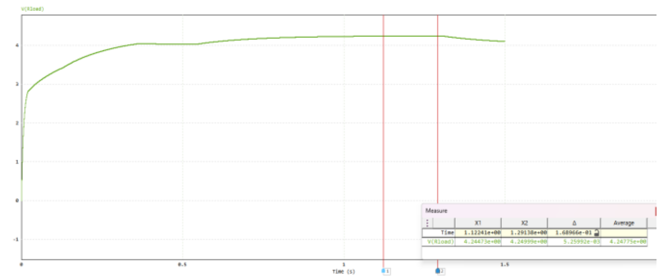


Figure 24(b). Output Voltage Curve (PSIM)
$(\boldsymbol{D} = \mathbf{0.33}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

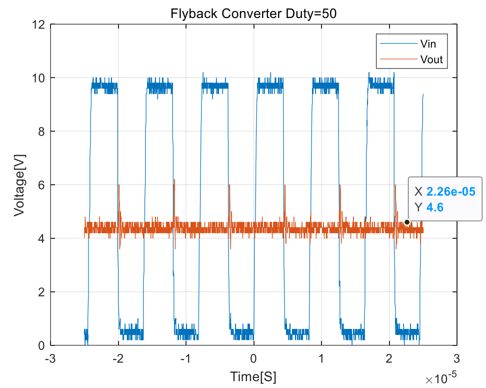


Figure 25(a). Output Voltage Curve
$(\boldsymbol{D} = \mathbf{0.5}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

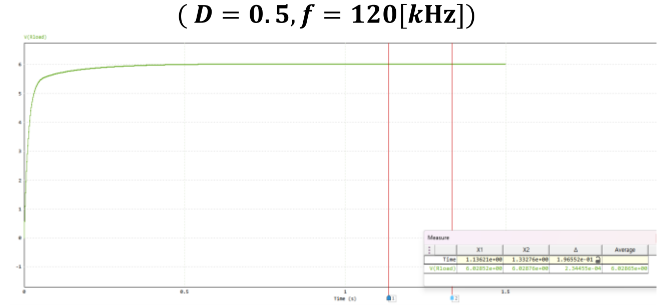


Figure 25(b). Output Voltage Curve (PSIM)
$(\boldsymbol{D} = \mathbf{0.5}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

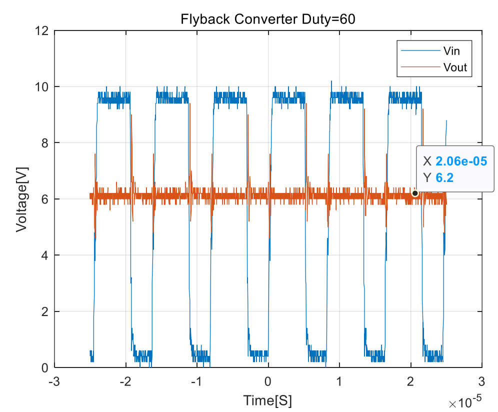


Figure 26(a). Output Voltage Curve
$(\boldsymbol{D} = \mathbf{0.6}, \boldsymbol{f} = \mathbf{120}[\boldsymbol{k}\mathbf{Hz}])$

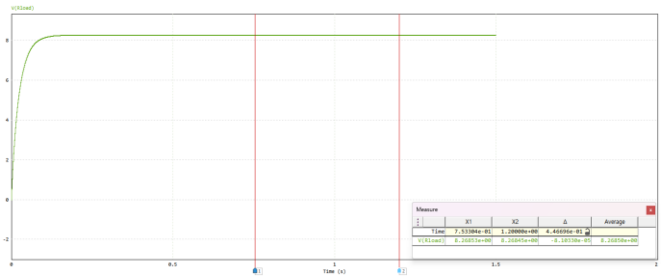


Figure 26(b). Output Voltage Curve (PSIM)
($D = 0.6, f = 120[kHz]$)

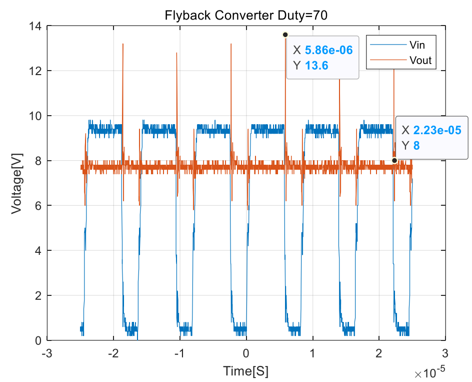


Figure 27(a). Output Voltage Curve
($D = 0.7, f = 120[kHz]$)

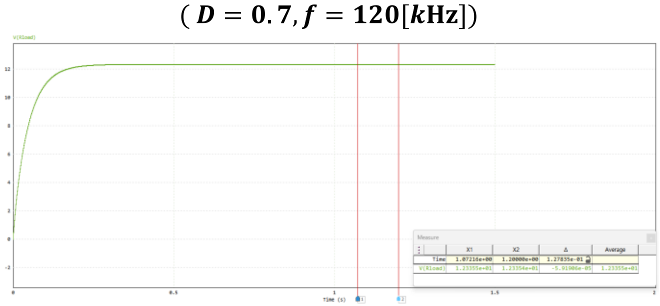


Figure 27(b). Output Voltage Curve (PSIM)
($D = 0.7, f = 120[kHz]$)

Duty Curve is below,

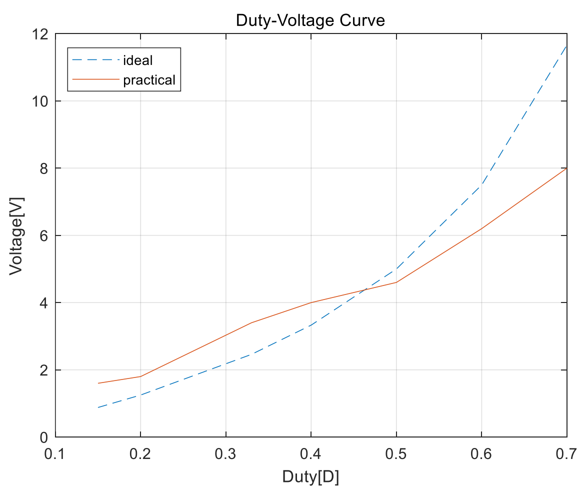


Figure 28. Duty Voltage Curve
($f = 120[kHz]$)

Looking at the Duty-voltage curve, it may be seen that a voltage has change according to Duty appears in an actual converter operation. However, there is a large difference between the experimental value and the ideal duty value because a value lower than the actual inductance (L_m) component was chosen.

$$i_{L_m,min} = I_{L_m} - \frac{\Delta i_{L_m}}{2} = \frac{V_s D}{(1-D)^2 R}\left(\frac{N_2}{N_1}\right)^2 - \frac{V_s D}{2L_m \cdot f} \geq 0$$

This means that the flyback converter operates with DCM when the frequency is lowered or duty is lower than 0.5, so the frequency was lowered to confirm the actual operation. Critical frequency is below,

IV. OBSERVATION

A. Voltage Drop

In this experiment, it is confirmed that there is a difference between the theoretical output power value and the experimental value depending on the duty of the flyback converter. It can be confirmed that the experimental value > theoretical value in the section where the duty is 0.5 or less, and the experimental value < theoretical value in the section exceeding 0.5. This can be analyzed for two reasons, the first being the magnetization inductance value and the second being the transformer characteristics.

First is the magnetization inductance.

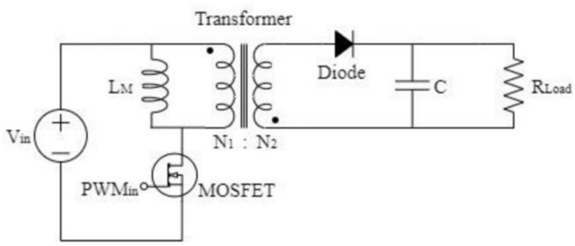


Figure 29. Flyback converter topology

In Result, we calculate L_m as a $370.37[\mu$H]. But, in the experiment, $150[\mu$H]. were chosen.

$$i_{L_m,min} = I_{L_m} - \frac{\Delta i_{L_m}}{2} = \frac{V_s D}{(1-D)^2 R}\left(\frac{N_2}{N_1}\right)^2 - \frac{V_s D}{2L_m \cdot f} \geq 0$$

$\frac{\Delta i_{L_m}}{2}$ was changed by L_m, so in some specific duty intervals, the converter performs a DCM operation. If $L_m = 150[\mu$H].

$$I_{L_m} = \frac{5 \times 0.4}{(0.6)^2 \times 200} = 27.77[mA]$$
$$\Delta i_{L_m} = \frac{5 \times 0.4}{2 \times 150 \times 10^{-6} \times 120 \times 10^3} = 55.5[mA]$$

When duty is 0.4, converter operation in DCM interval.

$$I_{L_m} = \frac{5 \times 0.7}{(0.3)^2 \times 200} = 194.07[mA]$$
$$\Delta i_{L_m} = \frac{5 \times 0.7}{2 \times 150 \times 10^{-6} \times 120 \times 10^3} = 97.22[mA]$$

When duty is 0.7, converter operation in CCM interval.
The experimental value was larger than the theory, as the Output voltage increased to satisfy the voltage-sec balance in the DCM section.

$$\langle v_L \rangle = D(V_g) + (1-D)\left(-\frac{V_o}{n}\right) + \Delta_1 = 0$$

$$\frac{V_o}{V_g} = \frac{D + \Delta_1}{1 - D}$$

If we choose L_m as a $370.37[\mu$H], how does the converter work?

$$I_{L_m} = \frac{5 \times 0.4}{(0.6)^2 \times 200} = 27.77[mA]$$
$$\Delta i_{L_m} = \frac{5 \times 0.4}{2 \times 370 \times 10^{-6} \times 120 \times 10^3} = 22.50[mA]$$

When Duty is 0.4

$$I_{L_m} = \frac{5 \times 0.7}{(0.3)^2 \times 200} = 194.07[mA]$$
$$\Delta i_{L_m} = \frac{5 \times 0.7}{2 \times 370 \times 10^{-6} \times 120 \times 10^3} = 39.38[mA]$$

When duty is 0.8
We can see all duty operate in CCM interval. Through this, how the magnetization inductance value is selected affects the converter operation and output voltage.

Second is the characteristic of the transformer.

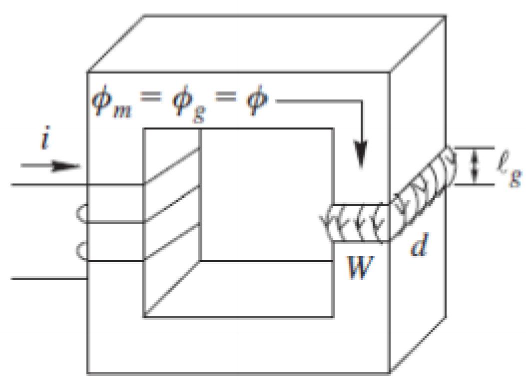


Figure 30. Transformer

Since the converter circuit connected through the transformer is in a form that the input and output terminals are separated by the transformer. It is possible to prevent the reverse current of the output terminal from entering the input terminal. But it can occur core loss of transformer.

Now, we calculate about core loss of transformer. Transformer's Energy per cycle W flowing into n turn winding of an inductor, excited by periodic waveforms of frequency can be shown this form.

$$W = \int_{one\ cycle} v(t)i(t)dt$$

Using Faraday and Ampere's law, it can represent voltage and current expressions.

$$\oint H \cdot dl = I$$
$$\therefore n\, i(t) = H(t) l_m$$

$$v(t) = n\, A_c \frac{dB(t)}{dt}$$

$$W = \int_{one\ cycle} \left(A_c \frac{dB(t)}{dt}\right)\left(\frac{H(t)l_m}{n}\right) dt$$
$$W = (A_c l_m) \int_{one\ cycle} H\, dB$$

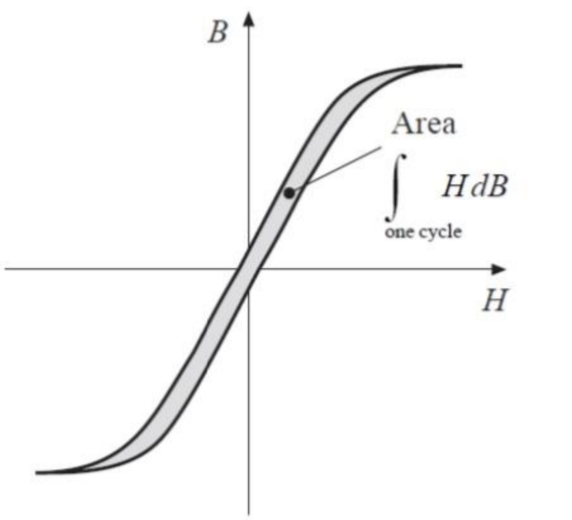


Figure 31. B-H curve

That is, the amount of energy loss can be calculate through area of the B-H curve and the volume of core.

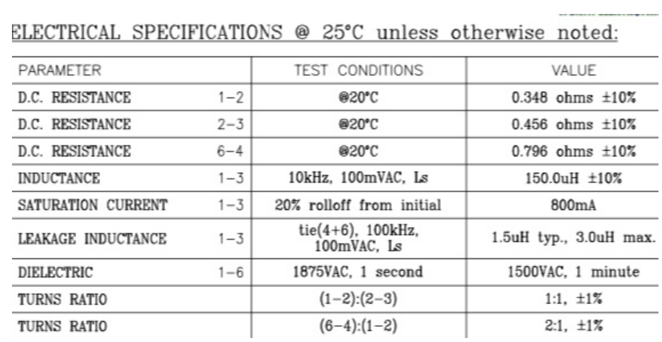
V. CONCLUSION

Through this experiment, it was possible to confirm how the flyback converter operates. During the experiment, a power loss occurred in the theoretical and experimental values of the converter circuit, which was analyzed for two causes. The first is whether the magnetization inductance size is suitable. In this regard, because of calculating the value used in the experiment, it was concluded that the power voltage was larger by the DCM operation generated in the duty interval. The second is core loss that occurs in transformers. A transformer has the advantage of reducing the effect by separating the input terminal and the ouput terminal, but the loss caused by magnetic force in the transformer itself may influence the result. In addition, the flyback converter can perform both buck and boost operations, but boost operations are difficult in sections where duty exceeds 70.

VI. WORK DISTRIBUTION

	Hyun ui	Gyeon heal
Circuit construction	60%	40%
Circuit Testing	50%	50%
Report	40%	60%

VII. APPENDIX



ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	1–2	@20°C	0.348 ohms ±10%
D.C. RESISTANCE	2–3	@20°C	0.456 ohms ±10%
D.C. RESISTANCE	6–4	@20°C	0.796 ohms ±10%
INDUCTANCE	1–3	10kHz, 100mVAC, Ls	150.0uH ±10%
SATURATION CURRENT	1–3	20% rolloff from initial	800mA
LEAKAGE INDUCTANCE	1–3	tie(4+6), 100kHz, 100mVAC, Ls	1.5uH typ., 3.0uH max.
DIELECTRIC	1–6	1875VAC, 1 second	1500VAC, 1 minute
TURNS RATIO		(1–2):(2–3)	1:1, ±1%
TURNS RATIO		(6–4):(1–2)	2:1, ±1%

Figure 32. Transformer (MID-FLYLT) Datasheet

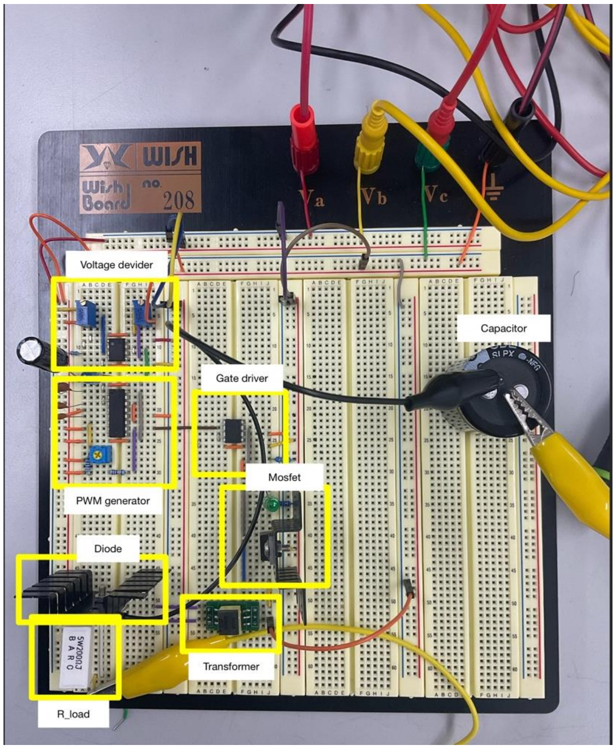


Figure 33. Breadboard Circuit

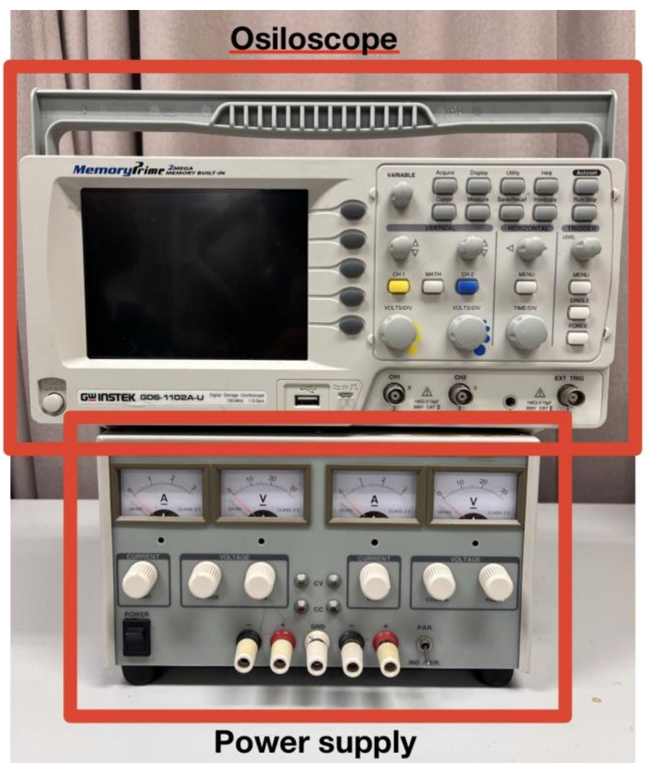


Figure 34. Experimental Equipment/

	$V_{out,ideal}$	$V_{out,practical}$
D=0.7	11.66	8.00
D=0.6	7.50	6.2
D=0.5	5.00	4.6
D=0.4	3.33	4.0
D=0.33	2.46	3.4
D=0.2	1.25	1.8
D=0.15	0.88	1.6

Table 2. Ideal-Actual Output Comparison Based on Duty-Ratio（$f = 120[kHz]$)