# LOW NOISE BLOCK POWER CIRCUIT DESIGN TO AVOID CURRENT PEAKS WITH A PARALLEL RESONANT CONVERTER

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# LOW NOISE BLOCK POWER CIRCUIT DESIGN TO AVOID CURRENT PEAKS WITH A PARALLEL RESONANT CONVERTER

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*To my family...*

# DECLARATION OF ORIGINALITY

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Cansel Sahin Ceter

# ABSTRACT

Low Noise Block (LNB) circuits are an essential component of satellite receiving systems in televisions. LNB converts high-frequency satellite signals into a lower frequency range for transmission to the receiver. Also, LNB ensures low-noise signal reception, enables polarization control, supports multiple frequency bands, and amplifies signals. The LNB power circuits provide power to the LNB. Voltage-controlled boost converters are commonly used in these circuits; the current limiting feature used in these circuits can be insufficient to handle sudden current spikes, leading to feedback from end users. They are not immune to short circuits because of installation problems with satellite cables, which are a common failure mode that potentially damages the LNB power or other components in the television, resulting in a loss of satellite signal. Hence, leading to a poor user experience and harming the manufacturer's reputation. Replacing a damaged LNB power circuit is also difficult because it is often integrated into the TV's design and is not easily replaceable. To mitigate this problem, a parallel resonant converter approach is introduced that limits the output current up to a pre-defined level by frequency control. Parallel resonant converter circuits operate as current sources so maximum current cannot exceed this defined operation frequency point under any circumstances. In this study, the mathematical equations of the proposed circuit were obtained, and then the operating conditions were determined. The operation frequency ranges were interpreted graphically using Matlab, and the parallel resonant converter design was evaluated using a simulation model by using MATLAB's Simulink Toolbox. These results show that the parallel resonant converter approach maintains a stable current and reduces the risk of short-circuit damage. The proposed design is expected to reduce repair costs due to LNB power circuits for TV manufacturers.

***Keywords***: Parallel resonant converter, low noise block power, satellite systems.

# ÖZET

Düşük Gürültü Blok (LNB) devreleri, televizyonlardaki uydu alım sistemlerinin önemli bir bileşenidir. LNB, yüksek frekansta gelen uydu sinyallerini alıcılara iletmek için daha düşük bir frekansta çevirir. LNB, düşük gürültülü sinyal alımını sağlar, polarizasyon kontrolünü mümkün kılar, çoklu frekans bantlarını destekler ve sinyalleri amplifiye eder. LNB güç devreleri, LNB'ye güç sağlar. Bu devrelerde yaygın olarak kullanılan gerilimi kontrol eden yükseltici dönüştürücüler, bu devrelerde kullanılan akım sınırlama özelliğinin ani akım dalgalanmalarını ele almak için yetersiz olabileceğini ve kullanıcı geri bildirimlerine neden olabileceğini göstermektedir. Ayrıca uydu kablolarının kurulumuyla ilgili sorunlardan kaynaklanan kısa devreler nedeniyle zarar görebilirler. Bu, televizyondaki LNB güç veya diğer bileşenlerin zarar görmesi ve uydu sinyali kaybına yol açabilir. Hasarlı bir LNB güç devresini değiştirmek genellikle televizyonun tasarımına entegre edildiği ve kolayca değiştirilemediği için zordur. Bu sorunu hafifletmek için, bir paralel rezonant dönüştürücü yaklaşımı tanıtılmıştır. Bu yaklaşım, frekans kontrolü ile çıkış akımını belirli bir seviyeye kadar sınırlar. Paralel rezonant dönüştürücü devreleri, akım kaynakları olarak çalıştığı için maksimum akımın hiçbir koşulda bu belirlenmiş çalışma frekans noktasını aşamayacağı anlamına gelir. Bu çalışmada, önerilen devrelerin matematiksel denklemleri elde edildi ve ardından çalışma koşulları belirlendi. İşletim frekans aralıkları Matlab kullanılarak grafiksel olarak yorumlandı ve paralel rezonant dönüştürücü tasarımı, MATLAB'ın Simulink Araç Kutusu kullanılarak simülasyon modeli kullanılarak değerlendirildi. Bu sonuçlar, paralel rezonant dönüştürücü yaklaşımının istikrarlı bir akım sağladığını ve kısa devre hasar riskini azalttığını göstermektedir.

***Anahtar Kelimeler:*** Paralel Resonant Dönüştürücüler, Düşük Gürültü Blok Güç, Uydu Sistemleri

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| | |
|---|---|
| **AC** | Alternating Current |
| **CMOS** | Complementary Metal Oxide Semiconductor |
| **fsw** | switching frequency |
| **fo** | resonant frequency |
| **fc** | cut-off frequency |
| **DC** | Direct Current |
| **DVB** | Digital Video Broadcast |
| **DVBC** | Digital Video Broadcast Cable |
| **DVBS** | Digital Video Broadcast Satellite |
| **DVBT** | Digital Video Broadcast Terrestrial |
| **FEC** | Forward Error Correction |
| **GPIO** | General Purpose Input Output |
| **HH** | Horizontal High |
| **HL** | Horizontal Low |
| **IC** | Integrated Circuit |
| **I2C** | Inter-Integrated Circuit |
| **IEEE** | Institute of Electrical and Electronics Engineer |

| | |
|---|---|
| **IF** | Intermediate Frequency |
| **I&Q** | In-phase and Quadrature |
| **KU** | K-Under |
| **LC** | Inductance-Capacitance |
| **LLC** | Leakage inductance Magnetizing inductance Capacitance |
| **LNA** | Low Noise Amplifier |
| **LNB** | Low Noise Block |
| **LNBP** | Low Noise Block Power |
| **LO** | Local Oscillator |
| **MDPI** | Multidisciplinary Digital Publishing Institute |
| **MOSFET** | Metal Oxide Semiconductor Field Effect Transistör |
| **MPEG** | Moving Pictures Experts Group |
| **PI** | Proportional and Integral |
| **PCB** | Printed Circuit Board |
| **PWM** | Pulse Width Modulation |
| **QPSK** | Quadrature Phase Shift Keying |
| **RF** | Radio Frequency |
| **SAT** | Satellite |
| **SMD** | Surface Mount Device |

| | |
|---|---|
| **SNR** | Signal Noise Ratio |
| **STB** | Set-Top Box |
| **USA** | United States of America |
| **VAB** | Voltage of A-B range |
| **VCB** | Voltage of C-B range |
| **VDC** | Voltage value of Direct Current |
| **VIN** | Input Voltage |
| **VFB** | Feedback Voltage |
| **VH** | Vertical High |
| **VL** | Vertical Low |
| **TV** | Television |
| **XC** | Reactances value of Capacitor |

# 1. INTRODUCTION

Television systems are widely used everywhere, satellite systems play a significant role. The LNB devices used in these systems facilitate signal reception and transmission in satellite antennas. However, current protection is crucial for these devices to operate safely and efficiently. The study aims to address the power supply and current protection processes for LNB devices, aiming to stabilize the current and ensure reliable operation using a parallel resonant converter. This study strives to make a significant contribution to communication technologies.

## 1.1 Motivation

In the LNB power (LNBP) circuits mounted on television mainboards, some issues such as improper antenna cable connections or broken antenna cables can lead to short circuits at the output of the LNB power IC. In short circuit conditions, very high current peaks are observed, and these currents exceed the current limiting capabilities of the LNBP ICs. This causes the LNBP ICs to overheat and eventually burn out. Based on field discussions and customer feedback, an examination of millions of products revealed that 13.2% of LNBP ICs experienced burnouts. Customer complaints indicate that these issues have significantly increased. Furthermore, the financial costs associated with fixing these faults and replacing products have had a negative financial impact on companies.

This study aims to solve the issue of current peaks in Low Noise Block power circuits, providing a more stable and efficient power supply solution by using a parallel resonant converter. This solution involves the utilization of a parallel resonant converter as a constant current source, which plays a central role in the design and is crucial for ensuring the stable operation of LNB circuits.

The motivation for this thesis stems from our strong interest in power electronics and communication technologies. We believe that the findings of this study can make a significant contribution to professionals working in these fields and future researchers.

The execution of this thesis study provides opportunities to acquire new skills and in-depth knowledge. Simultaneously, it offers the chance to work towards the important goal of enhancing the performance of communication systems and ensuring the stability of LNB circuits.

In conclusion, the successful completion of this thesis can make a substantial contribution to improving the stability of LNB circuits and enhancing the reliability of communication systems.

## 1.2 Previous Work

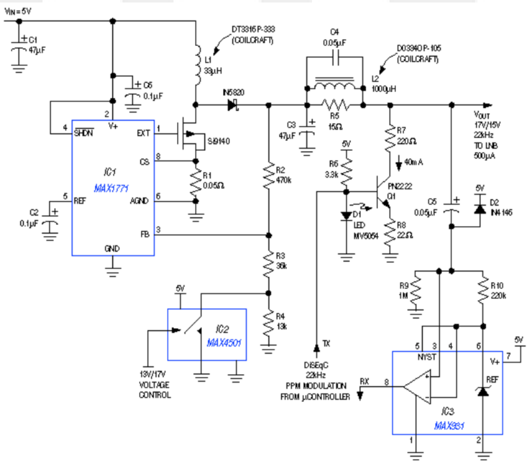
The literature reveals multiple designs for powering LNB circuits, often utilizing DC-DC converters with voltage regulation. However, these methods are prone to current peaks and short-circuit risks, especially during sudden load changes. This study proposes an alternative approach using a parallel resonant converter.

Many different circuit designs have been developed to provide power to LNB circuits. Among these designs, there are various options such as those using DC/DC converters and those designed analogically. In particular, circuits developed in conjunction with a 22 kHz signal to control the 13V/18V and horizontal/vertical broadcast polarizations have played a significant role in television broadcasting.

A commonly used method to provide power to LNB circuits is the use of DC/DC converters. These converters transform the input voltage into appropriate levels to supply the required power to the LNB. Especially when there is a need for two different voltage levels, such as 13V and 18V, DC/DC converters can generate different voltages.DC/DC converters are commonly used to transform the low voltage from the satellite receiver into the higher voltage required by the LNB circuit. Boost converters are a prevalent type of DC/DC converter used to raise the input voltage above the output voltage level.

Components referred to as integrated circuits (ICs), such as MAX1771, can be employed in the design of these DC/DC converters. As seen in Figure 1.1, according to Maxim Integrated's technical document AN1808 [1], DC/DC converters are frequently used Max1771 is a control IC specifically designed for such applications. This integrated circuit can be utilized to boost a low-voltage source to a higher voltage level. This type of circuit design enables the satellite receiver to generate different voltage levels such as 13V or 18V. Boost converters are often used in industrial and electronic devices to elevate low-voltage sources to higher levels. This allows the satellite receiver to control the LNB and change the signal polarization. Such a circuit design is a common approach used to supply the necessary power to the LNB, ensuring its proper functioning.

**Figure 1.1:** *Adjustable LNB Power Supply Circuit [1]*




As an example of another LNB power regulator, Texas Instruments TPS652353 can be mentioned in Figure 1.2. TPS652353 is an integrated circuit designed by Texas Instruments as an LNB voltage regulator, specifically intended for effectively regulating and supplying power to the LNB in satellite receiver systems. The adjustable output voltage feature Horizontal/Vertical provides users with extensive flexibility, enabling the creation of customized solutions for different LNB types or specific application requirements.

TPS652353 ensures the high-sensitivity reception of satellite signals by preserving low noise levels. This enhances signal quality and optimizes system performance. Operating with voltage control, this IC provides automatic current limiting and over current protection features, ensuring safe operation under high current conditions. Additionally, it incorporates thermal protection features to safeguard the circuit in case of operation under extreme temperature conditions.

The programmability and monitoring capability of TPS652353 through I2C (Inter-Integrated Circuit) offers users the ability to actively monitor and control the operating parameters of the integrated circuit. Thus, it provides a high-performance solution for energy management and power supply requirements in satellite receiver systems. TPS652353 has been designed to be versatile, making it suitable for various application scenarios with its advanced features and flexible design.

**Figure 1.2:** *Simplified Schematic LNB Power IC of Texas Instrument [2]*

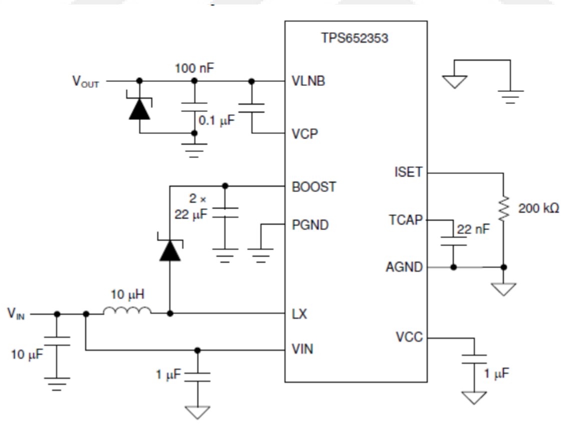
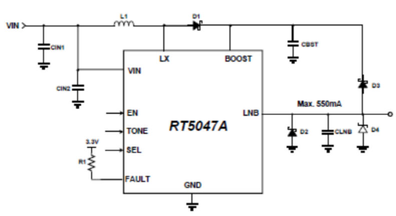



**Figure 1.3:** *Simplified Application Circuit LNB Power IC of Richteck [3]*




Another voltage-controlled LNB power IC that can be mentioned is the RT5047A shown in Figure 1.3. It is a Low Noise Block power regulator IC developed by Richtek and specifically designed for use in satellite receiver systems. This integrated circuit combines the tasks of power supply and management of control signals. With its independent current-mode boost controller and low dropout linear regulator, it has the capabilities to raise a low-voltage source to a higher voltage and maintain a specific voltage level. Additionally, it supports DiSEqC™1.x communication through its 22KHz tone shaping circuit. It incorporates fault protections such as over current, over-temperature, and under voltage lockout, ensuring the RT5047A can operate safely and provide an effective solution for supplying power to the LNB in satellite receiver systems. The GPIO control feature of this integrated circuit provides users with additional control and customization options.

Parallel resonant converters play a significant role in providing efficiency and reliability in the field of power electronics. In particular, these types of converters offer various advantages in designs for Low Noise Block circuits, particularly in current control and energy management.

1. **Efficiency Optimization in LLC Resonant Converters:** Bellido et al. have achieved up to **98.5% efficiency** in LLC resonant converters by utilizing current-controlled variable inductors and phase shift techniques. These methods have been developed to reduce efficiency losses in high-power systems and can also be applied to prevent short circuits in LNB circuits [4].

2. **Intelligent Power Management Techniques:** High frequency switching techniques and electronic control systems play a crucial role in energy management for parallel resonant converters. Intelligent control algorithms optimize the operating conditions of circuit components, improving system performance and reducing the risk of failure. These techniques can lead to more robust and efficient operation of LNB circuits [4].

3. **High-Frequency Switching Techniques:** The use of high-frequency switching techniques in parallel resonant converters helps reduce the noise spectrum, allowing the system to operate more stably. Frequency modulation and narrow frequency-range control methods are effective in preventing current peaks and improving energy efficiency [4, 5].

4. **Current Control in Parallel Resonant Converters:** Studies indicate that the current control mechanisms in parallel resonant converters can limit sudden current peaks, making them suitable for use in LNB circuits. Such control strategies enhance the reliability of the LNB and ensure the longevity of the system. Additionally, resonant converters operate with high efficiency, thus reducing overall energy consumption [5].

5. **Resonant Tank Networks and Power Electronics Applications:** The design of resonant tank networks used in parallel resonant converters is critical for energy storage and improving transmission efficiency. While two-element resonant tanks are commonly used, third-generation tanks offer higher efficiency. They are particularly advantageous in high-voltage applications [5].

6. **Digital Feedback and Control:** In modern parallel resonant converters, digital feedback methods minimize current and voltage fluctuations, enhancing the stability of the system. These advanced control techniques help achieve better energy efficiency and lower noise levels in LNB circuits [5].

# 2. LOW NOISE BLOCK AND WORKING PRINCIPLE

Television broadcasting under Digital Broadcast Satellite (DVBS) regulations is one of the most popular consumer applications [6]. A Low Noise Block is a vital component in satellite communication systems, especially in satellite TV setups. Its primary role is to receive and enhance the weak signals sent by satellites while minimizing the introduction of additional noise. The Low Noise Block circuit is a component of satellite systems and is a converter that connects to the satellite antenna. This circuit receives very high frequency signals from the satellite and converts these signals to a lower frequency [7]. The satellite receiver captures the radio frequency (RF) signal that is transmitted from a satellite antenna. The signal is then sent to the LNB circuitry on the antenna, which converts the signal to a lower frequency intermediate frequency (IF) signal [8]. The IF signal is then sent to the demodulation chip inside the satellite receiver, which demodulates the signal and converts it back to the original digital signal. The LNB power supply is a crucial part of satellite communication systems and plays a big role in TV signals being broadcast according to Digital Broadcast Satellite rules.

## 2.1 Low Noise Block

Low Noise Block is a receiver device used in satellite television systems. It is mounted on satellite dish antennas and receives signals from the satellite. The LNB converts these signals and sends them to the receiver in the building via a cable [9].

The LNB contains several circuits, including a low noise amplifier (LNA), frequency mixer, local oscillator (LO), and intermediate frequency (IF) amplifier. These circuits amplify weak satellite signals and convert them into a lower frequency, making them suitable for transmission. The LNB is typically a small box located in front of the focus point of the dish, attached to short booms or feed arms.

The LNB receives signals from the parabolic satellite dish, amplifies them, and mixes them down to a lower frequency. This process allows the signals to be sent to the receiver, allowing users to view satellite broadcasts on their televisions. For the LNB to work efficiently, it is important that the satellite dish is properly aligned with the satellite signals. This ensures that the signals are captured as effectively as possible by the LNB [10]. The more detailed explanations of the fundamental components inside the Low

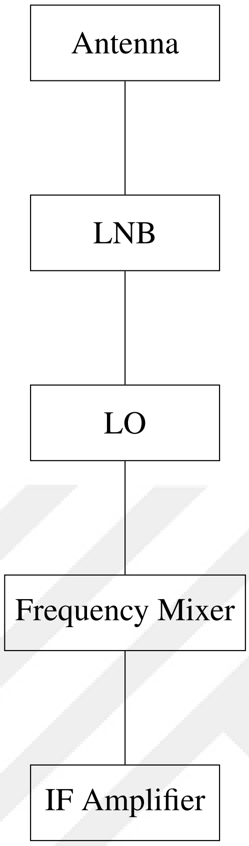
**Figure 2.1:** *Low Noise Block Downconverter component in antennas*

Noise Block that contribute to its functionality are as follows.

### *2.1.1 Low Noise Amplifier*

The Low Noise Amplifier is an essential component in satellite and wireless communication systems. Its main job is to amplify weak signals received by antennas, improving the signal-to-noise ratio for better signal processing. The LNA ensures that weak signals from distant or low-strength sources can be received effectively. It strengthens these signals while adding minimal extra noise, making it easier to distinguish the desired

**Figure 2.2:** *Flowchart of the LNB Circuit*




signal from unwanted interference. This leads to improved communication performance, as the signals can be transmitted and processed more effectively, even over long distances or with weak initial signals [11].

### *2.1.2 Frequency Mixer*

Frequency Mixers are fundamental components in radio frequency systems and are used to convert signals by combining different frequencies. According to Smith in RF Circuit Design: Theory, Components, and Applications, the frequency mixer combines signals through multiplication processes to produce intermediate frequencies essential for communication systems [12]. A frequency mixer is an electronic circuit used to convert high-frequency signals into a specific intermediate frequency. It is widely employed in radio frequency systems and communication devices like radio receivers. The primary role of the frequency mixer is to combine or multiply two or more signals at distinct frequencies, generating a new signal at a different frequency.

Frequency mixers typically interact with a Local Oscillator, which provides an additional oscillation signal necessary for the mixing process. This allows the adjustment and control of the frequency conversion. The process, known as heterodyning, involves combining signals at different frequencies through multiplication. The resulting intermediate frequency signal is further filtered and amplified for information extraction.

Frequency mixers are vital components, especially in superheterodyne radio receivers and other communication systems. They facilitate signal processing and enable operation across various frequency ranges, improving signal manipulation and analysis.

### *2.1.3 Local Oscillator*

The Local Oscillator used in the Low Noise Block circuit is an essential component that enables the conversion of received high-frequency satellite signals to a specific intermediate frequency. Mounted on a parabolic antenna, the LNB plays a vital role in satellite receiver systems by transforming signals into a form that is easier to process and transmit.

The Local Oscillator generates oscillations at a constant frequency and interacts with incoming signals through the heterodyne mixing process to produce an intermediate frequency signal. This principle has been explored extensively by Konishi and Fukuoka, highlighting its role in satellite receiver technologies [6]. Furthermore, LO's frequency adjustment capabilities are critical in satellite communication systems, as explained by Brown (2021) [11]. This allows for better signal management by converting the high-frequency satellite signals into a lower intermediate frequency. The ability to adjust the LO frequency is crucial for accommodating different satellite signal frequencies and meeting the requirements of various receiver systems. In essence, the LO ensures efficient signal processing by enabling smooth conversion and better compatibility with other components of the LNB system.

### *2.1.4 Intermediate Frequency Amplifier*

The Intermediate Frequency Amplifier is an essential part of the Low Noise Block system used in satellite communication. Its main role is amplifying signals after they have been converted to a lower, specific intermediate frequency by processes such as mixing with the Local Oscillator signal. These IF signals are created by converting high frequency signals received by a satellite dish through the frequency mixing process.

The IF Amplifier operates by strengthening these intermediate-frequency signals while adding minimal additional noise. This allows the desired signal to remain clear and distinguishable, improving the overall signal to noise ratio (SNR). By amplifying signals while reducing noise, the IF Amplifier ensures that even weak satellite signals can be received effectively and processed by subsequent stages in the communication system.

Furthermore, the IF Amplifier works within specific frequency ranges to filter out signals that are not part of the target communication band. This ensures that only relevant signals are amplified and transmitted to other stages of the receiver system for decoding. Once the signals are amplified, they are sent for demodulation, translating the processed data into audio or video output that can be displayed on television or other receiving devices.

Without the IF Amplifier, the system would struggle with weak signals or noise interference, leading to poor reception quality. In essence, the IF Amplifier significantly improves the efficiency and reliability of satellite communication systems by preparing and enhancing signals for decoding.

The Intermediate Frequency Amplifiernis vital in enhancing the signal quality of satellite systems by focusing on amplifying weak signals while minimizing noise interference (Brown, 2021) [11]. Research suggests that IF Amplifiers can significantly improve the signal-to-noise ratio by filtering and selectively amplifying only the desired frequencies. This allows satellite systems to maintain stable performance under weak signal conditions. The historical significance of IF Amplifiers in satellite communications is further supported by foundational research from Konishi and Fukuoka (1988) [6], who explored their use in signal processing within LNB circuits.

### *2.1.5 Low Noise Block Power Integrated Circuit*

The Low Noise Block Power Integrated Circuit is specifically designed as a voltage regulator to power satellite receiver systems, including set-top boxes (STBs) and televisions. These ICs are used within LNB or multi-switch modules in antenna systems. By utilizing a boost converter, the IC can supply voltages ranging from 13V to 18V, enabling the reception of both vertically and horizontally polarized signals. Additionally, many LNBp ICs include circuits for generating a 22 kHz tone, which is essential for supporting multi antenna configurations such as DiSEqC™1.x [11]. Advanced ICs may also feature fault protection mechanisms, enhancing durability and performance.

The LNB Power feature is fundamental for the operation of satellite receivers, providing the necessary voltage to drive the internal circuits of the LNB. This power, delivered via a cable from the satellite receiver or STB, allows the LNB to process and convert high frequency satellite signals into a format suitable for transmission.

Key functionalities of LNB Power include supplying energy to the LNB, controlling polarization, and facilitating frequency conversion. Integrated circuits designed for these tasks are essential for efficient signal handling in modern satellite systems. Moreover, some advanced LNB Power ICs integrate fault protection features to ensure stable and reliable performance, even under challenging operating conditions [9].

## 2.2 DVB-S Standard and LNB Circuits in Television Broadcasting

Recently, with technological advancements, the use of television in human life has become widespread. In this way, television broadcasting also plays an important role. Television broadcasts can now be accessed using both analog and digital communication technologies. Analog signals were affected by environmental factors like weather conditions, which resulted in interruptions and visual distortions on television screens. However, the introduction of Digital Video Broadcasting (DVB) resolved these issues by offering a higher-quality and more reliable method of video transmission [13].

Nowadays, multiple methods are available for delivering broadcasts to televisions. Therefore, the DVB standard consists of several versions, each improving video signal transmission efficiency and methods. The most common DVB standards include Digital Video Broadcasting Terrestrial (DVB-T/DVB-T2), Digital Video Broadcasting Satellite (DVB-S/DVB-S2), and Digital Video Broadcasting Cable (DVB-C) [14].

DVB-C represents a DVB standard used for the transmission of video broadcasts through cable systems. Although widely used in Latin America, its usage has become less common in recent years [15].

DVB-T/DVB-T2, on the other hand, is a widely accepted standard used globally for digital terrestrial broadcasting. In this system, antenna transmitters send signals over certain distances to televisions and receivers. DVB-T/DVB-T2 is known for its high-quality image and multimedia capabilities, offering numerous advantages compared to older analog methods.

The DVB-S standard was introduced in 1997 as a method for standardizing digital satellite television broadcasting. This development was in response to the growing demand for technological advancements and digital broadcasting capabilities. The DVB-S standard incorporates key technologies, such as Quadrature Phase Shift Keying (QPSK) modulation, Forward Error Correction (FEC) algorithms, and MPEG-2, a standard for compressing audio and video signals. These elements ensure efficient and error-free digital transmission for satellite television [16].

The DVB-S standard evolved over time, leading to the introduction of DVB-S2 in 2005. DVB-S2 introduced higher transmission rates, improved error correction capabilities, and more efficient use of the available frequency spectrum compared to the original DVB-S standard.

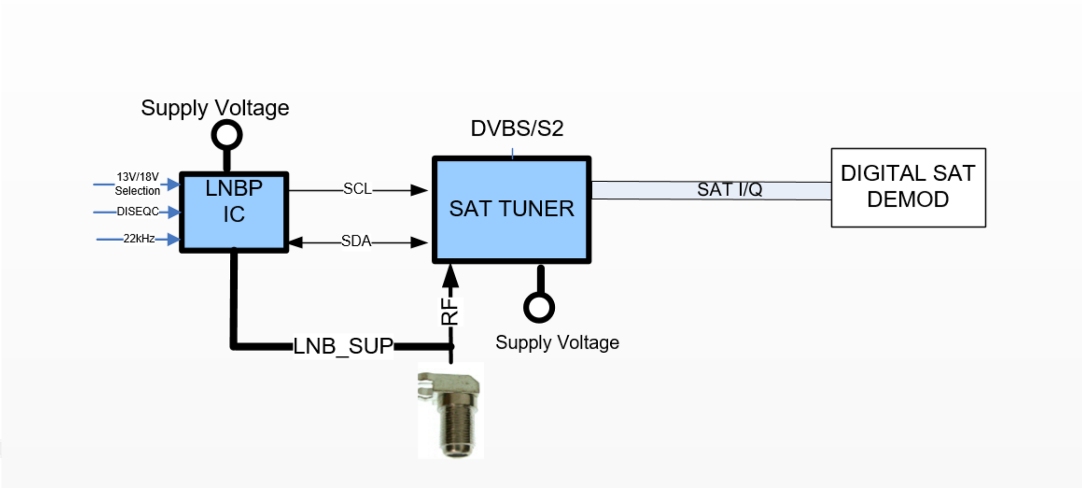
DVB-S is currently the most widely used digital broadcasting method in Turkey for transmitting television signals via satellite. Initially developed between 1993 and 1997, its first commercial applications included Star TV in Asia and Galaxy in Australia. This standard paved the way for modern satellite television broadcasting [17].

LNB circuit is essential for the transmission of video signals using the DVB-S standard. Universal LNBs operate by adjusting voltage from the satellite receiver to switch between horizontal and vertical polarization signals. Additionally, they use a continuous 22 kHz tone to alternate between high and low satellite frequency bands. LNBs support signal oscillations in the 10.7 GHz to 12.75 GHz Intermediate Frequency satellite band and are typically used to process signals within the K-Under (KU) satellite band (950 MHz to 2150 MHz). The low band oscillates signals at frequencies from 10.7 GHz to 11.7 GHz, while the high band oscillates signals at frequencies from 11.7 GHz to 12.75 GHz or higher frequencies like 10,600 MHz. These signals are critical for processing signals and determining the presence or application of 22 kHz tones as part of signal communication between the satellite receiver and LNB.

**Table 2.1:** *Satellite Broadcast Tapes*

| | |
|---|---|
| Vertical Low (VL) | 13V |
| Horizontal Low (HL) | 18V |
| Vertical High (VH) | 13V + 22Khz |
| Horizontal High (HH) | 18V + 22Khz |

**Figure 2.3:** *The Block Diagram of the Digital Broadcast Satellite*




The Figure 2.3 illustrates the connection between a Low Noise Block and a Satellite Tuner within a satellite television system. The LNB, responsible for receiving high-frequency satellite signals, determines signal polarity based on the voltage supplied, either 13V or 18V. It also communicates control data via the I2C. The Satellite Tuner receives the RF signal from the LNB, demodulates it, and processes it into a usable form. This processed signal is transmitted to the Digital Satellite Demodulator through the SAT I/Q (In-phase and Quadrature) interface. The Digital Satellite Demodulator decodes the satellite signal and delivers the final output to the television or set-top box, enabling content viewing.

## 2.3 Exploring the Power Supply Architecture of TV Systems: A Detailed Examination of LNBp Circuitry

The boost converter structure used in the LNBP circuit emerges as a critical component for processing weak satellite signals with low noise [18]. The boost structure is designed to elevate input signals, which are amplified by a low noise amplifier, to higher levels. It is commonly implemented as a high efficiency switched mode DC/DC converter [19]. This converter is utilized to raise low input voltages to desired higher output voltages.

The main components of the boost structure include an inductor, a switch (such as a transistor or MOSFET), a diode, and capacitors [20]. The inductor stores the energy of the input voltage and releases it when the switch is turned on and off. The switch functions as a component controlling the input voltage. The diode ensures the flow of energy stored by the inductor in the correct direction. Capacitors are used to smooth out fluctuations in the output voltage and provide a stable output voltage.

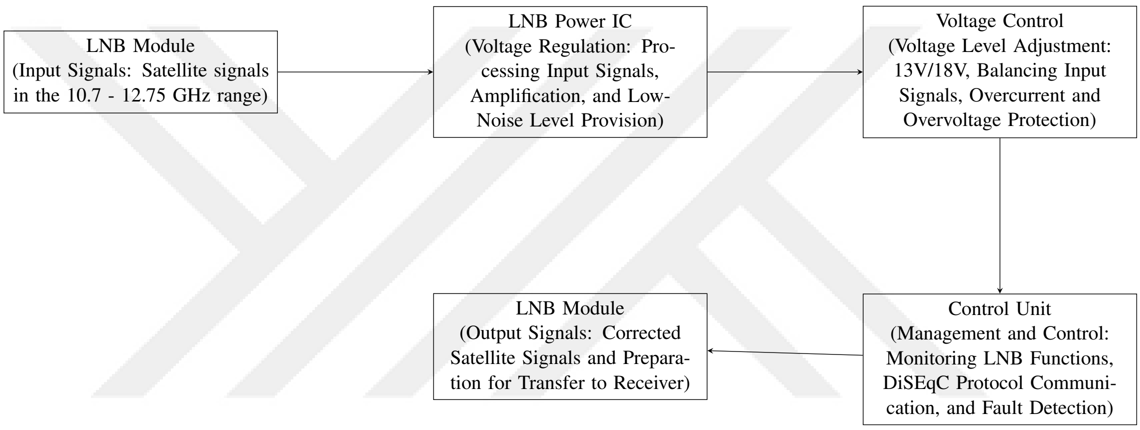
The boost structure stores and releases energy to the inductor as the switch opens and closes. This process facilitates the conversion of input voltage to output voltage. In a boost converter, the output voltage depends on factors like the switching frequency and the values of the inductor and capacitor. This structure enables the generation of higher output voltages from low input voltages, thereby providing signals that can be processed by other components of the LNBp circuit.

The efficiency of the boost structure depends on factors such as the selection of the inductor and capacitors, the processing speed of the switch, and the control strategy [5]. Furthermore, the proper design and optimization of the boost structure have a significant impact on the overall performance of the LNBP circuit.

In television satellite systems, LNB Power integrated circuits are designed by most companies, and these integrated circuits typically incorporate a boost DC/DC converter structure. These circuits are designed to elevate low input voltages to high output voltages and provide voltage control [18].

LNB Power integrated circuits used in television satellite systems stand out for their voltage control feature. These circuits typically incorporate a boost DC/DC converter structure designed to convert low input voltages to high output voltages. Voltage control provides users with flexibility between different voltage levels, adapting to various voltage requirements for different devices. This feature is particularly critical in cases where different voltage levels such as 13V or 18V are required, especially for LNB devices. Thanks to this structure, users gain extensive flexibility in managing the power supply of satellite receiver systems and providing suitable voltage levels for different devices. LNB Power integrated circuits play a crucial role in power management in television satellite systems, optimizing system performance.

**Figure 2.4:** *Flowchart of LNB Power IC and Control Circuitry*




## 2.4 Evaluation of LNB Power IC Performance under Stress Conditions

### *2.4.1 Voltage Stress Test*

This section evaluates the performance of the LNB Power IC under voltage conditions that exceed its design and operational limits. The purpose of the Voltage Stress Test is to determine if the IC operates safely and accurately under extreme voltage variations, both high and low, and to identify potential failures or performance issues when these limits are exceeded.

The test begins by defining the maximum and minimum operational voltage limits as specified by the manufacturer, which are usually documented in the IC's datasheet or technical specifications. The IC is then subjected to these voltage conditions using a controlled power supply. The voltages are applied for a specified duration, ranging from several hours to days, to monitor the IC's performance and durability. During the test, voltage levels are adjusted incrementally, either increasing or decreasing, to analyze the IC's response to voltage fluctuations.

Throughout the observations, the IC's performance is carefully monitored to evaluate signal quality, output voltage, and overall functionality. The operational stability of the IC is assessed both within and beyond voltage limits, observing any signs of degradation, overheating, or performance drops. Additionally, any severe failures, such as burning, short circuits, or overheating, are documented to determine if they cause permanent damage.

The measurements include recording the maximum and minimum voltage values that impact the IC's performance, along with assessing signal quality, temperature response, and overall stability. The results of this test provide insights into the voltage endurance and reliability of the IC, highlighting performance limitations and failure mechanisms. These findings are crucial for improving the design and manufacturing processes of the IC and establishing safe operational voltage ranges [6].

### *2.4.2 Current Stress Test*

The Current Stress Test evaluates how the IC performs under high current conditions and assesses its reliability in handling overcurrent situations. This test is crucial for determining the IC's ability to tolerate excessive current without failure and ensuring it operates correctly under abnormal conditions.

The test procedure involves applying a current level that typically exceeds the IC's design specifications. This current level is carefully chosen to test the IC's limits and analyze its response to stress conditions. The high current is maintained continuously for a set duration, which can range from minutes to hours, depending on the test requirements. The current level may be varied in steps during the test to observe how the IC responds to different levels of overcurrent.

Key observations include monitoring the IC's temperature to identify any overheating issues, as high current conditions can cause significant thermal stress, affecting performance and reliability. The test also evaluates performance degradation, such as reduced signal quality or erratic behavior. Any signs of failure, such as abnormal noises, smoke, or physical damage, are documented. The effectiveness of the IC's built-in overcurrent protection mechanisms is also assessed to ensure they activate as intended to prevent damage.

The results involve analyzing the applied current levels, the duration of the test, and the IC's performance, including temperature stability and the reliability of protection mechanisms. This data helps identify the IC's current-handling capabilities and informs potential design improvements to enhance its robustness against high current scenarios.

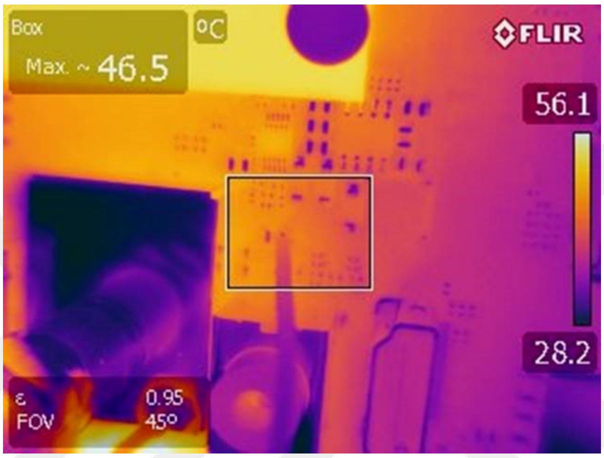
### *2.4.3 Thermal Test*

The Thermal Test assesses the IC's performance under a range of temperature conditions, including extreme heat and rapid temperature changes. This evaluation is critical for determining the IC's thermal endurance and long-term stability.

The test exposes the IC to temperatures beyond the manufacturer's specified operating range, including both low and high extremes. The IC is also subjected to temperature cycling, where it is repeatedly heated and cooled to analyze its response to rapid temperature shifts. The rate of temperature change and the duration at each level are carefully controlled. Additionally, the IC's long-term thermal stability is tested by maintaining it at elevated temperatures for extended periods [21].

Performance under high temperatures is continuously monitored, focusing on signs of thermal stress, such as efficiency loss, signal distortion, or altered output characteristics. Indicators of overheating, like thermal shutdown, physical deformation, or discoloration, are noted. The IC's resilience to rapid temperature changes is also evaluated, looking for issues like thermal shock, cracking, or shifts in electrical properties.

**Figure 2.5:** *Thermal camera image of the LNB Power circuit. The maximum temperature is measured as 46.5°C.*




Measurements include minimum and maximum operating temperatures, thermal response times, and the IC's ability to stabilize after temperature variations. The IC's overall functionality under thermal stress is analyzed, including changes in electrical characteristics and signal integrity. The test results provide a comprehensive understanding of the IC's thermal performance, revealing potential areas for design enhancement to improve heat management and ensure long-term reliability.

### *2.4.4 Short-Circuit Test*

The Short-Circuit Test investigates how the IC responds to fault conditions involving short circuits and evaluates the effectiveness of its protection mechanisms. This is essential for determining whether the IC can handle such conditions without sustaining damage and can recover to normal operation afterward.

The test involves intentionally creating a short circuit between specific terminals of the IC, such as between power or signal terminals, to simulate real-world fault conditions. The short circuit is applied under controlled conditions, with current and voltage carefully monitored to ensure safety. The duration and severity of the short circuit are varied to assess the IC's response to different fault scenarios. The test is repeated multiple times to ensure the IC's protection mechanisms are reliable and effective.

Observations focus on whether the IC's protection features, such as current limiting or thermal shutdown, activate as expected. Current flow and voltage levels during the short circuit are observed, noting any unusual spikes or signs of protection failure. The IC's performance after the short circuit is removed is evaluated to check for permanent damage or malfunctions. Thermal behavior is also tracked, noting any rapid temperature increases [22].

The results document the IC's resilience to short circuits, the speed and reliability of its protection mechanisms, and any damage sustained. These findings are critical for ensuring the IC's robustness in real-world applications and may inform design improvements.

### *2.4.5 Continuous Operation Test*

The Continuous Operation Test assesses the IC's long-term stability and reliability when operated continuously over an extended period. This test simulates real-world scenarios where the IC must function for days, weeks, or even months without interruption.

The IC is operated continuously under normal or stress conditions, such as elevated temperatures or higher loads, to accelerate potential failure mechanisms. Environmental factors, like ambient temperature, humidity, and load conditions, are controlled or varied to reflect the range of conditions the IC might experience. Performance, power consumption, and thermal behavior are monitored continuously or at regular intervals to detect signs of degradation or failure [23].

Thermal behavior is closely monitored, noting any temperature increases that could lead to overheating. The test evaluates performance degradation over time, such as reduced efficiency, signal quality issues, or other signs of wear-out, like electro migration. Signs of failure, such as physical damage or complete loss of function, are also documented. The IC's overall stability is analyzed, ensuring it maintains consistent operation without unexpected resets or signal instabilities.

Measurements include the duration of continuous operation, environmental conditions, power consumption trends, and thermal stability. The results reveal the IC's long-term performance and reliability, identifying potential failure modes and opportunities for design improvements. These insights ensure the IC can operate reliably over its expected lifespan and inform strategies for preventative maintenance or replacement in practical applications.

## 2.5 DC-DC Converters

DC-DC converters are power electronic circuits that convert a DC voltage to different DC voltage levels [24]. DC-DC converters are widely used circuits to efficiently produce the desired voltage level from a source to a load.

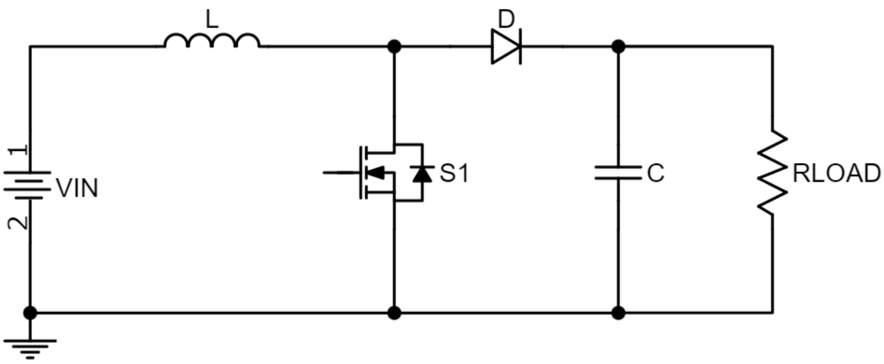
There are multiple electronic components in DC-DC converter circuits. In these circuits, inductance, capacitance, and mosfet are used based on high-switching frequency techniques [25]. The duty cycle is determined according to the on and off time of the MOSFET, and the voltage and current at the output are adjusted by changing the duty cycle. Feedback systems also can be added to these DC-DC circuits to maintain the constancy of the output voltage or current. These feedback systems control the desired output voltage or current and ensure that it stays constant when it drops or increases. Examples of feedback systems are Simple analog feedback control circuits built in opamp, transistors and digital feedback control circuits such as microprocessor basic and ICs. [26].

It can be seen in electronic devices that use DC-DC converter circuits in many areas of human life such as television, computers, refrigerators, etc [27]. Commonly used buck, boost, buck-boost, and resonant converter topologies are examples of high-efficiency DC-DC converters [28].

### *2.5.1 Boost DC-DC Converter*

Boost converters, also known as step-ups, are DC-DC high-frequency switched converters in which the output voltage is greater than the input voltage. They always have an output voltage greater than the input voltage. Since the input power and output power in the circuit will be equal, the output current is less than the input current. In the

**Figure 2.6:** *Boost DC-DC Converter*




boost converter, L (inductor) C (capacitor), D(diode), MOSFET, and Rload are connected as shown in Figure 2.6. Mosfet is turned on and turned off using Pulse Width Modulation. It is the triggering method used to control the system with a square wave. PWM is a modulation process or technique used in most communication systems to encode the amplitude of one signal into a direct pulse width or duration for transmission of another signal, usually a carrier signal. With this PWM technique, the duty cycle of the system is adjusted. The boost converter has two operating modes. These modes are switched on Ton and switched off Toff. The ratio of the switch-on mode to one period cycle that total period T, is called the duty cycle. The switching frequency (fsw) in the converter is the rate at which the switching device is turned on and off.

$$T = Ton + Toff \tag{2.1}$$

$$fsw = 1/T \tag{2.2}$$

$$D = Ton/T \tag{2.3}$$

When the switch is on mode, the diode is off, and the current flows through the switch, inductor and back to the DC input source. So, inductor stores energy in its magnetic field. Also, The Rload is supplied only capacitor.

$$diL/dt = VIN/L \tag{2.4}$$

When the switch is off mode, The energy stored on the inductor is transferred to the capacitor C and the load via the D diode.In this mode, the capacitor recharges through the coil. This results in two voltages, the supply voltage VIN and the back Vo (drop voltage on Rload) across L in series with each other.

$$\frac{diL}{dt} = \frac{(VIN - Vo)}{L} \tag{2.5}$$

Inductor current change must be zero in steady state condition and boost converter general formula is given Equation 2.6.

$$Vo = \frac{VIN}{(1 - D)} \tag{2.6}$$

### *2.5.2 Resonant Converter*

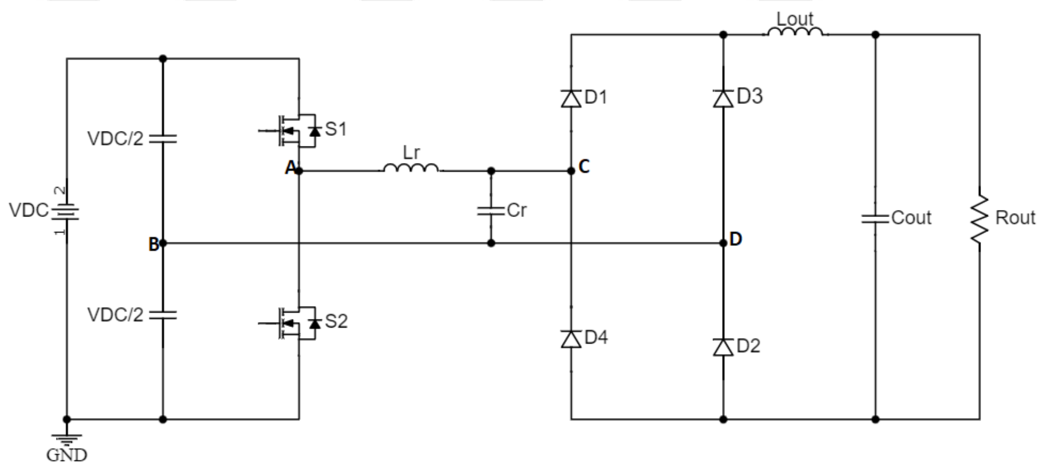
A resonant converter is electric power converter that includes a network of inductors and capacitors called a resonant tank, tuned to resonate at a specific frequency.

Resonant converters consist of LC resonant tank cirucit and oscillating voltage and current applied to the load. Also power flow the the load is controlled by the resonant tank impedance which turns to controlled resonant frequency.

#### 2.5.2.1 Parallel Resonant DC-DC Converter

The converter in Figure 2.7 is a parallel DC-DC converter that whole rectifier circuit in parallel with the resonant tank. There is a current source which is the inductor (Lout) and then connect the output capacitor (Cout).

**Figure 2.7:** *Parallel Resonant DC-DC Converter*




The output inductor Lout is connected to the rectifier output to produce constant current from the bridge to the load since the resonant capacitor is acting as a voltage source.VDC/2 is directly across this Cr capacitor and Cr capacitor is directly across this resistor Rout. A current of the resonant tank is flowing Lr and Cr and the output of this resonant rectifier is average current flow resistance Rout. MOSFETs S1 and S2 in half-bridge inverter are driven separately with phase shifting duty cycle.

There are 4 operative modes in the parallel resonant converter. When the capacitor voltage is positive, rectifier diodes D1 and D2 are on mode and carry current Io. When the capacitor voltage is negative, D3 and D4 are on mode and carry current Io. The current at the input to the rectifier bridge is therefore a square wave current of Io. The bridge output voltage is the full-wave rectified waveform of voltage. The average voltage across the output inductor Lo is zero, so the output voltage is the average of rectified voltage.

Mode 1: During this time period, Iout is positive and the current of input to the rectifier bridge is equal to Iout.So resonant capacitor (Vcr) is positive as well. S1 is ON, and S2 is OFF therefore VAB=VDC/2. D1, D2 are ON and D3,D4 are OFF.

Mode 2: During this time period, Iout is negative and the current of input to the rectifier bridge is equal to -Iout. Also, the resonant capacitor (Vcr) is negative. S1 is ON, S2 is OFF therefore VAB=-VDC/2. D1, D2 are OFF and D3,D4 are ON

Mode 3: During this time period, Iout is positive and the current of input to the rectifier bridge is equal to -Iout. The resonant capacitor (Vcr) is positive. S2 is ON, and S1 is OFF therefore VAB=VDC/2. D1, D2 are ON and D3,D4 are OFF.

Mode 4: During this time period, Iout is negative, and the current of input to the rectifier bridge is equal to -Iout. Also, the resonant capacitor (Vcr) is negative. S2 is ON, S1 is OFF therefore VAB=-VDC/2. D1, D2 are OFF and D3,D4 are ON.

# 3. METHODOLOGY

The proposed LNB Power circuit is designed using the capabilities provided by parallel resonant DC/DC converters, which are widely used in modern satellite receiver systems and offer high performance. These converters are known for their high efficiency, low noise levels, and ability to provide current limitation up to 500mA, with the required 13V/18V operating frequencies being determined.

The operation principle of the circuit begins by monitoring load changes at the output and calculating the output current accordingly. This calculated current value is then transmitted to the frequency control circuit, where necessary frequency adjustments are made to limit the current. The circuit is designed to limit the current to a maximum of 500mA by using frequency control. In this way, it is aimed to minimize the short circuit problems experienced during the wiring problems of the TV users.

The circuit addresses common cable connection problems encountered by TV users, particularly the frequent damage to LNB Power integrated circuits due to sudden current surges or short circuits. The newly designed circuit offers an intelligent approach to minimize such issues. With current limitation and frequency control, the circuit prevents the occurrence of unwanted situations, enhancing the system's robustness.

This new approach addresses the weaknesses of traditional LNB Power circuits while providing a more reliable and durable solution. With high current limitations and intelligent power control, users experience a longer-lasting and smoother operation of satellite receiver systems.

## 3.1 Proposed Circuit

Figure 2.7 shows the proposed parallel resonant converter circuit. 2 mosfets S1 and S2 form a half-bridge converter. The full bridge rectifier circuit consists of four diodes D1, D2, D3, and D4. Inductor $L_r$ and capacitor $C_r$ are used to create an oscillation in the circuit and to ensure that this oscillation continues at the desired frequency and waveform. Lout and Cout are represented as output filters that minimize fluctuations in the output voltage and current, providing the desired smooth output voltage and current.

## 3.2 Parallel Resonant Converter Operating

The parallel resonant DC/DC converter circuit is operated at a fixed %50 duty cycle with frequency control according to the output current. The circuit described starts with applying a square wave voltage VAB, controlled by switches, to a desired parallel resonant circuit. When the voltage is in the correct polarity, it creates a magnetic field in the inductor, storing energy in the capacitor. Once the magnetic field is established, the circuit allows the energy to discharge from the capacitor to the inductor, creating a sinusoidal voltage at a resonant frequency, which is called VCB. This voltage is rectified and filtered, resulting in a current Iout. So, when VCB is positive, the output of the current takes a positive value of Iout, otherwise, VCB is negative, and the output of the current takes a negative value of Iout. The average value of the square wave voltage of the bridge VCB is equal to the output voltage, assuming that the voltage across the $C_r$ capacitor is sinusoidal.

The features of the proposed LNB power circuit design are as follows:

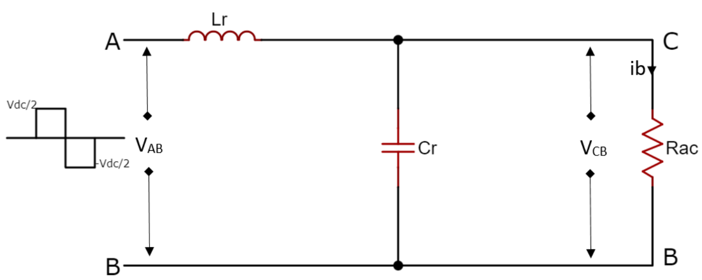
- The proposed circuit limits the current and prevents short circuits that may occur in satellite cable installations.
- Working in high-frequency ranges can reduce electromagnetic interference problems.
- The circuit meets the required specifications, including the determination of the 13V/18V operating frequencies.

- The calculated current value is transmitted to the frequency control circuit, which adjusts the frequency as needed to limit the current.

## 3.3 Converter Analysis

A square wave voltage with a magnitude of $V_{DC}$ between $-V_{DC}/2$ and $V_{DC}/2$ is generated at the frequency determined by the switching operation and applied to the $L_r$-$C_r$ network. Assuming sinusoidal voltage across capacitor $C_r$, the analysis of the parallel DC-DC converter can be undertaken, with consideration given to the only fundamental frequencies of the square wave voltage input and square wave current [19]. This assumption allows the converter to be modeled as a simple voltage source with a series resistor and inductor, which simplifies the analysis and design of the converter. Hence, AC analysis can be used to calculate the voltages of the equivalent circuit shown in Figure 3.1. The $L_r$-$C_r$ network is designed to filter out all harmonic voltage components except for the fundamental component that exists in voltage VAB. The AC resistance, $R_{ac}$, is included in the AC equivalent circuit to represent the non-linear characteristics of the rectifier. The reactances of $L_r$ and $C_r$ are indicated by $XL_r$ and $XC_r$ respectively. To put it simply, the $L_r, C_r$ network is a filter that only allows the fundamental voltage component to pass through, while the AC resistance and reactances of $L_r$ and $C_r$ are used to account for the nonlinearities in the rectifier. Equation (3.1) can be used to solve the VCB voltage of the

**Figure 3.1:** *Equivalent AC circuit*

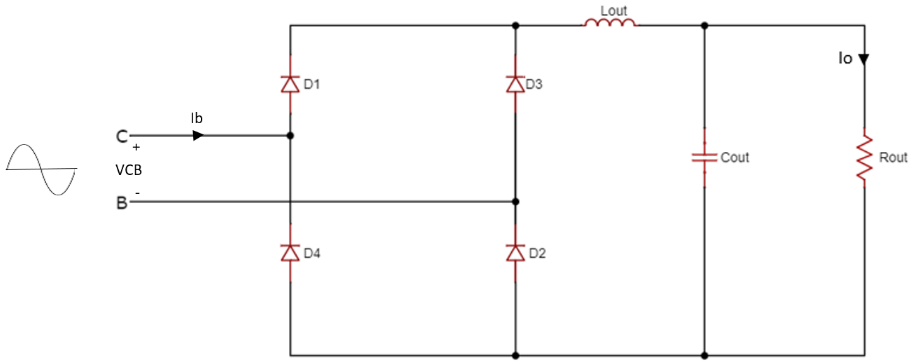


equivalent circuit in Figure 2.7.

$$\frac{V_{CB}}{V_{AB}} = \frac{1}{1 - \frac{XL_r}{XC_r} + j\frac{XL_r}{R_{ac}}} \tag{3.1}$$

VCB represents the amplitude of the fundamental frequency component of the input

**Figure 3.2:** *$R_{ac}$ Equivalent Circuit*




voltage waveform, also Ib refers to the amplitude fundamental frequency component of the square wave current waveform. So, $R_{ac}$ can be shown equivalent circuit is Figure 4.4 and calculated by Equation (3.2).

$$R_{ac} = \frac{V_{CB}(rms)}{I_b(rms)} = \frac{V_o\frac{\pi}{2}}{\frac{4I_o}{\pi}} = \frac{\pi^2}{8}\frac{V_o}{I_o} = \frac{\pi^2}{8}R_{out} \tag{3.2}$$

where Vo is the average value of the full-wave rectified voltage waveform at the output of the bridge as defined in Equation (3.3).

$$V_o = \frac{2V_{CB}(rms)}{\pi} \tag{3.3}$$

The resonant frequency, defined as $f_o$ in Equation (3.4) is the point at which the circuit exhibits its highest response, and it is the most efficient operating point of the converter.

$$w_o = 2\pi f_o = \frac{1}{\sqrt{L_r C_r}} \tag{3.4}$$

The output voltage is a final expression as given in Equation (3.5).

$$V_o = \frac{4V_{DC}}{\pi^2 \sqrt{\left(1 - \frac{XL_r}{XC_r}\right)^2 + \left(\frac{XL_r}{R_{ac}}\right)^2}} \tag{3.5}$$

## 3.4 Calculating and Designing Steps

The designed LNB power circuit is based on the principle of frequency control that varies with load changes and operates with a %50 duty cycle. In order to determine the operating frequencies of the circuit, the transfer function of the circuit has been calculated in terms of frequency using equations.

$$V_o^2 = \frac{16V_{DC}}{\pi^4 \left|\left(1 - \frac{XL_r}{XC_r}\right)^2 + \left(\frac{XL_r}{R_{ac}}\right)^2\right|} \tag{3.6}$$

$$XL_r = 2\pi f_s L_r \tag{3.7}$$

$$XC_r = \frac{1}{2\pi f_s C_r} \tag{3.8}$$

where $f_s$ is the switching frequency as defined in Equation (3.9).

$$w_s = 2\pi f_s \tag{3.9}$$

Equations (3.7) and (3.8) are substituted and the resulting expression can be simplified as in Equation (3.10).

$$\frac{16V_{DC}^2}{V_o^2} = \pi^4 \left(1 - w_s^2 L_r C_r\right)^2 + \left(\frac{w_s L_r}{R_{ac}}\right)^2 \tag{3.10}$$

When the equation is rearranged into a two-variable equation format, the final form of the function is obtained as given in Equation (3.11).

$$w_s^4 (L_r^2 C_r^2) + w_s^2 \left(\frac{L_r^2}{R_{ac}^2} - 2L_r C_r\right) + 1 - \frac{16V_{DC}^2}{V_o^2 \pi^4} = 0 \tag{3.11}$$

Later, the discriminant method can be used to calculate the two root switching frequency values of the equation: one that is greater and one that is smaller than the resonant frequency.

$$f_{sw1} = \sqrt{\frac{-\left(\frac{L_r}{R_{ac}}\right)^2 + 2L_rC_r + \sqrt{\left(\frac{L_r}{R_{ac}}\right)^4 - \frac{4L_r^3C_r}{R_{ac}}^2 + \frac{64V_{DC}^2L_r^2C_r^2}{V_o^2\pi^4}}}{8L_r^2C_r^2\pi^4}} \tag{3.12}$$

$$f_{sw2} = \sqrt{\frac{-\left(\frac{L_r}{R_{ac}}\right)^2 + 2L_rC_r - \sqrt{\left(\frac{L_r}{R_{ac}}\right)^4 - \frac{4L_r^3C_r}{R_{ac}}^2 + \frac{64V_{DC}^2L_r^2C_r^2}{V_o^2\pi^4}}}{8L_r^2C_r^2\pi^4}} \tag{3.13}$$

The switching frequency in the designed circuit is $f_{sw1}$ frequency selected which is to be higher than the resonant frequency to improve better stability of circuit behavior.

## 3.5 Proposed Circuit Calculations

$V_{out}$ should be $13V$ for vertical polarization and $18V$ for horizontal polarization respectively. In this circuit, $V_{DC}$ has been chosen as $12V$, the current limits have been defined to vary within the range of 1mA-500mA and the resonant frequency has been determined to be 300kHz. The calculations for $V_{out}$ = $13V$ are as follows:

- $V_{out}$ =13$V$, $V_{DC}$=12$V$, $I_o$=500mA;

$$R_{out} = \frac{V_o}{I_o} = \frac{13V}{500mA} = 26\Omega \tag{3.14}$$

$R_{ac}$ can be calculated using Equation (3.2).

$$R_{ac} = \frac{\pi^2}{8}26 = 32.07\Omega \tag{3.15}$$

- $V_{out}$ =13$V$, $V_{DC}$=12$V$, $I_o$=1mA;

$$R_{out} = \frac{V_o}{I_o} = \frac{13V}{1mA} = 13k\Omega \tag{3.16}$$

$$R_{ac} = \frac{\pi^2}{8} 13k\Omega = 16.038k\Omega \tag{3.17}$$

When the values of $R_{ac}, V_o$, and $V_{DC}$ are substituted into the switching frequency equation in Equation (3.12) for both maximum current and minimum current, the operating frequency range (Δf) can be decided.

$$f_{sw,1mA} = \sqrt{\frac{-\left(\frac{L_r}{16038}\right)^2 + 2L_rC_r + \sqrt{\left(\frac{L_r}{16038}\right)^4 - \frac{4L_r^3C_r}{16038}^2 + (0.559L_r^2C_r^2)}}{8L_r^2C_r^2\pi^4}} \tag{3.18}$$

$$f_{sw,500mA} = \sqrt{\frac{-\left(\frac{L_r}{32.07}\right)^2 + 2L_rC_r + \sqrt{\left(\frac{L_r}{32.07}\right)^4 - \frac{4L_r^3C_r}{32.07}^2 + (0.559L_r^2C_r^2)}}{8L_r^2C_r^2\pi^4}} \tag{3.19}$$

The calculations for $V_{out}$ = 18V are as follows:

- $V_{out}$ =18V, $V_{DC}$=12V, $I_o$=500mA;

$$R_{out} = \frac{V_o}{I_o} = \frac{18V}{500mA} = 36\Omega \tag{3.20}$$

$R_{ac}$ can be calculated using Equation 2.

$$R_{ac} = \frac{\pi^2}{8} 36 = 44.41\Omega \tag{3.21}$$

- $V_{out}$ =18V, $V_{DC}$=12V, $I_o$=1mA;

$$R_{out} = \frac{V_o}{I_o} = \frac{18V}{1mA} = 18k\Omega \tag{3.22}$$

$$R_{ac} = \frac{\pi^2}{8} 18k = 22.206k\Omega \tag{3.23}$$

$$f_{sw,1mA} = \sqrt{\frac{-\left(\frac{L_r}{22206}\right)^2 + 2L_rC_r + \sqrt{\left(\frac{L_r}{22206}\right)^4 - \frac{4L_r^3C_r}{22206}^2 + (0.292L_r^2C_r^2)}}{8L_r^2C_r^2\pi^4}} \tag{3.24}$$

$$f_{sw,500mA} = \sqrt{\frac{-\left(\frac{L_r}{44.42}\right)^2 + 2L_rC_r + \sqrt{\left(\frac{L_r}{44.42}\right)^4 - \frac{4L_r^3C_r}{44.41}^2 + (0.292L_r^2C_r^2)}}{8L_r^2C_r^2\pi^4}} \tag{3.25}$$

## 3.6 Selection $L_r$ and $C_r$ values

The $L_r$ and $C_r$ components are obtained from Equation (3.5).

$$L_rC_r = \left(\frac{1}{2\pi f_o}\right)^2 \tag{3.26}$$

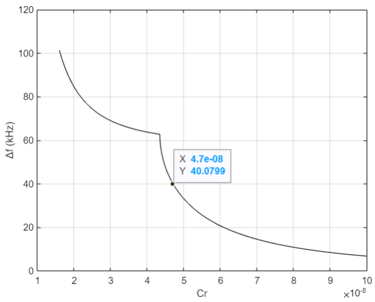
After selecting resonant frequency $f_o$ as 300kHz, is expressed as

$$L_rC_r = 28.14 \cdot 10^{-14} \tag{3.27}$$

When $L_r$ value is written as an equation in terms of $C_r$, the Δf $(f_{sw,1mA} - f_{sw,500mA})$ graph can be plotted as a function of the $C_r$ values for output voltages of 13V and 18V.

$$C_r = \frac{28.14 \cdot 10^{-14}}{L_r} \tag{3.28}$$

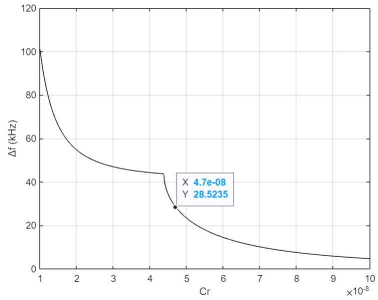
**Figure 3.3:** *Operating frequency differences (Δf) for $V_{out}$=13V at $f_o$=300kHz*




As seen in Figure 3.3 and Figure 3.4, the slope of the curves changes after a certain point, because there is an imaginary part at the $f_{500mA}$ switching frequency. When considering only the real parts and taking the capacitance value as a readily obtainable parameter, a capacitance value of 47nF has been selected as the maximum value for the Δf. So, $L_r$ can be calculated by Equation (3.28).

$$L_r = \frac{28.14 \cdot 10^{-14}}{47 \cdot 10^{-9}} = 6uH \tag{3.29}$$

**Figure 3.4:** *Operating frequency differences ($\Delta f$) for $V_{out}$=18V at $f_o$=300kHz*




When the equations are substituted in order, the switching frequencies are found in Table 3.1.

**Table 3.1:** *Maximum and minimum switching frequencies*

| **Horizontal/Vertical** | **Minimum $f_{sw}$ $f_{(sw,500mA)}$ (kHz)** | **Maximum $f_{sw}$ $f_{(sw,1mA)}$ (kHz)** |
|---|---|---|
| 13V | 311.18 | 351.29 |
| 18V | 309.18 | 337.70 |

Approximate operating frequency ranges are

$$\Delta f = \begin{cases} 28kHz, V_{out} = 18V \\ \\ 40kHz, V_{out} = 13V \end{cases} \tag{3.30}$$

Therefore, the circuit's operating frequency range has been designed between 309 kHz and 351 kHz.

## 3.7 Selection of Lo and Co

The selection of the cutoff frequency is an important parameter in a power electronics circuit and can help mitigate interference at high frequencies. In such a circuit, it is crucial to control and minimize the noise and fluctuations caused by the switching frequency, and to ensure that undesirable effects are kept to a minimum. Additionally, it may be necessary to ensure that the average values of current and voltage fluctuations conform to specific limits.

The cut-off frequency (fc) for an LC circuit is typically calculated using the following Equation (3.31).

$$fc = \frac{1}{2\pi\sqrt{LC}} \tag{3.31}$$

To ensure that the average value of current and voltage ripple does not exceed 10%, and to prevent any interference from the switching frequency, a $10uH$ inductor and a $10uF$ capacitor have been selected, with a cut-off frequency lower than 300 kHz. As a result, the inductor and capacitor combination leads to a cutoff frequency of approximately 159 kHz. This lower cutoff frequency, in comparison to the switching frequency, can be effectively utilized to control and mitigate the noise and fluctuations generated by the switching operation. Consequently, it contributes significantly to maintaining current and voltage fluctuations at acceptable levels.

## 3.8 Simulation Results of Designed Circuit

The proposed LNB power circuit has been simulated using Matlab Simulink, which is a parallel resonant converter circuit designed with PI feedback, as shown in Figure 3.5. The required switching frequencies for minimum and maximum currents for $18V$ output voltage are shown in Figure 3.6 and Figure 3.7. Similarly, the required frequencies for minimum and maximum currents for $13V$ output voltage are shown in Figure 3.8 and Figure 3.9. In simulation studies, diodes and MOSFETs are considered ideal. The circuit is designed to have a maximum output current of $500mA$, and the current is limited by using a PI controller to maintain the current within the calculated frequency range without exceeding 500mA. In the proposed circuit, an overdamped PI control has been designed to provide the output voltage stabilized to the desired value and simultaneously minimize undesired overshoots. As shown in Figure 3.10, the circuit's maximum output current within the specified frequency range (309 kHz-351 kHz) has been simulated when the output resistance is nearly zero, as in the case of a short circuit. In Figure 3.11, it is noted that the maximum output current has been measured as 13.2A when the output voltage of an LNB power IC has been short circuited. However, it has been shown by simulation that current peaks can not occur in short-circuit conditions in the operating frequency range, thanks to the use of the parallel resonant converter circuit.

**Figure 3.5:** *Parallel Resonant DC/DC Converter Simulation Circuit with PI controller feedback*

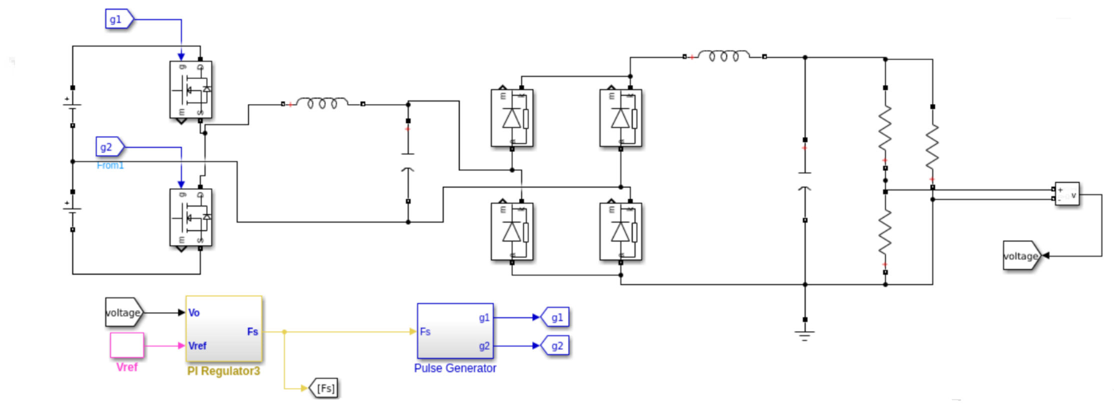
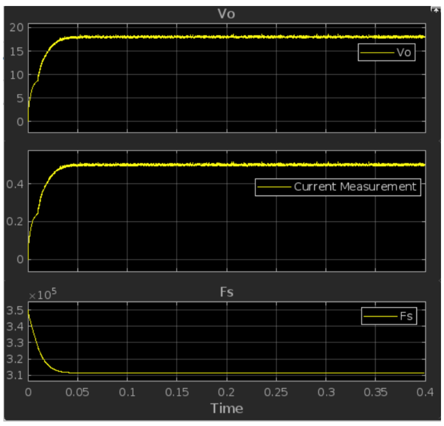



**Figure 3.6:** *Simulation results for* $V_o = 18V$ *and* $I_o = 500mA$




The simulation results for $V_o = 18V$ and $I_o = 500mA$ demonstrate that the circuit maintains stable output under these conditions, as seen in Figure 3.6. The current remains within the safe operating range, preventing potential damage.

**Figure 3.7:** *Simulation results for* $V_o = 18V$ *and* $I_o = 1mA$

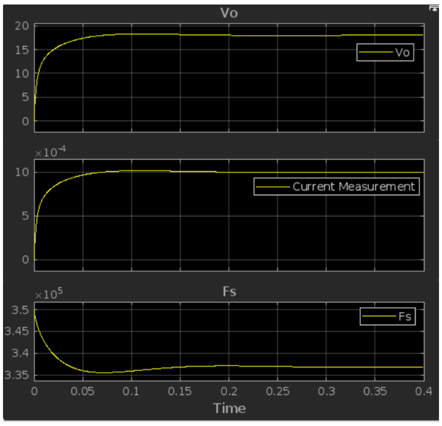



**Figure 3.8:** *Simulation results for* $V_o = 13V$ *and* $I_o = 500mA$

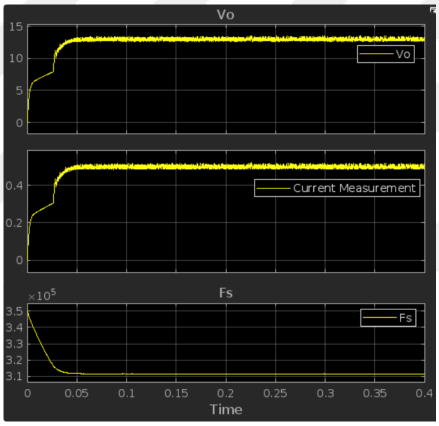
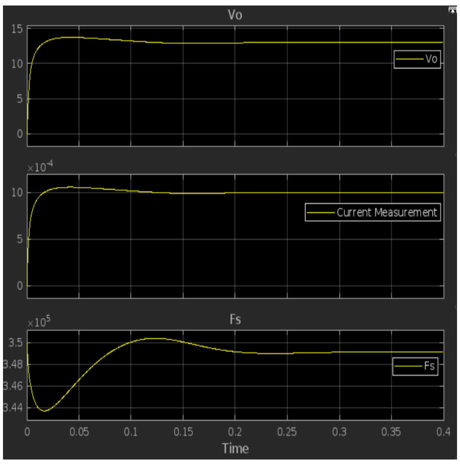



**Figure 3.9:** *Simulation results for* $V_o = 13V$ *and* $I_o = 1mA$



In the simulations result for $V_o = 13V$ and $I_o = 500mA$ similarly, the current limiting capability of the circuit was maintained, and the circuit continued to operate safely in the event of a short circuit as seen in Figure 3.8.

**Figure 3.10:** *Simulation results for Short Circuit $V_o = 0V$ and $R_{out} = 0.01R$*

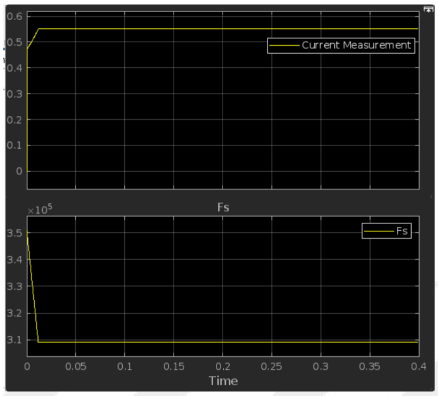
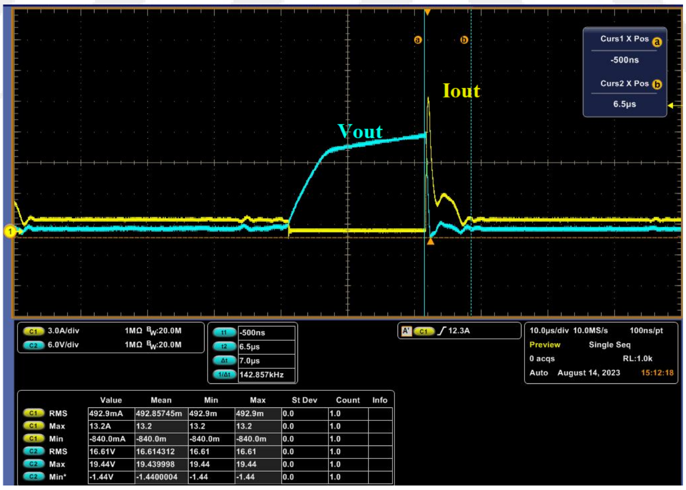


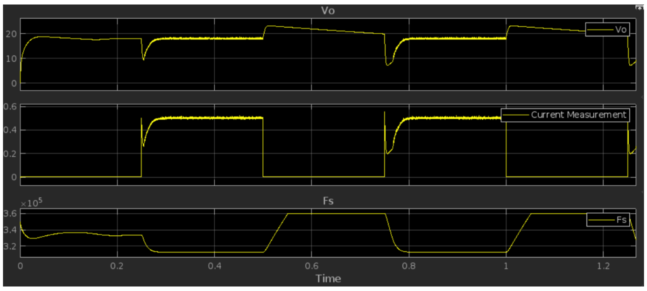

**Figure 3.11:** *LNB Power IC peak current measurement during Short Circuit Test Condition*



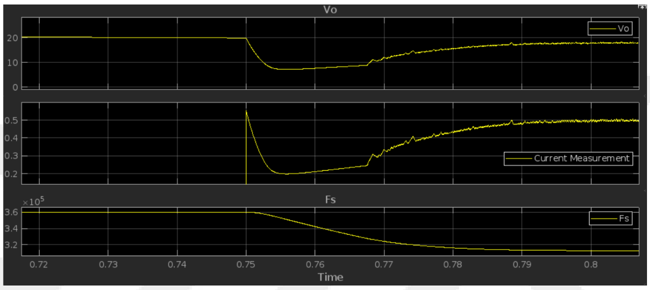

A PI control circuit was designed to create a control loop that predicts output changes by adjusting to the frequency range. In the design, the output current was set to 1mA, and a MOSFET operating with a 500ms period was used. A parallel resistor was connected to the MOSFET's output. With these settings, the output current was increased from 1mA to 500mA as demonstrated in Figure 3.12(a), and changes in the circuit's output

**Figure 3.12:** *Simulating the steady-state performance of the designed circuit*

**((a))**




**((b))**




were observed. The suitability of the Proportional (P) and Integral (I) parameters of the PI control circuit was evaluated through this simulation process. As seen more clearly in Figure 3.12(b), the proposed circuit has been reached steady state point roughly 0.05 second.

As a result, the simulations demonstrate that the parallel resonant converter effectively controls sudden current peaks in LNB power circuits and reduces the risk of short circuits.

# 4. POWER MANAGEMENT IN SATELLITE COMMUNICATION SYSTEMS: LNB POWER CIRCUIT DESIGN AND TEST RESULTS

This study focuses on the design and implementation of a customized power circuit for a Low Noise Block used in satellite communication systems. The primary objective of the project is to develop a stable and highly efficient power supply that maximizes the performance of the LNB. Unlike conventional LNB power integrated circuits that rely on voltage control, this design adopts a frequency-based control mechanism to regulate the current.

The developed circuit is analog based and achieves current stabilization through frequency feedback. This design provides a constant current source required by the LNB while minimizing signal noise. The choice of frequency control over voltage control was driven by the need for the system to operate with high precision across a wider operating range. Moreover, this approach allows the power supply to be less susceptible to temperature variations and other environmental factors.

This configuration helps to introduce a new perspective for future LNB power circuit designs and satellite communication system research. The analog implementation increases the modularity and scalability of the system, allowing for hybrid solutions when integrated with digital systems.

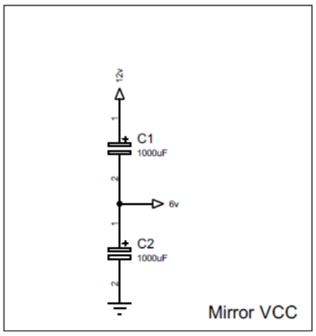
## 4.1 Circuit Design and Implementation

The following diagram illustrates the power circuit developed for the LNB. The design is based on a frequency controlled feedback loop that ensures stable current delivery to the LNB. Key components include a frequency oscillator, a current stabilization module, and filtering elements to minimize noise. The analog nature of the circuit allows for smooth operation across a wide range of environmental conditions, with minimal interference in signal transmission. Below is the schematic representation of the circuit.

## 4.2 General Structure of the Circuit

### *4.2.1 Power Input Stage*

**Figure 4.1:** *Input Part of Circuit*

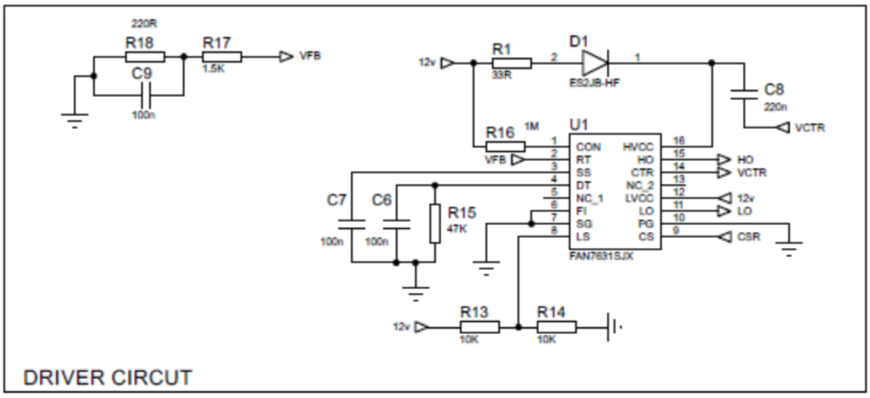



As seen in Figure 4.1, the circuit is connected to a 12V power supply, which is regulated and processed through various components in the circuit. The capacitors C1 and C2, each with a capacitance of 1000µF, play a crucial role in maintaining the stability of the voltage from the power supply. These capacitors ensure that the voltage remains smooth and consistent by filtering out sudden voltage spikes and unwanted noise, thanks to their high capacitance. This helps to prevent any interference or instability in the circuit's operation.

### *4.2.2 Switching Stage*

As illustrated in Figure 4.2, U1 (FAN7631SJX) is a PWM controller that manages the switching of the MOSFETs to regulate the input voltage and provide a stable output required by the LNB. It performs frequency control by determining the switching frequency of the PWM signal. This frequency adjustment allows precise control of the output voltage, ensuring stability under varying load conditions. The resonant frequency

**Figure 4.2:** *PWM Control and MOSFET Drivers of Circuit*




of the circuit is set to 300 kHz, while the switching frequency values were calculated in MATLAB as $f_{\text{min}} = 310$ kHz and $f_{\text{max}} = 351$ kHz. Considering switching and diode losses, the frequency range was adjusted to $f_{\text{min}} = 270$ kHz and $f_{\text{max}} = 351$ kHz, optimizing the circuit's performance and stability.

The circuit as seen in Figure 4.3 also incorporates Q1 and Q2 (STD100N10F7 MOSFETs), which act as high-power switches. Controlled by the PWM signal, these MOSFETs regulate voltage by alternating between on and off states, achieving high efficiency due to their minimal heat generation during high current flows. To protect and regulate the current at the MOSFET gate pins, resistors R1, R2, and R3 (33 $\Omega$) are used. These resistors ensure the proper functioning of the MOSFETs during the switching process, contributing to the overall efficiency and reliability of the circuit.

### *4.2.3 Voltage Protection and Filtering (LC Circuit)*

As shown in Figure 4.3, the circuit integrates multiple components to regulate voltage, filter noise, and ensure a stable output. Diodes play critical roles in protection and noise reduction. High-speed switching diodes (1N4148 SMD, D2 and D3) prevent reverse voltage and mitigate noise, safeguarding the circuit, while Schottky 1A/40V diodes (D4-D7) provide power protection by preventing damage caused by excessive voltage or

**Figure 4.3:** *Mosfets and Gate Drivers*

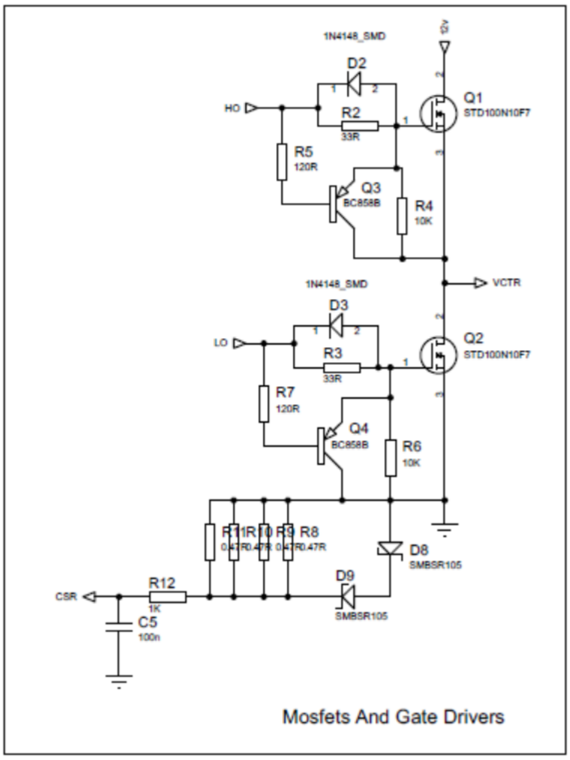
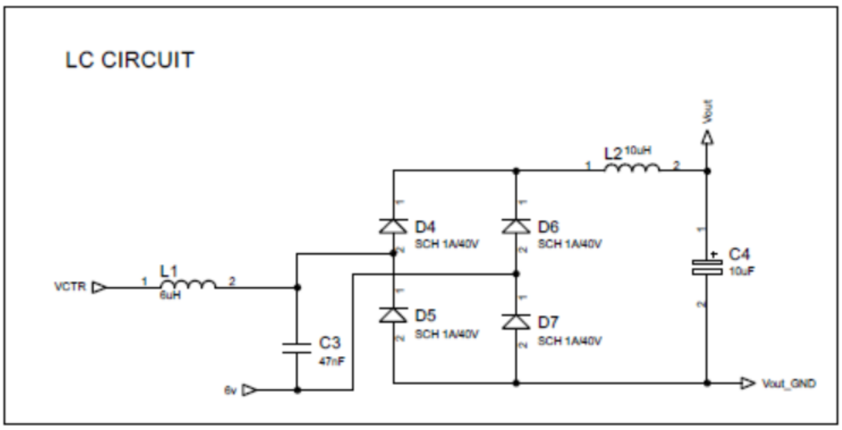



**Figure 4.4:** *Parallel Resonant Circuit and Filtering Part*

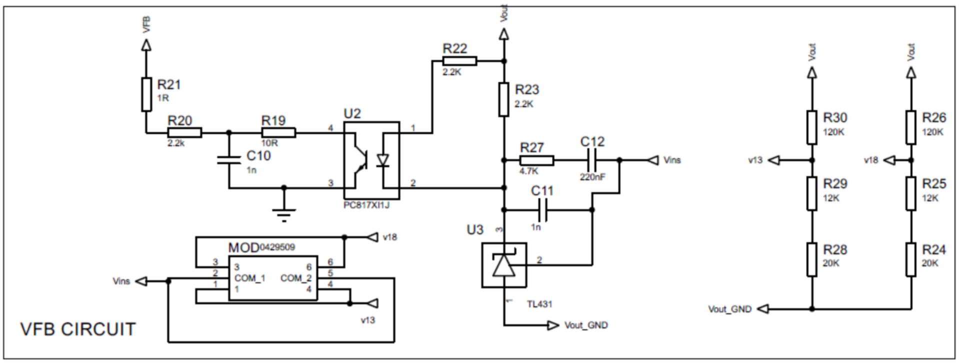


current. Additionally, SMBSR105 diodes (D8 and D9), employed in the output stage, ensure low voltage drop and fast switching, minimizing power losses. Inductive and capacitive components also contribute to stability; C4 (10 µF) and L2 (10 µH) filter out voltage fluctuations and noise in high-frequency circuits. Furthermore, the LC circuit as seen in Figure 4.4, comprising L1 (6 µH) and C3 (47 nF), acts as a parallel resonant filter to selectively allow the resonant frequency while rejecting unwanted harmonics and noise. At the resonant frequency, this circuit exhibits high impedance, effectively stabilizing the power supply and ensuring a noise free output, which is critical for the LNB.

In the output stage Figure 4.3, R8-R11 (0.47 Ω) resistors are essential for measuring and controlling the current, ensuring stability and current limiting. Meanwhile, R12-R14 (1 kΩ, 10 kΩ) resistors distribute the output voltage effectively, contributing to the proper operation of the circuit. Together, these components enhance the overall performance and reliability of the system, providing the stable power and clean signal required for sensitive satellite communication equipment.

### *4.2.4 Feedback and Control Stage*

**Figure 4.5:** *Feedback Part of Circuit*

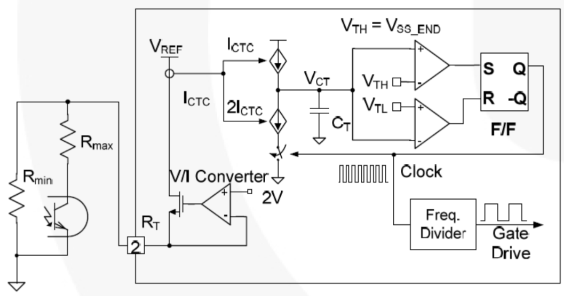



As depicted in Figure 4.5, U2 (PC817XI1J) serves as an optocoupler, enabling an isolated feedback loop that regulates the output voltage. It isolates the high-voltage side while controlling the feedback signal. Based on the reference derived from the output voltage, the optocoupler adjusts the circuit to maintain the correct voltage level. If output voltage deviates from the desired range, the optocoupler signals the driver IC (FAN7631) to implement the necessary adjustments. Complementing this, U3 (TL431) functions as a voltage reference and error amplifier, acting like an adjustable Zener diode to provide a reference voltage. It compares the output voltage—divided by resistors R24, R25, and R26 with its internal reference. If a discrepancy exists, the TL431 triggers the feedback signal, driving the optocoupler to adjust the driver IC for accurate voltage regulation.

Resistors in the feedback loop play a critical role in adjusting sensitivity and ensuring signal stability. Components like R19, R20, and C10 filter the feedback signal to maintain proper signal levels, while R27, R28, and C12 stabilize the signal at the output of the TL431, ensuring overall circuit stability. These components collectively enhance the feedback mechanism, allowing precise control over the output voltage and improving the system's reliability.

As a summary, the Vout and VFB circuits constantly monitor the output voltage using the TL431 and optocoupler. If the output voltage goes outside the set range, the TL431 and optocoupler adjust the switching frequency of the FAN7631 to regulate the output voltage. The reference voltage of the TL431, along with adjustable resistors (such as R24, R25, R26), provides precise feedback. This feedback signal ensures that the desired voltage is maintained.

**Figure 4.6:** *Current Controlled Oscilator*



As seen in Figure 4.6 [29], the voltage at the RT pin of the FAN7631 IC is internally regulated at 2V. This voltage provides a current to charge the oscillator capacitor, and this current is a reflection of the current flowing through the RT pin. The capacitor voltage is compared to certain thresholds driving a flip-flop to generate the clock signal. As the current through the RT pin increases, the switching frequency also increases.

An optocoupler is connected to the RT pin through the Rmax (R19, R20, R21) resistor to modulate the switching frequency. During an overload condition, the optocoupler is fully turned off, and the current is determined by the Rmin (R17, R18) resistor. These values are calculated based on simulation results showing a frequency ranges.

$$f_{\text{min}} = \frac{11.6\,\text{k}\Omega}{R_{\text{min}}} \times 50\,\text{kHz} \tag{4.1}$$

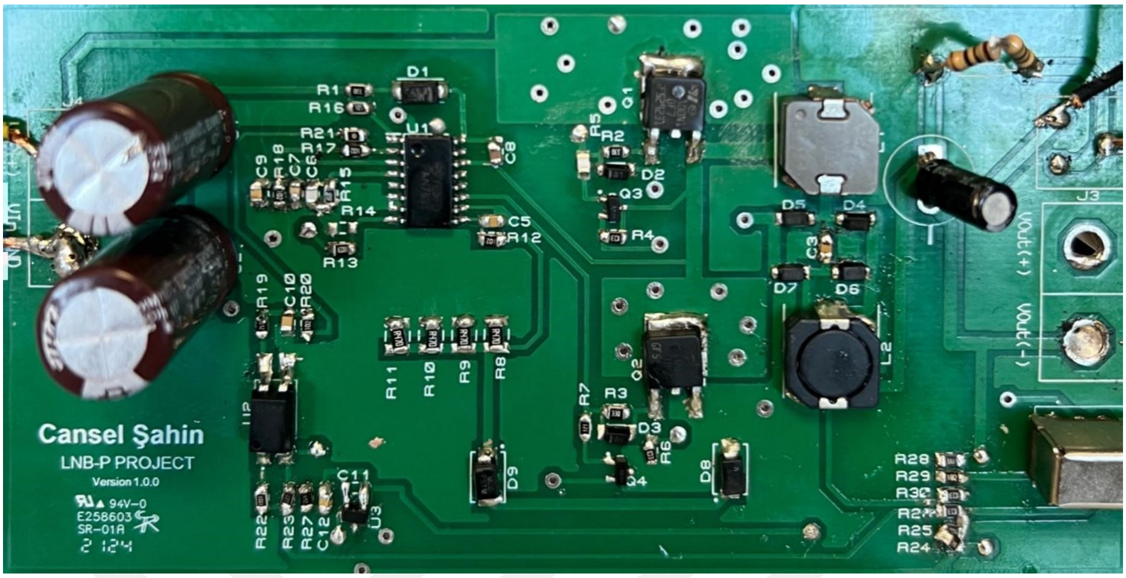
$$f_{\text{max}} = \left(\frac{11.6\,\text{k}\Omega}{R_{\text{min}}} + \frac{10.4\,\text{k}\Omega}{R_{\text{max}}}\right) \times 50\,\text{kHz} \tag{4.2}$$

#### *4.2.5 Protection and Thermal Monitoring*

Q3 and Q4 (BC858B transistors) play a crucial role in protecting the circuit during overload or short-circuit conditions at the output. They assist in maintaining voltage control and regulation, ensuring stable operation under varying conditions. Additionally, resistors R12 through R18 contribute to the circuit's thermal protection by preventing excessive current draw in high-temperature scenarios. These resistors help safeguard the circuit components from thermal damage, enhancing reliability and efficiency.

As shown in Figure 4.7, the overall circuit is designed to ensure the stable and efficient operation of the LNB power supply. The circuit includes multiple components, each serving a specific role in voltage regulation, signal processing, and protection. The PWM controller (U1, FAN7631) manages the switching of the MOSFETs (Q1, Q2) to regulate the input voltage and maintain a stable output. Key passive components, such

**Figure 4.7:** *Overall Circuit*




as the high-capacitance capacitors (C1, C2) and inductors (L1, L2), contribute to filtering noise and stabilizing the voltage. The feedback loop, consisting of the optocoupler (U2, PC817XI1J) and voltage reference IC (U3, TL431), ensures precise voltage regulation by adjusting the PWM controller based on the output voltage. Additional diodes (e.g., D2-D9) and resistors (e.g., R12-R18) provide protection against reverse voltage, excessive current, and high-temperature conditions, enhancing the overall reliability and performance of the circuit.

In the Figure 4.8, 2-layer PCB design is optimized for the LNB power circuit, with input-output connections, capacitors, resistors, transistors, and diodes arranged in an organized manner. The separation of signal and power paths aims to reduce interference, enhance performance, and improve reliability and thermal management.

## 4.3 Test Results

As seen in Figure 4.9 the waveforms show that the High Side Gate (Q1) signal operates at a frequency of 300.12 kHz with roughly duty cycle of 50%, while the Low Side Gate signal (Q2) also has a duty cycle of roughly 50%. Tests on the physical circuit

**Figure 4.8:** *PCB Layout Design*

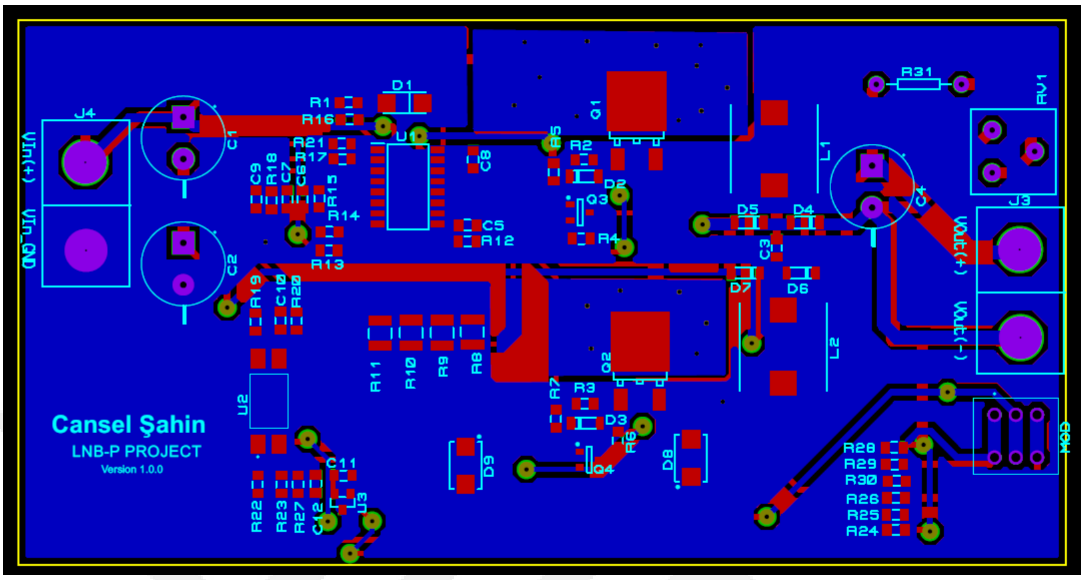
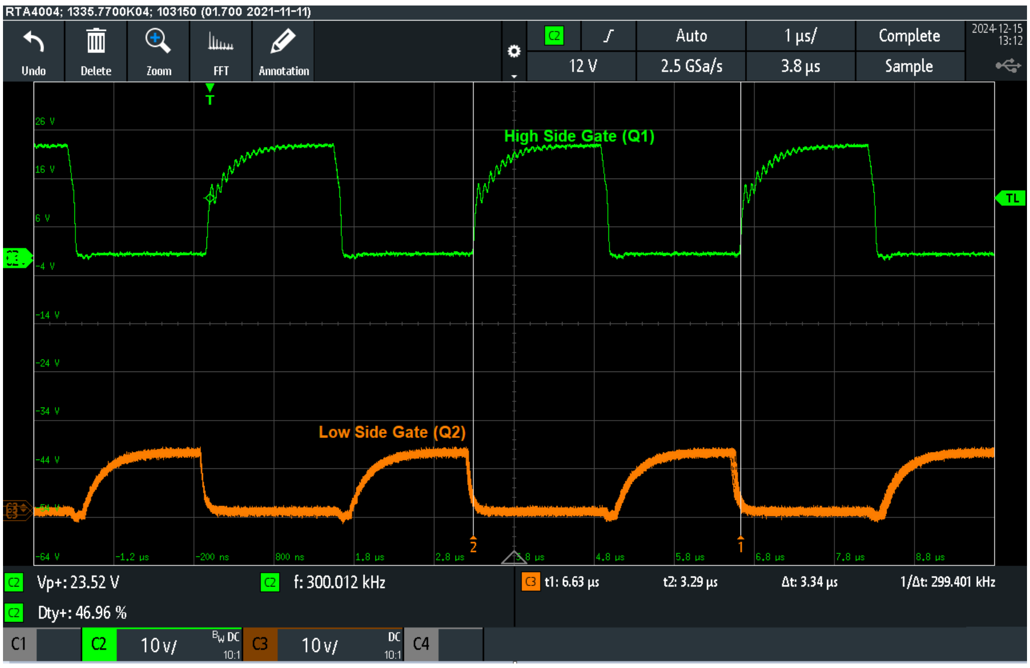
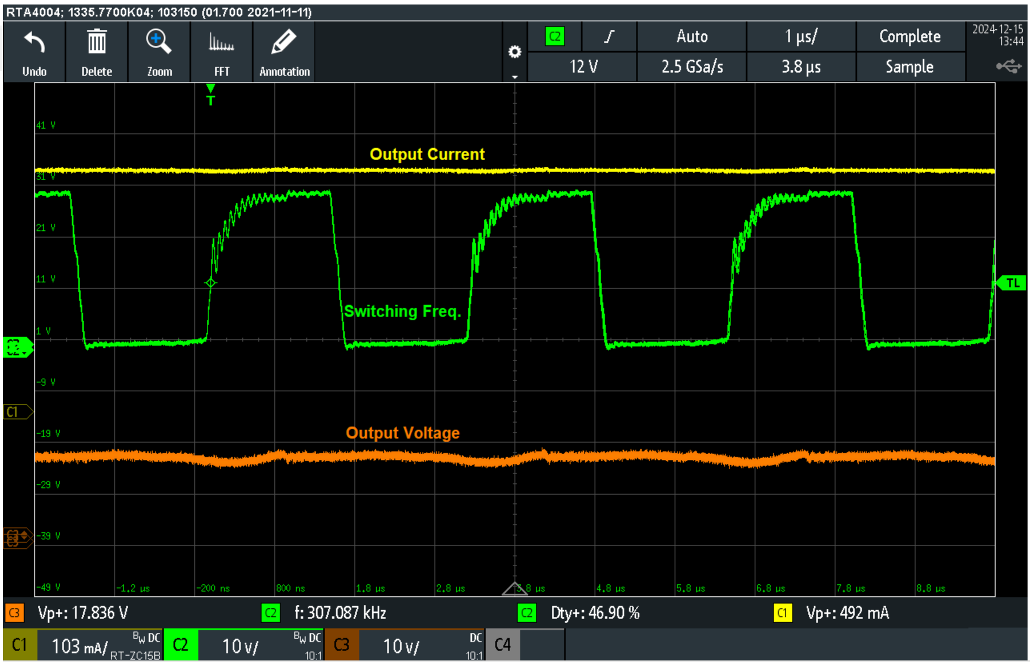



**Figure 4.9:** *High Side and Low Side Gate Switching*



confirmed that it achieved the target 18V output voltage and 500mA output current in Figure 4.10. As shown in Figure 4.11, the frequency changes at minimum current while the voltage remains constant. Similarly, stable current limitation and voltage stability were observed at 13V output in Figure 4.12 and Figure 4.13. The output current and voltage were sensitive to operating frequency. At the nominal frequency of 300 kHz, performance was consistent with simulation results. Slight deviations were observed at the boundaries of the frequency range.

**Figure 4.10:** *18V output maximum current voltage with frequency control*




The Table 4.1. highlights the stability of output voltage, current limits, and the behavior under short-circuit conditions. Minor deviations in real test results are observed due to component limitations.

As shown in Figure 4.14, the output current has been successfully limited under short-circuit conditions. During the short circuit, the current limiting mechanism was functional, but the maximum current level was measured to be slightly higher than

**Figure 4.11:** *18V output voltage minimum current with frequency control*

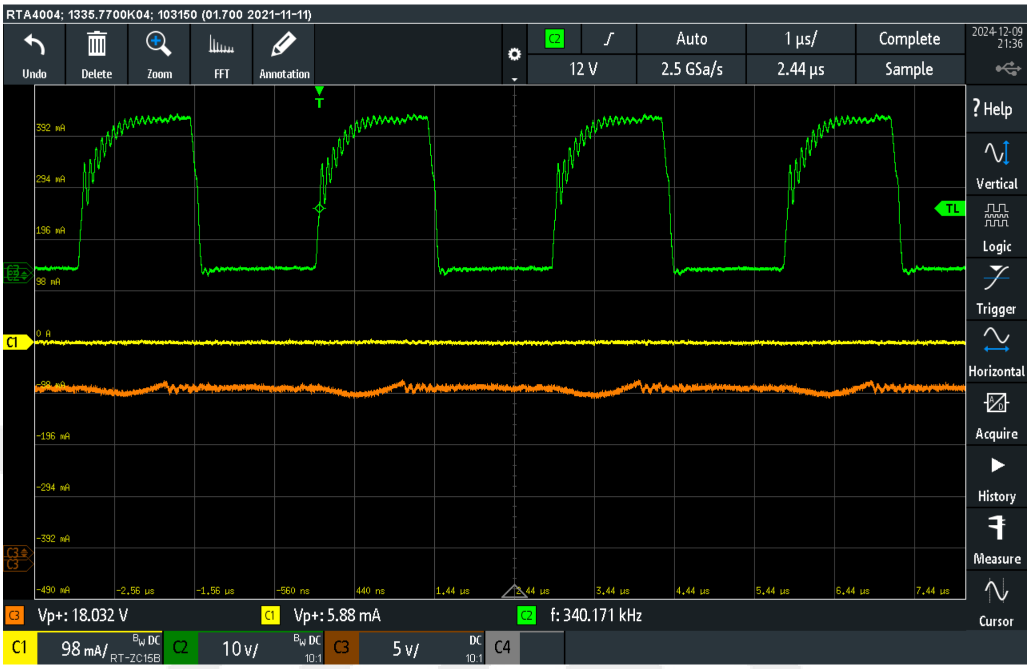



**Figure 4.12:** *13V output voltage maximum current with frequency control*

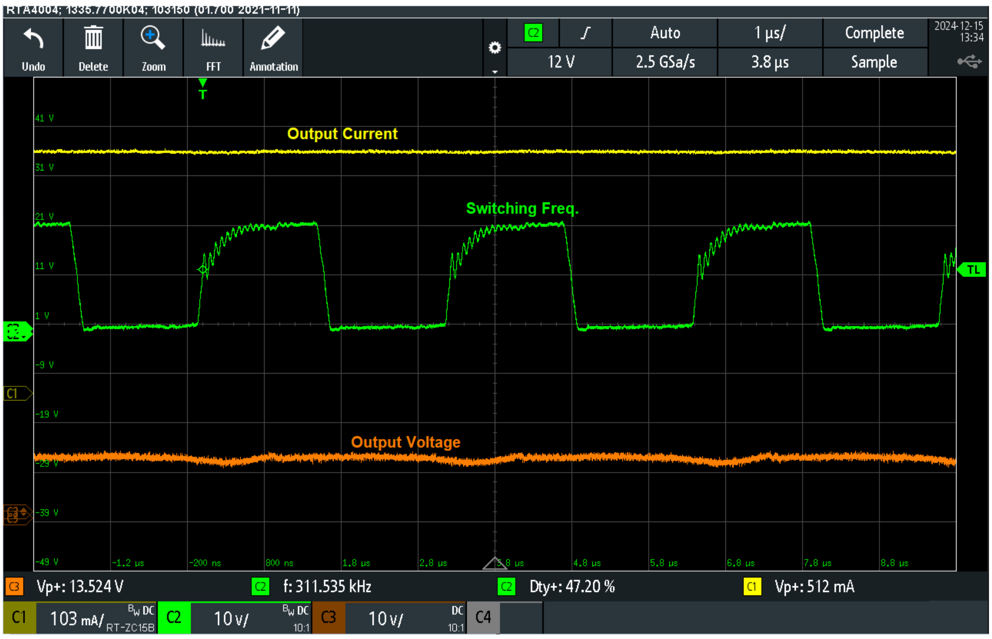


**Figure 4.13:** *13V output voltage minimum current with frequency control*

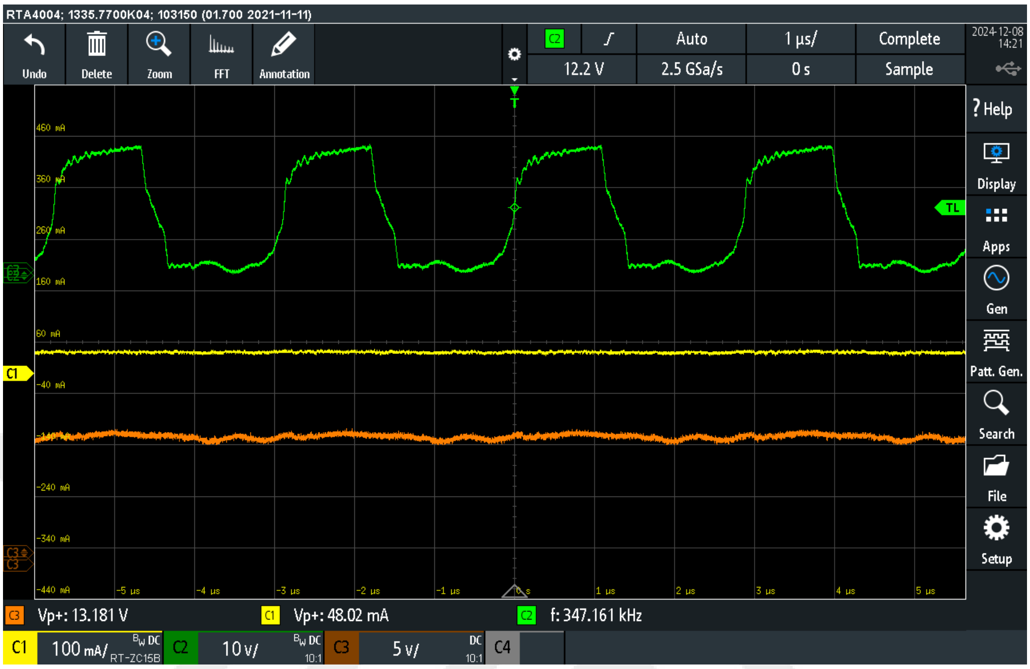



**Figure 4.14:** *Short Circuit Condition*

**Table 4.1:** *A comparison of simulation and real test results of the designed circuit*

| **Criteria** | **Simulation Results** | **Real Test Results** |
|---|---|---|
| Output Voltage | Stable at 18V and 13V | Stable at 18V and 13V |
| Maximum Current | Did not exceed the defined limit | Slightly exceeded the limit (10% deviation) |
| Short-Circuit Condition | Output voltage dropped to zero, current limited | Output voltage dropped to zero, current limited |
| Frequency Control | Performance consistent with correct frequency | Slight deviations within the frequency range |

expected. The measured maximum current was approximately 10% higher than the simulated value.This situation is due to the limitations in the switching speeds of the active components used. Additionally, during the short circuit, the switching frequency dropped to the minimum value of 270 kHz as set in the real tests. This adjustment was made to account for variations in parasitic elements and component tolerances in the actual circuit, ensuring a broader frequency range and improved reliability. However, these factors were not fully modeled in the simulation environment.

# 5. FUTURE WORKS

While the proposed parallel resonant converter design successfully addresses the issues related to current protection in LNB circuits, several potential avenues for future research can further enhance the design's effectiveness and broaden its application scope.

Performance Optimization at Higher Frequencies: Optimizing the design to operate at higher frequencies could improve its efficiency, particularly in systems where more sensitive satellite signals are received. By fine-tuning the selection of circuit components, the frequency range could be expanded, allowing the converter to operate more effectively across a broader spectrum. This would enhance the converter's performance and suitability for more demanding applications.

Integrated Circuit Design: The proposed converter could be developed into an integrated circuit, offering a more compact and cost effective solution for television manufacturers. An IC design would allow for easier integration into existing systems and potentially reduce production costs while maintaining the high performance and reliability of the converter.

Broadening Application Areas: While this study focuses on LNB circuits, the parallel resonant converter design could be adapted for use in other power management systems. For example, the converter could be applied to areas such as renewable energy, automotive electronics, and telecommunications, where similar current protection and management challenges exist.

# 6. CONCLUSIONS

In this study, a new parallel resonant converter design was developed and analyzed to address the issue of current protection in Low Noise Block circuits, which are critical components in satellite television systems. LNB circuits are typically powered using voltage-controlled boost converters, but these systems struggle to manage sudden current surges and are prone to short circuits. In this study, a current-limiting method based on frequency control rather than voltage control was proposed. The design aimed to improve circuit safety and ensure long-term system reliability, particularly in areas where traditional approaches fell short.

The designed circuit was initially analyzed through theoretical methods and tested via simulations using MATLAB Simulink. During the simulations, the operational principles of the frequency-controlled converter were thoroughly examined, and it was observed that the output current was maintained within desired limits, ensuring system stability. The designed converter operates as a constant current source, limiting the maximum current through frequency adjustment. This is crucial for preventing short circuits, a common issue in satellite television systems. Simulation results showed that the circuit successfully provided a constant output voltage of 13V or 18V, with an output current limited to 500mA.

In addition to simulation, the circuit was physically implemented in a laboratory environment using real components. Key components such as MOSFETs, diodes, and resonant elements L and C were selected based on theoretical calculations. The design employed a half-bridge topology for frequency control, and MOSFET drivers were utilized to ensure safe operation of the circuit. The circuit was controlled using Pulse Width Modulation with a 50% duty cycle, and frequency adjustments at the output ensured that the current limit was not exceeded during load changes.

When reviewing the circuit schematic and photographs of the implementation, the structure of the parallel resonant converter can be clearly seen, consisting of two main sections: the input power stage and the frequency-controlled current-limiting stage. The LC filter at the input helps smooth out voltage fluctuations, while the parallel resonant circuit at the output limits the current at a specific frequency, ensuring the safe operation of the system. Upon examining the schematic, it becomes evident that the circuit maintains stability despite operating at high frequencies and consistently limits the output current. The values of the resonant capacitor and inductor were optimized to align with the simulation results, effectively preventing sudden current surges and significantly reducing the risk of short circuits in LNB circuits.

During the experimental tests, the performance of the circuit under various load conditions was evaluated. The results confirmed that the circuit provided a constant current of up to 500mA at output voltages of 13V and 18V, with a rapid response to sudden load changes. Notably, during the short-circuit tests, the current-limiting mechanism performed effectively, preventing damage to the circuit. These results validate the reliability of the design in protecting LNB circuits from short-circuit conditions.

In conclusion, the parallel resonant converter developed in this study offers an effective solution to the current-limiting challenges encountered in LNB circuits. This frequency-controlled system provides a safer and more robust alternative to traditional voltage-controlled designs, preventing current surges and protecting LNB circuits from damage. The approach offers significant advantages in terms of reliability and cost-effectiveness in satellite television systems. The circuit was validated through both simulation and real world testing, confirming its potential for broader applications beyond LNB power circuits.

Future research will focus on further optimizing the performance of this circuit at higher frequencies and designing a compact integrated circuit version for improved efficiency and scalability. Additionally, the integration of advanced protection mechanisms such as over-temperature and over-voltage protection will ensure greater reliability over the long term. Overall, this study contributes to the development of reliable power management solutions in modern satellite television systems, facilitating the creation of safer and more user-friendly technologies.

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