DESIGN OF SPIKE PULSER FOR ULTRASONIC APPLICATIONS

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CANDIDATE'S DECLARATION

I, Manisha, Roll No. 2K21/VLS/12 student of M. Tech (VLSI & Embedded systems), hereby declare that the project Dissertation titled "Design of spike pulser for ultrasonic applications" which is submitted by me to the Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology is unique and has not been copied without proper citation. This work has never before been used to give a degree, diploma associateship, fellowship, or other equivalent title or recognition.

Place: Delhi

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CERTIFICATE

I hereby certify that the Project Dissertation titled “Design of spike pulser for ultrasonic applications” which is submitted by Manisha, 2K21/VLS/12, to the Department of Electronics & Communication Engineering, Delhi Technological University, Delhi in partial fulfillment of the prerequisite for the award of the degree of Master of Technology, is a documentation of the student's project work completed by her. This is not original work and referred from the paper “Design and development of high voltage ultrasonic spike pulser for immersion applications” by Eaglekumar G.Tarpara and V.H.Patankar.

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ABSTRACT

The spike pulser serves the purpose of generating high-energy pulses with precise characteristics necessary to excite ultrasonic transducers effectively. It consists of essential elements including an amplifier stage, timing/control circuitry, and power supply components. By receiving an input signal, typically in the form of pulses or square waves, the spike pulser triggers the production of high-energy pulses with specific timing and amplitude properties.

In the realm of ultrasonic imaging, the spike pulser plays a vital role in exciting the transducer, which converts electrical energy into ultrasonic waves that propagate through the target medium. The resulting echoes from the medium are subsequently received and processed to produce detailed images of internal structures or potential defects. The pulse characteristics of the spike pulser, including amplitude, duration, and repetition rate, significantly impact the quality and resolution of the resulting ultrasound images.

Non-destructive testing and industrial applications also heavily rely on the spike pulser to assess the integrity of materials. By transmitting ultrasonic waves and detecting their reflections, the spike pulser facilitates flaw detection, identification of cracks, and evaluation of material properties. Its ability to generate high-energy pulses enables the detection of subtle flaws and the accurate characterization of materials.

This thesis discusses the design and simulation of a high-voltage spike pulser that can deliver voltage up to 650V . The pulse width of the input signal given to the spike pulser is in range from 20ns to 100000ns. Also discussed were power consumed, the amplitude of the spike at the output of spike pulser, and current at load for different pulse widths of input signal given to spike pulser.

CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO ULTRASOUND

Ultrasound is a versatile and widely used imaging modality that utilizes high-frequency sound waves to generate real-time images of the internal structures of the human body or objects. It has revolutionized the field of medical diagnostics, providing valuable insights into anatomical structures, blood flow, and tissue characteristics. However, its applications extend far beyond medicine, finding utility in industrial testing, non-destructive evaluation, and various scientific fields. This introduction aims to provide an overview of ultrasound, including its principles, applications, advantages, and limitations.

Ultrasound imaging relies on the principles of sound waves and their interactions with tissues or materials. Sound is a mechanical wave that travels through a medium, such as air or water, in the form of compressions and rarefactions. The frequency of sound waves determines their pitch, while the amplitude corresponds to their intensity or energy.

In ultrasound imaging, a transducer emits high-frequency sound waves into the body or object of interest. These sound waves propagate through the medium and interact with tissues or structures encountered along their path. When the sound waves encounter boundaries between different tissues or reflect off structures, a portion of the energy is reflected back to the transducer.

The transducer then receives these reflected sound waves and converts them into electrical signals. These signals are processed and analyzed to construct an image that represents the internal structures or objects being imaged. The timing and strength of the reflected sound waves allow for the determination of distances and the creation of detailed images.

One of the primary applications of ultrasound is in medical imaging. It provides a non-invasive and real-time visualization of internal structures, making it an invaluable tool for diagnosis, monitoring, and guidance during medical procedures. Ultrasound imaging is commonly used in various medical specialties, including obstetrics, cardiology, radiology, and gastroenterology.

In obstetrics, ultrasound plays a crucial role in monitoring fetal development, detecting abnormalities, and assessing the health of both the mother and the baby. It allows obstetricians to visualize the fetus, measure its size, determine its position, and evaluate the placenta and amniotic fluid.

Cardiologists utilize ultrasound to examine the heart's structure and function, diagnosing conditions such as heart valve abnormalities, heart defects, and assessing blood flow patterns. This imaging technique, known as echocardiography, provides detailed information about the heart's chambers, valves, and blood vessels, helping in the diagnosis and management of cardiovascular diseases.

In radiology, ultrasound imaging is used to examine various organs and structures, such as the liver, kidneys, gallbladder, thyroid, and blood vessels. It aids in the detection and characterization of tumors, cysts, stones, and other abnormalities. Ultrasound-guided procedures, such as biopsies or fluid aspirations, offer precise targeting and real-time monitoring during interventions.

Ultrasound imaging offers several advantages over other imaging modalities, contributing toits widespread use and popularity in medical diagnostics. Some of the key advantages include:

- Safety: Ultrasound does not involve the use of ionizing radiation, making it a safe imaging modality, especially for vulnerable populations, such as pregnant women and children.
- Real-time Imaging: Ultrasound provides real-time imaging, enabling dynamic visualization of moving structures, such as blood flow, heart valves, and fetal movements. This real-time feedback is particularly useful during interventions or surgeries.
- Portability: Ultrasonography equipment is generally compact and portable, allowing for bedside examinations, emergency evaluations, and remote or point-of-care settings.
- Cost-effectiveness: Ultrasound imaging is relatively cost-effective compared to other imaging modalities, making it accessible in various healthcare settings. It

has lower equipment and maintenance costs, and it can often reduce the need for more expensive imaging techniques or exploratory surgeries.

- Versatility: Ultrasound is versatile and can be used to image a wide range of anatomical structures and organs. It can also be combined with other imaging techniques, such as Doppler ultrasound, to evaluate blood flow or contrast agents to enhance visualization.
- Non-invasive: Ultrasound imaging is non-invasive, meaning it does not require incisions or the injection of contrast agents in most cases. This reduces patient discomfort, eliminates the risk of complications, and allows for repeated examinations when needed.

While ultrasound imaging offers numerous advantages, it also has some limitations that should be considered:

- Limited Tissue Penetration: Ultrasound waves have limited penetration through certain tissues, such as bone or air-filled structures. Consequently, imaging deep-seated structures or evaluating organs obscured by bone can be challenging.
- Operator Dependency: The quality and accuracy of ultrasound images depend on the operator's skill and experience. The interpretation of ultrasound images requires specialized knowledge and expertise, as subtle differences in tissue characteristics can significantly affect diagnosis.
- Image Interpretation Challenges: The interpretation of ultrasound images can be challenging, as they often rely on subjective visual analysis. Differentiating subtle abnormalities or complex anatomical structures may require additional imaging modalities or expertise.
- Limited Field of View: The field of view in ultrasound imaging is generally smaller compared to other modalities, such as computed tomography (CT) or magnetic resonance imaging (MRI). This limitation may hinder the assessment of larger structures or the overall spatial context.

Ultrasound's applications extend beyond the field of medicine. In industrial testing and non-destructive evaluation, ultrasound is employed to assess the integrity of materials, detect flaws or defects in manufactured products, and evaluate structural components. It is commonly used in industries such as aerospace, automotive, and manufacturing to ensure product quality, assess welds, and monitor equipment performance.

In scientific research, ultrasound is utilized in various disciplines, including physics, chemistry, biology, and material science. It enables the characterization of materials, the study of fluid dynamics, and the investigation of biological tissues and processes. Ultrasound has also found applications in environmental monitoring, underwater exploration, and veterinary medicine.

1.2 ULTRASONIC NON-DESTRUCTIVE TECHNIQUE

Ultrasonic non-destructive testing (NDT) is a versatile and widely used technique for evaluating the integrity and quality of materials without causing any damage or alteration to the tested object. It utilizes high-frequency sound waves, typically above the range of human hearing, to inspect and analyze the internal structure, dimensions, and defects within a material. This technique finds applications across various industries, including manufacturing, aerospace, automotive, construction, and more.

When the sound waves encounter a boundary, such as the back surface of the material or a defect like a crack or void, part of the sound energy is reflected back to the transducer. By analyzing the reflected waves, ultrasonic NDT can determine the size, shape, and location of defects, measure material thickness, identify discontinuities, and assess the overall quality of the material.

Ultrasonic NDT operates based on the principles of sound wave propagation and interaction with materials. A specialized transducer generates high-frequency sound waves, typically in the range of 1 to 10 MHz, which are directed into the test object. These sound waves propagate through the material until they encounter a boundary or a defect within the material.

Ultrasonic NDT offers several advantages over other non-destructive testing techniques, contributing to its widespread adoption:

- High Sensitivity: Ultrasonic waves can detect small defects and imperfections within a material, even those that are not visible to the naked eye. This high sensitivity allows for accurate detection and characterization of flaws, cracks, voids, and other types of defects.

- Depth Penetration: Ultrasonic waves have the ability to penetrate deep into materials, enabling inspection of thick sections and providing valuable information about the internal structure and condition. The depth of penetration depends on the frequency of the sound waves and the material being tested.
- Real-Time Imaging: Ultrasonic NDT can provide real-time imaging, allowing inspectors to visualize the internal features and defects in the material as they perform the inspection. This real-time feedback enables on-the-spot decision-making and immediate assessment of the material's quality.
- Versatility: Ultrasonic NDT is versatile and can be applied to a wide range of materials, including metals, composites, plastics, ceramics, and more. It can be used for weld inspection, quality control, flaw detection, thickness measurement, and material characterization across various industries.
- Portability: Ultrasonic NDT equipment is often portable and can be easily transported to different inspection sites. This portability facilitates on-site inspections, field testing, and in-service evaluations, reducing the need to transport large or heavy objects to a testing facility.
- Cost-Effectiveness: Ultrasonic NDT is generally a cost-effective method compared to destructive testing or other sophisticated inspection techniques. It eliminates the need for sample removal, reducing material waste and minimizing overall testing expenses.
- While ultrasonic NDT has numerous advantages, it also has some limitations that should be considered:
- Limited Surface Accessibility: Ultrasonic NDT requires direct contact or coupling between the transducer and the material being inspected. This can be challenging for materials with rough surfaces, irregular shapes, or limited access points. Additional techniques, such as phased array or immersion testing, may be required to overcome these limitations.
- Skill and Training Requirements: Proper training and expertise are crucial for performing accurate ultrasonic NDT inspections and interpreting the acquired data. Inspectors must have a thorough understanding of ultrasonic principles, equipment operation, signal analysis, and interpretation to ensure reliable and accurate results.

- Material Dependency: The effectiveness of ultrasonic NDT may vary depending on the material being tested. Factors such as material thickness, composition, density, and acoustic properties can affect the sound wave propagation and the detectability of defects. Adjustments in equipment settings and techniques may be necessary for different materials.

Limited Resolution: The resolution of ultrasonic NDT is influenced by the frequency of the sound waves used. Higher-frequency waves provide better resolution but have reduced penetration capabilities. Conversely, lower-frequency waves offer greater penetration but lower resolution. The selection of the appropriate frequency depends on the specific inspection requirements and material characteristics. The frequency range for ultrasonic NDT typically falls within 0.5 MHz to 50 MHz, with the selection depending on the material thickness, type of defects, desired resolution, and specific application requirements.

1.3 ULTRASOUND IMAGING

Ultrasonic imaging, also known as ultrasound imaging, is a medical imaging technique that uses high-frequency sound waves to visualize internal structures of the human body or animals. It is a non-invasive and safe imaging modality widely used in various medical applications.

The frequency range used in ultrasonic imaging typically falls between 2 to 18 megahertz (MHz), although it can vary depending on the specific application and the depth of the structures being imaged.

Lower frequencies, such as 2 to 5 MHz, are used for imaging deep structures within the body, as they offer better penetration but lower resolution. This range is commonly employed for imaging organs like the liver, kidneys, or fetus during pregnancy.

Higher frequencies, ranging from 7 to 18 MHz, are used for imaging superficial structures closer to the skin surface. These frequencies provide better resolution and are commonly used for imaging the breast, thyroid, or superficial soft tissues.

The choice of frequency in ultrasonic imaging depends on the specific imaging requirements, such as the depth of the structures being imaged and the desired resolution. Lower frequencies are suitable for deeper structures but sacrifice resolution, while higher frequencies offer better resolution but have limited penetration.

CHAPTER 2

ULTRASOUND TRANSMITTER AND RECEIVER

2.1 HARDWARE ARCHITECTURE FOR ULTRASOUND SYSTEM

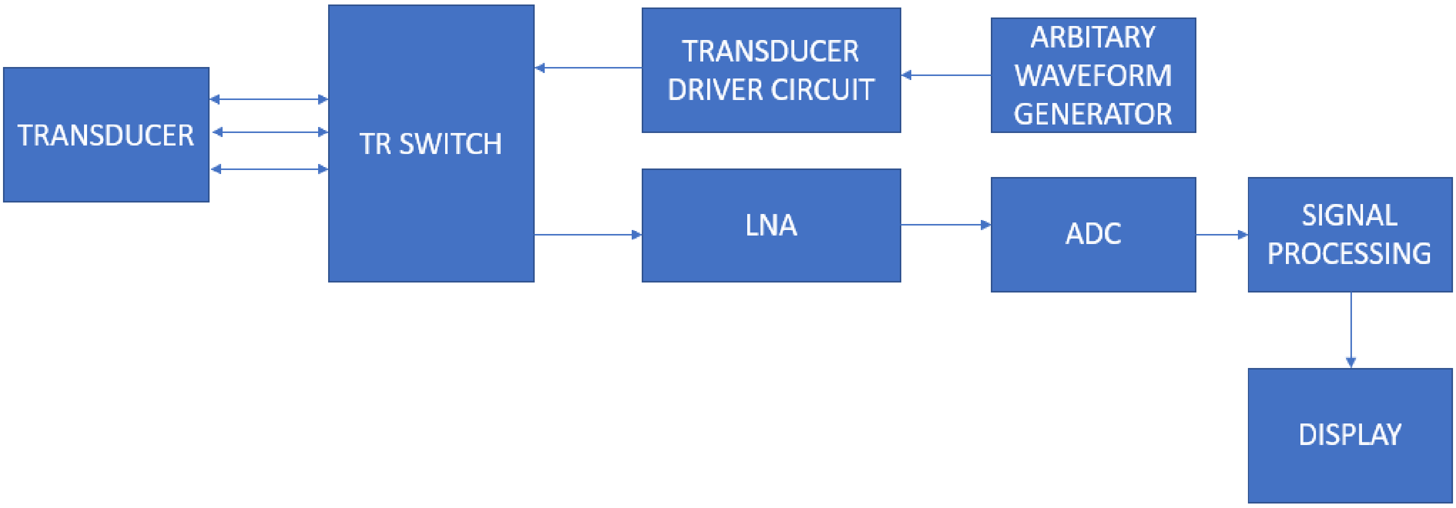


Fig 1: Ultrasound system architecture[2]

TRANSMITTER:

Waveform is generated by an arbitrary waveform generator and the generated waveform is given input to transducer driver circuitry which amplifies the signal to high voltage as required. Shape of the waveform generated by the driver circuit can be arbitrary such as square wave, sine wave and gaussian pulse depending on which pulsar is used.

RECEIVER:

The TR switch protects the receiver circuit from the high voltage transmitter circuit. The transducer reflects back the weak signal to LNA.The LNA amplifies the weak signal. ADC converts the analog signal received from LNA to a digital signal then further signal processing will be done and displayed on the screen.

2.2 ULTRASONIC TRANSDUCER

The ultrasound transducer device produces ultrasonic waves .When waves incident on body internal parts then waves reflect back to the transducer which sends it to the computer and creates a sonogram.. The three categories of ultrasonic transducers are piezoelectric ultrasonic transducers, capacitive micromachined ultrasonic transducers, and piezoelectric micromachined ultrasonic transducers (PMUTs). Piezoelectric transducers are affordable and easily available so it is in more use but capacitive micromachined ultrasonic transducers are the future. It offers many benefits in terms of bandwidth, fabrication of layer arrays, efficiency, and sensitivity. PMUTs have not yet been extensively embraced because of challenges with fabrication, problems with performance, and a lack of precise design/modeling tools[2].

2.2.1 PIEZOELECTRIC TRANSDUCER

A piezoelectric transducer is an electronic device that converts electrical energy into mechanical vibrations (and vice versa) using the piezoelectric effect. This effect is observed in certain materials, such as crystals or ceramics, which possess the ability to generate an electric charge when subjected to mechanical stress or deform when an electric field is applied.

In a piezoelectric transducer, a piezoelectric material, typically in the form of a crystal or ceramic element, is sandwiched between metal electrodes. When an electrical voltage is applied to the electrodes, the piezoelectric material undergoes deformation or vibration due to the inverse piezoelectric effect.

The applied voltage causes the charges within the piezoelectric material to move, resulting in the material expanding or contracting. This deformation creates mechanical vibrations or acoustic waves in the material, which are emitted into the surrounding medium.

Conversely, when mechanical vibrations or acoustic waves in the surrounding medium impinge on the piezoelectric material, they cause the material to deform or vibrate. This deformation induces a charge separation within the material, generating an electric signal that can be measured or processed.

Piezoelectric transducers are preferred in non-destructive testing techniques due to their high sensitivity, broad frequency range, efficient energy conversion, compact size, portability, fast response time, durability, reliability, and cost-effectiveness. These characteristics make them well-suited for various NDT applications, enabling accurate and efficient inspection of materials without causing damage.

2.2.2 CAPACITIVE MICROMACHINED ULTRASONIC TRANSDUCER

In the field of ultrasonic transducers, a capacitive micromachined ultrasonic transducer (CMUT) is a relatively recent idea. Over three decades have gone into developing CMUT technology. CMUTs were reported in the late 20th century. CMUTs are devices that can sense and generate ultrasonic signals of frequencies greater than 20KHz. They are increasingly used in numerous industrial and medical applications, including microscopes, inkjet printers, portable scanners, and a wide range of others. As shown in fig 2, a CMUT consists of a metal layer which is a top electrode , the silicon substrate is the bottom electrode and there is a vacuum gap between movable membrane and insulation layer [3]. The passivation layer provides protection while the insulating layer stops the two electrodes from shorting[2][24].

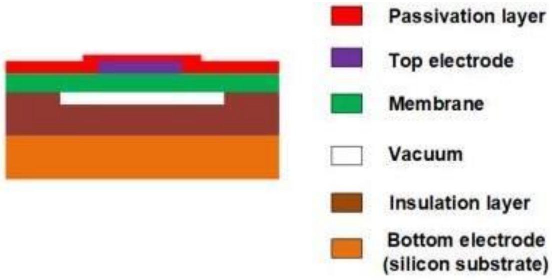


Fig 2. CMUT cross section (Reproduced from [2])

CMUT acts as a transmitter when AC signal is applied across input electrodes. The membrane will vibrate and produce ultrasonic waves. CMUT acts as a receiver when ultrasonic waves are received by it ,the CMUT capacitance will vary and produce output which is a current signal.

2.3 TRANSDUCER DRIVER CIRCUIT

The transducer driver circuit drives the transducer with a high-voltage signal. The basic goal of the transducer driver circuit is that it should amplify the signal generated by the waveform generator to the voltage that is required in the design. Continuous-wave and pulsed-wave systems are two categories of transducer drivers [2]. The development of pulsed-wave systems is receiving substantially greater attention in the microelectronics research community. Therefore, we will concentrate on pulsers—transducer driver circuits used in pulsed-wave applications. The transducer elements receive short bursts of electrical pulses from a pulser. The transducer is driven by a pulser with voltage pulses of large amplitude more than 100V. To supply high-voltage pulses to the transducer there is a requirement for high-voltage transistors in the driver circuit. Therefore, the pulser consumes a lot of power due to the requirement of high-voltage transistors [2].

The two types of pulsars are spike-wave pulsers ,square-wave pulser and arbitrary waveform pulsers. The advantages of ultrasonic spike pulsers over other pulsars include higher resolution, greater sensitivity, wide frequency range, fast pulse repetition rate, compact size, minimal heat generation, energy efficiency, compatibility with different transducers, precise signal control, and advanced signal processing capabilities. Therefore ,in this project, we discussed ultrasonic spike pulser.

2.4 TRANSMIT/RECEIVE SWITCH(TR SWITCH)

The function of the T/R Switch is to protect a low noise receiver from the high voltage transmit pulses. The transmit/receive (T/R) switches are also called duplexers. TR switch should be designed in such a way that it can maintain isolation between transmitter and receiver, the power rating of the switch should be such that he high voltage signal applied to the switch doesn’t damage the switch and speed switching must be such that it can provide isolation between a transmitter and a receiver[2]

During the transmit mode, the TR switch connects the ultrasonic transmitter, typically a pulsar or generator, to the ultrasonic transducer. This allows the electrical pulse generated by the transmitter to be efficiently transferred to the transducer, which converts it into an ultrasonic wave for transmission into the medium or target.

Once the ultrasonic pulse has been transmitted, the TR switch swiftly switches to the receive mode. In this mode, the TR switch disconnects the transmitter from the transducer and establishes a connection between the transducer and the receiver circuitry. This configuration allows the transducer to detect and capture any echoes or signals that bounce back from the medium or target under investigation[2].

2.5. LOW NOISE AMPLIFIER

Low Noise Amplifier (LNA) is the first component of the receiver part of an ultrasound system. In an ultrasonic system, the low noise amplifier (LNA) is designed to amplify the weak electrical signals received by the transducer after they have been converted from ultrasonic waves. The primary objective of the LNA is to boost the signal strength while introducing as little additional noise as possible. The LNA operates at the front end of the receiver circuitry and is responsible for amplifying the received signals to a level suitable for further processing and analysis. It is designed to have a high gain, allowing it to amplify weak signals without introducing significant distortion or noise.

2.6. LNA WITH TIME GAIN COMPENSATION:

A time gain compensation is required when the input signal is dynamic[2]. A time gain compensator is an automatic gain controller which amplifies the signal with a large gain when the signal is weak and takes more time to arrive whereas it amplifies the signal with a small gain when the signal is strong so that a flat amplitude response can be obtained at the output of compensator, as shown in fig 6.

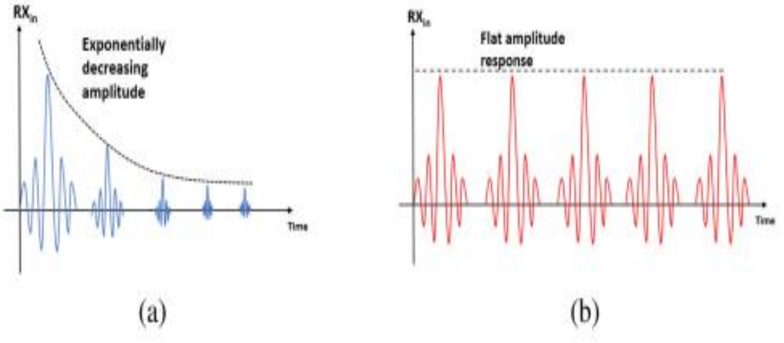


Fig 3. (a)Receiver output without Time gain compensation. (b) Receiver output with Time gain compensation(Reproduced from [2]).

There are two categories of time gain compensators – programmable gain amplifiers(PGA) , Variable gain amplifiers.

1)Programmable gain amplifier- It amplifies the signal with discrete gain steps.

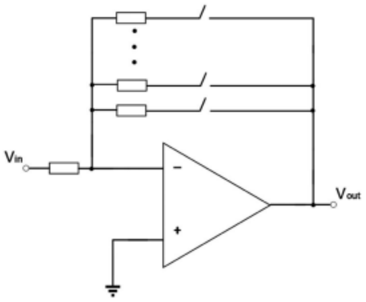


Fig 4. The architecture of PGA (Reproduced from [20])

The TGC shown in fig 7 approximates the exponentially varying gain with multiple gain steps. TGC uses a resistive feedback network or the capacitive feedback network[20].

There can be more than one amplification stage For Example, the LNA can apply fixed gain while the subsequent PGA executes multiple gain steps [2], [24], [25].

The advantages of PGA are gain steps that are precise that do not change with process and temperature variations[2]. The disadvantage of PGA is that when input varies exponentially then more gain steps are required due to which more resistances and capacitances are required so chip area will increase.

2) Variable gain amplifiers- VGAs provide a gain that is continuous in nature[20]. As shown in fig 8, an analog control input Vctrl can be used to adjust the amplification [20].

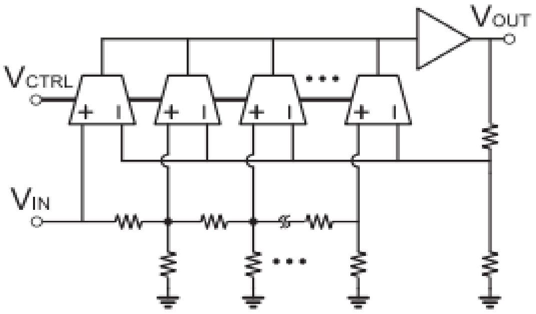


Fig 5.The architecture of variable gain amplifiers(Reproduced from [20]).

2.7 ANALOG TO DIGITAL CONVERTER

The output of LNA is converted into a digital signal by ADC for further digital signal processing(DSP). An analog signal must have an ADC sampling rate that must be two times as large as the signal's frequency range in order to accurately convert it to digital form. ADCs depend on three major parameters: Sampling Speed, Resolution, and Power Consumption. The choice of ADC in an ultrasonic system depends on factors such as the required . sampling rate, resolution, and the specific application's needs. There are various types of ADCs available, including successive approximation ADCs, delta-sigma ADCs, and flash ADCs, among others. Each type has its advantages and limitations in terms of speed, resolution, and power consumption.

- Successive Approximation ADCs: Successive Approximation ADCs are often preferred for their speed and moderate resolution capabilities. They utilize a binary search algorithm to rapidly determine the digital representation of the analog input signal. Successive Approximation ADCs can achieve high sampling rates, making them suitable for MHz frequency applications.
- Pipeline ADCs: Pipeline ADCs are commonly used in high-speed applications, including MHz frequency ultrasonic systems. They consist of multiple stages that process the analog signal in a sequential manner, enabling high-speed conversion with moderate to high resolution. Pipeline ADCs offer excellent performance in terms of speed and accuracy but may require more power and complex circuitry.
- Delta-Sigma ADCs: Delta-Sigma ADCs are known for their high-resolution capabilities and ability to achieve excellent signal-to-noise ratio (SNR). They employ oversampling and noise-shaping techniques to achieve high-resolution conversion. Delta-Sigma ADCs are suitable for demanding MHz frequency ultrasonic systems that require high accuracy and precision.
- Flash ADCs: Flash ADCs are renowned for their fast conversion speed and high sampling rates, making them well-suited for MHz frequency applications. Flash ADCs directly convert the analog input signal into a digital output using a large number of comparators, enabling very high sampling rates. However, they may have limited resolution and higher power consumption compared to other ADC types.

CHAPTER 3

ULTRASONIC SPIKE PULSER

3.1 INTRODUCTION TO ULTRASONIC SPIKE PULSER

Ultrasonic spike pulsers play a critical role in various applications such as ultrasonic imaging, non-destructive testing, and industrial inspection. They are specialized electronic devices designed to generate high-voltage, short-duration pulses that drive ultrasonic transducers. These pulses are essential for producing ultrasonic waves that propagate into a medium, allowing for the detection of flaws, imaging of internal structures, or measurement of material properties.

The primary purpose of an ultrasonic spike pulser is to provide a controlled and precise excitation signal to the transducer. By generating high-voltage spikes with fast rise and fall times, spike pulsers facilitate the transmission of well-defined ultrasonic pulses into the medium. These pulses contain a wide range of frequencies, depending on the specific application requirements.

The design of an ultrasonic spike pulser involves several key considerations. Firstly, the pulser must be capable of producing high-voltage pulses to effectively drive the transducer. Secondly, spike pulsers need to generate short-duration pulses to achieve good temporal resolution in ultrasonic applications. The duration of the pulse is typically determined by the rise and fall times of the generated spikes. Fast switching devices and appropriate waveform shaping techniques are employed to minimize pulse width and ensure precise temporal control.

Advanced spike pulsers may incorporate features such as adjustable pulse width, pulse repetition rate control, and synchronization capabilities. These features enable customization and optimization of the pulser's performance to suit specific application requirements.

Three parts make up an ultrasonic pulser: a power supply that provides electrical energy, a MOSFET driver that controls the power MOSFET, and a high voltage RF MOSFET that produces the high voltage spike signal needed to excite the ultrasonic transducer[5].

In these applications, lead-zirconate-titanate or bismuth titanate type piezoelectric transducers are most frequently used.When a high voltage, narrow pulse activates the Piezoelectric transducer, ultrasonic waves are produced[5].

3.1.1 PIEZOELECTRIC TRANSDUCER

A piezoelectric transducer is a key component in ultrasonic spike pulsers, utilized for converting electrical energy into mechanical vibrations and vice versa. It plays a critical role in generating ultrasonic waves for various applications such as imaging, non-destructive testing, and industrial inspections.

Piezoelectric transducers are widely preferred for use in ultrasonic spike pulsers due to their unique properties and advantages:

- High Sensitivity: Piezoelectric materials possess high sensitivity, allowing them to convert electrical energy into mechanical vibrations and vice versa efficiently. This high sensitivity enables the generation of ultrasonic waves with significant amplitude and power, which is essential for effective transmission and reception of ultrasonic signals in spike pulsers.
- Wide Frequency Range: Piezoelectric transducers offer a wide frequency range, making them versatile for various ultrasonic applications. The resonant frequency of the transducer can be tailored by selecting appropriate materials and dimensions, allowing for flexibility in meeting the specific frequency requirements of different applications.
- Fast Response Time: Piezoelectric transducers exhibit a fast response time, meaning they can rapidly convert electrical signals into mechanical vibrations and vice versa. This fast response time enables the generation of short-duration, high-intensity pulses required in spike pulsers. It ensures precise temporal control of the ultrasonic pulses and allows for accurate imaging, flaw detection, or material characterization.

- Compact Size: Piezoelectric transducers can be manufactured in compact sizes, making them highly suitable for integration into ultrasonic pulser designs. Their small form factor enables efficient coupling with the medium, ensuring effective transmission and reception of ultrasonic waves. The compact size of piezoelectric transducers also facilitates the development of portable and handheld ultrasonic devices.
- Durability and Reliability: Piezoelectric materials are known for their durability and long- term stability. They can withstand high temperatures, mechanical stress, and environmental factors, making them reliable for prolonged use in demanding ultrasonic applications. The robust nature of piezoelectric transducers ensures consistent performance and longevity in spike pulsers.

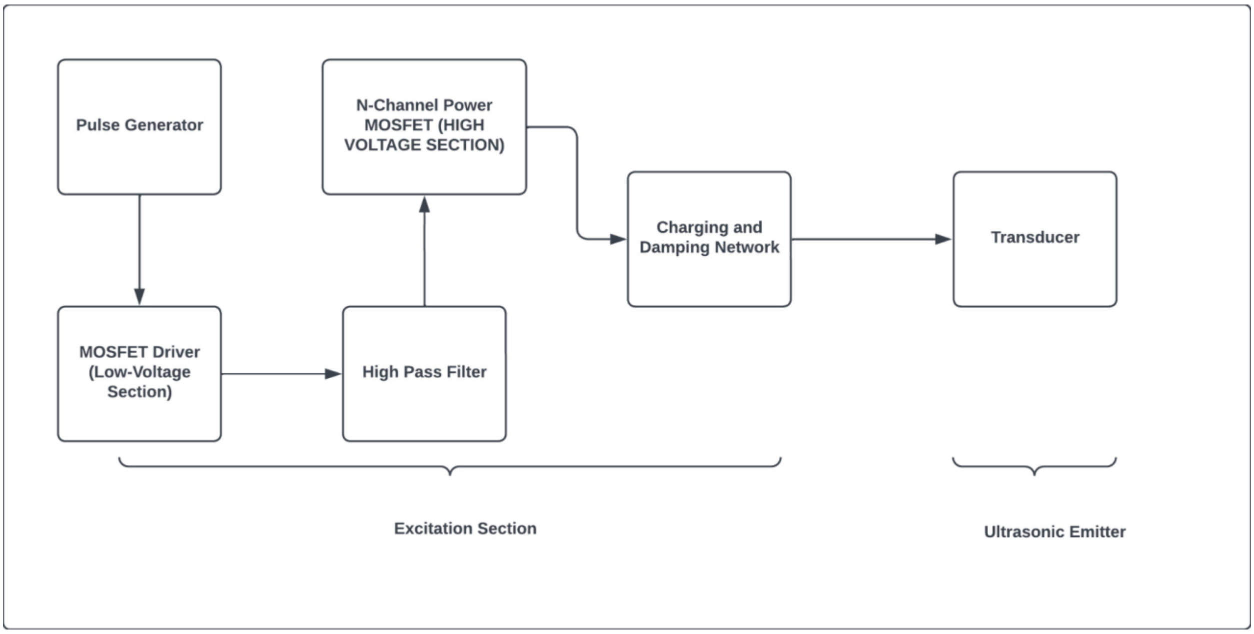


Fig 6 Block diagram of ultrasonic transmitter

3.1.2 GATE MOSFET DRIVER

A gate MOSFET driver is an essential component in an ultrasonic pulser, responsible for driving the gate of the MOSFET switches used in the circuit.

The gate MOSFET driver operates by providing the necessary voltage and current levels to rapidly switch the gate of the MOSFET switches on and off. MOSFETs are voltage-controlled devices, meaning their behavior and conductivity are determined by the voltage applied to their gate terminal.

The gate driver takes a low-voltage control signal from the driving circuit and amplifies it to a higher voltage level required to fully turn on the MOSFETs. It provides the necessary voltage and current capabilities to ensure fast and precise switching of the MOSFET gates.

The primary functions of gate mosfet driver are

1) Voltage Level Shifting: The gate driver converts the low-voltage control signal from the driving circuit to a higher voltage level suitable for fully activating the MOSFETs. This voltage level shifting is necessary to ensure efficient and reliable switching of the MOSFET gates.
2) Fast Switching Speed: Ultrasonic pulsers require fast rise and fall times of the generated pulses to achieve good temporal resolution. The gate driver provides the necessary current capability to charge and discharge the MOSFET gate capacitances rapidly, enabling the desired switching speed.
3) Gate Voltage Control: The gate driver allows precise control over the gate voltage of the MOSFETs. It ensures that the gate voltage rises and falls rapidly, maintaining the desired pulse shape and minimizing the pulse width. This control is crucial for generating short-duration, high-intensity pulses required in ultrasonic applications.

By utilizing a gate MOSFET driver in an ultrasonic pulser, designers can achieve efficient and precise control of the MOSFET switches.

High-pass filter between MOSFET driver and n-channel MOSFET is used to remove any dc component present in the signal.

3.1.3 N CHANNEL POWER MOSFET

The N-channel power MOSFET serves as a switching device in the output stage of an ultrasonic pulser. It is responsible for controlling the generation and transmission of high-intensity ultrasonic pulses. The MOSFET acts as a solid-state switch that turns on and off rapidly in response to the control signals, enabling the precise generation of short-duration, high-voltage pulses required for ultrasonic applications.

ADVANTAGES OF N-CHANNEL POWER MOSFET:

1) N-channel power MOSFETs exhibit fast switching characteristics, allowing for quick and precise control of the output pulse waveform. Their ability to transition rapidly between the on and off states enables the generation of short-duration pulses with high temporal resolution.

2) N-channel power MOSFETs typically have a lower on-resistance compared to P-channel counterparts. This low on-resistance results in reduced power losses and improved efficiency in the pulser circuit. It allows for efficient power delivery to the transducer, ensuring high energy transfer and minimal heat dissipation.

3) N-channel power MOSFETs are designed to handle high voltages, making them suitable for applications that require the generation of high-intensity ultrasonic pulses. They can efficiently switch and withstand the high voltages involved in the pulser circuit, providing the necessary voltage levels to excite the transducer.

4) N-channel power MOSFETs are widely available and cost-effective compared to other power switching devices. Their popularity and affordability make them a practical choice for designing ultrasonic pulsers without compromising performance and reliability.

3.1.4 CHARGING CAPACITOR EFFECT ON OUTPUT OF SPIKE PULSER

A charging capacitor is essential to the design of a spike pulser. When the power is turned off, the source-drain RSD resistance of the power MOSFET charges the capacitor CC and gradually Capacitor CC charges up to supply voltage (+HV). A minor voltage across the load will exist during the charging process before decreasing to zero as the capacitor charges. The MOSFET will suddenly turn on when a positive edge pulse is applied, discharging the capacitor's charge, which will subsequently exponentially degrade[6].

The drain capacitor value and load resistor value determine the output rise time and fall time at the drain terminal.

The primary function of the capacitor at the output is typically to couple the high-frequency components of the pulse while blocking any DC component. This coupling capacitor allows the pulse to pass through while preventing any DC bias from affecting the subsequent stages or components in the circuit.

A high output resistance can provide protection to sensitive or delicate components connected to the output of the spike pulser. It limits the current flowing into the load, preventing excessive current flow that could potentially damage or overload the load.

3.2 IMPLEMENTATION

Pulsar consists of a MOSFET driver which amplifies input voltage and provides sufficient voltage to make power MOSFET on and off. High pass filter is required to pass frequencies above cut-off frequency which is dependent on value of Rh and Ch. The N-Channel Power MOSFET is responsible for generation of high voltage spikes at output of pulsar. When MOSFET is in OFF condition , Cc gets charged exponentially to high voltage (+HV). When MOSFET is in ON condition Cc discharges through MOSFET and high voltage negative spike appears at the output load resistor[3].

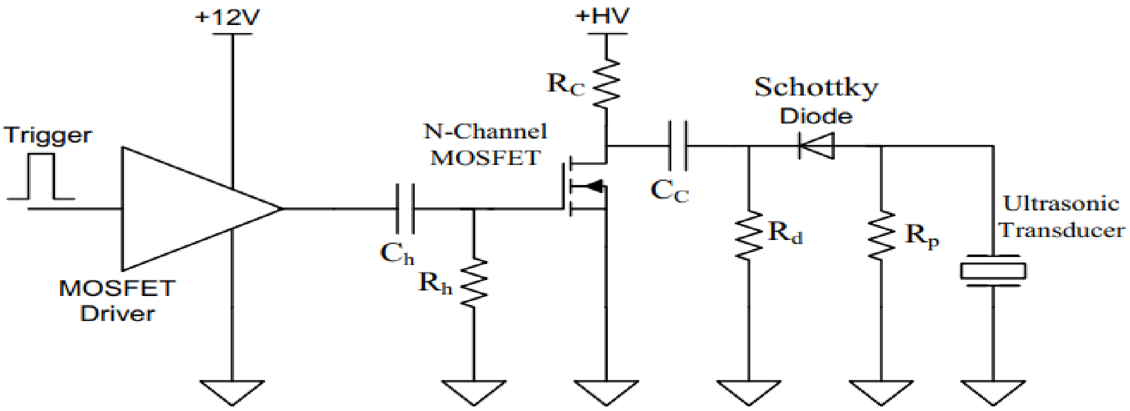


Fig 7: Schematic of spike pulser[3]

The spice models for the different components in the design were imported into spice, and the circuit was simulated.A high speed dual MOSFET driver is used as a MOSFET driver[6]. It’s a high-speed driver capable of delivering peak currents of 2.0 amps into highly capacitive loads. It has four pins Supply pin, ground pin, input pin, output pin. A low-voltage, power MOSFET non-inverting gate driver is also used which increases the frequency range of the spike pulser[7]. It has OCP pin for over current protection sense and a FAULT status output (Once it is active, EN/FLT pin is internally pulled down). The EN/FLT needs to be outside pulled up to provide normal operation, pulling EN/FLT low disables the driver. Internal circuitry on the VCC pin provides an under voltage lockout protection that holds output low until VCC supply voltage is within operating range.

An N-channel Enhancement switch mode MOSFET is used for high-voltage switching operation[8].It has a maximum breakdown voltage of 650V.

The value of Rc is low so that the capacitor at the output of the pulser can charge fast.

A high-pass filter is typically used in a spike pulser to shape the output pulse by allowing higher frequencies to pass through while attenuating lower frequencies. The cut-off frequency for the high pass filter is determined by:

cutoff frequency (f_cutoff) = 1 / (2 * π * Rh * Ch)

Here Rh and Ch are selected such that they can pass all frequencies above 1KHz.

The charging capacitance(Cc) determines the rate at which the capacitor charges and discharges, affecting the rise time and fall time of the output pulse. The damping resistor(Rd) is used to dampen or reduce oscillations or ringing in the pulse waveform, ensuring a clean and well-defined pulse. The damping resistor value can affect the shape and quality of the pulse waveform. A higher damping resistor value can help reduce ringing or oscillations, resulting in a sharper and cleaner pulse shape.

CHAPTER 4

SIMULATIONS RESULTS

A) SPIKE PULSER using EL7212 driver and SPA11N60C3 POWER MOSFET

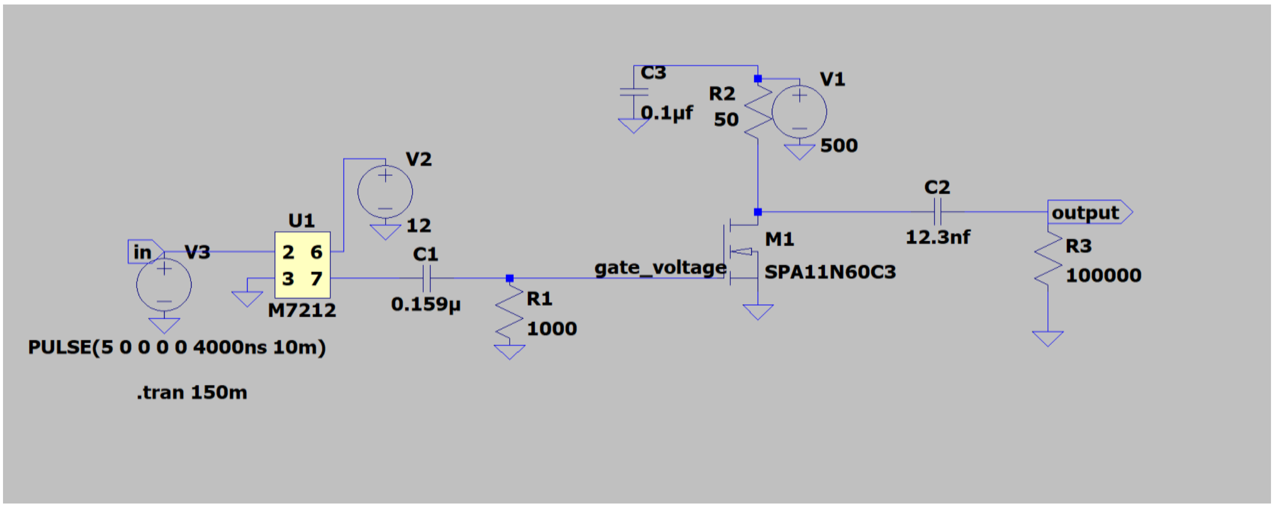


Fig 8: Schematic of spike pulser using EL7212 driver and SPA11N60C3 POWER MOSFET

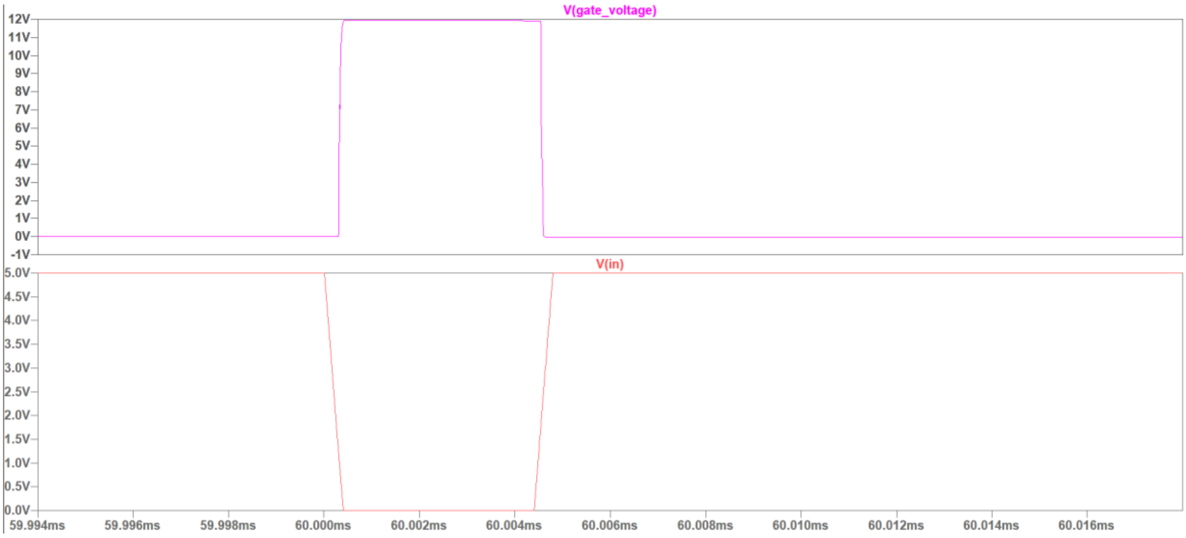


Fig 9: Output pulse response of EL7212 driver

1)+HV=500,C2=12.3nF,R3=100000,Pw=40ns,PRT=10ms

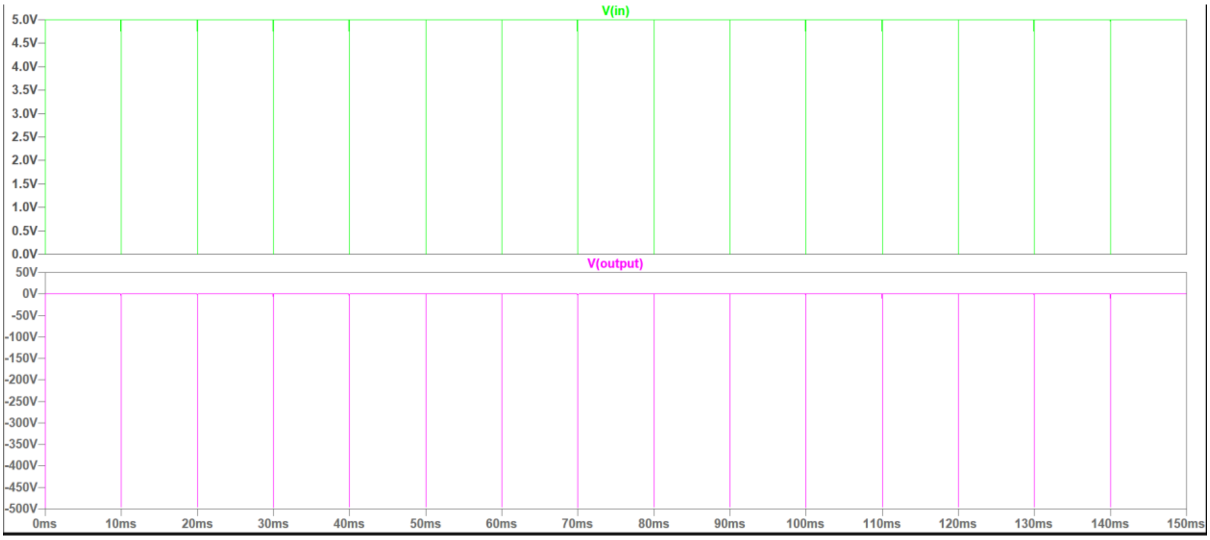
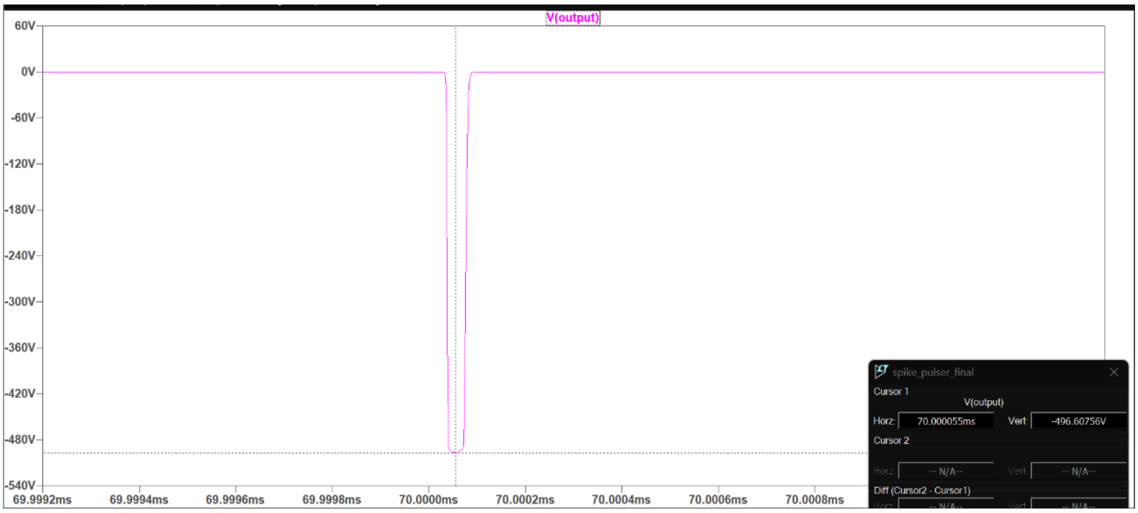
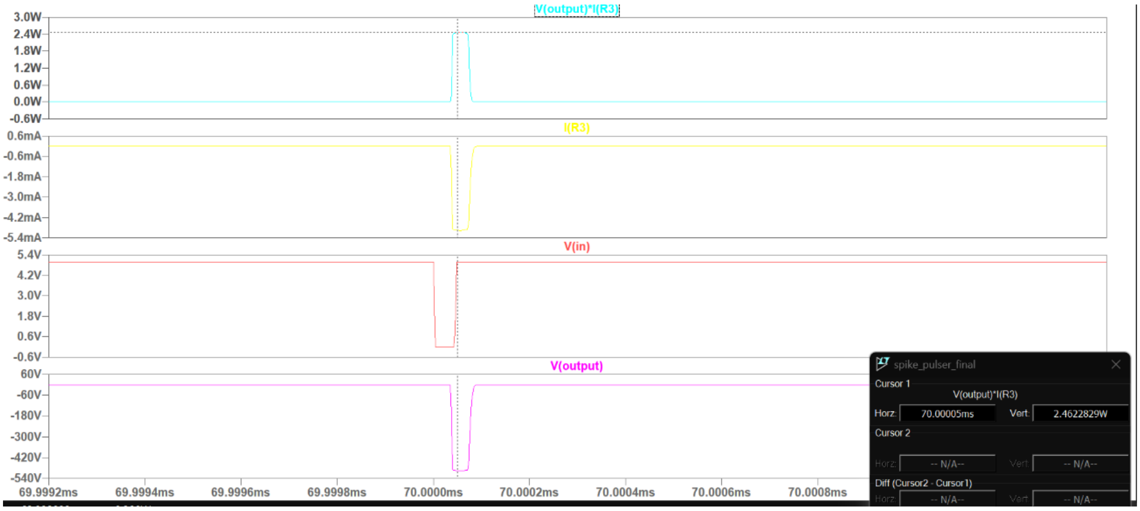


Fig 10: Output pulse response of spike pulser



Cursor 1
V(output)
Horz: 70.000055ms Vert: -496.60756V
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 11: Output pulse amplitude response of spike pulser



Cursor 1
V(output)*I(R3)
Horz: 70.00005ms Vert: 2.4622829W
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 12: Power response of spike pulser

Maximum Power consumed by spike pulser at the output =2.462W.

Maximum current at the output load=4.96mA

Maximum amplitude of negative spike =496.6V

2) +HV=500,C2=12.3nF,R3=100000,Pw=130ns,PRT=10ms

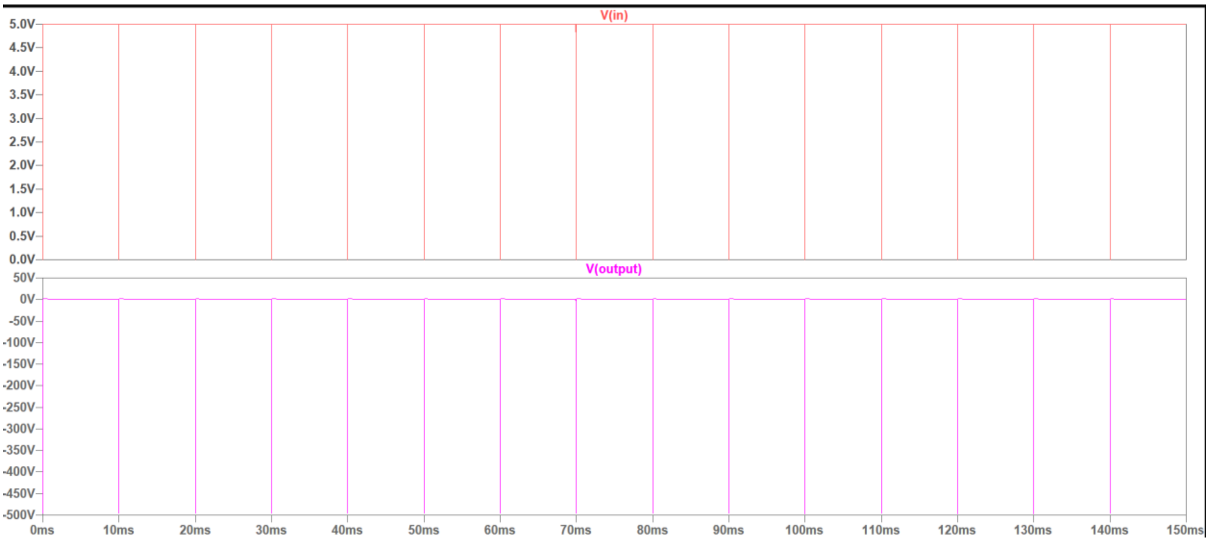
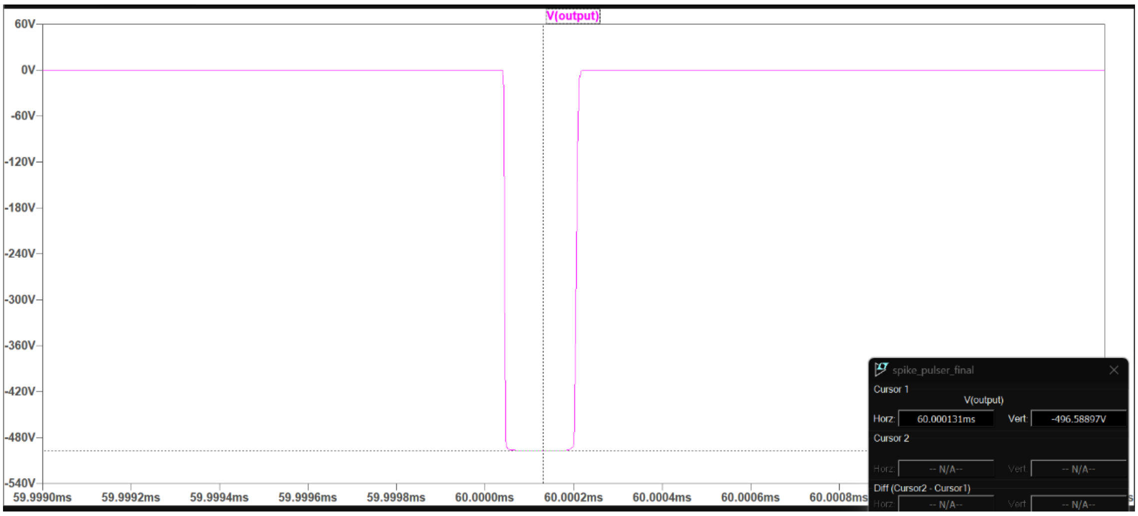
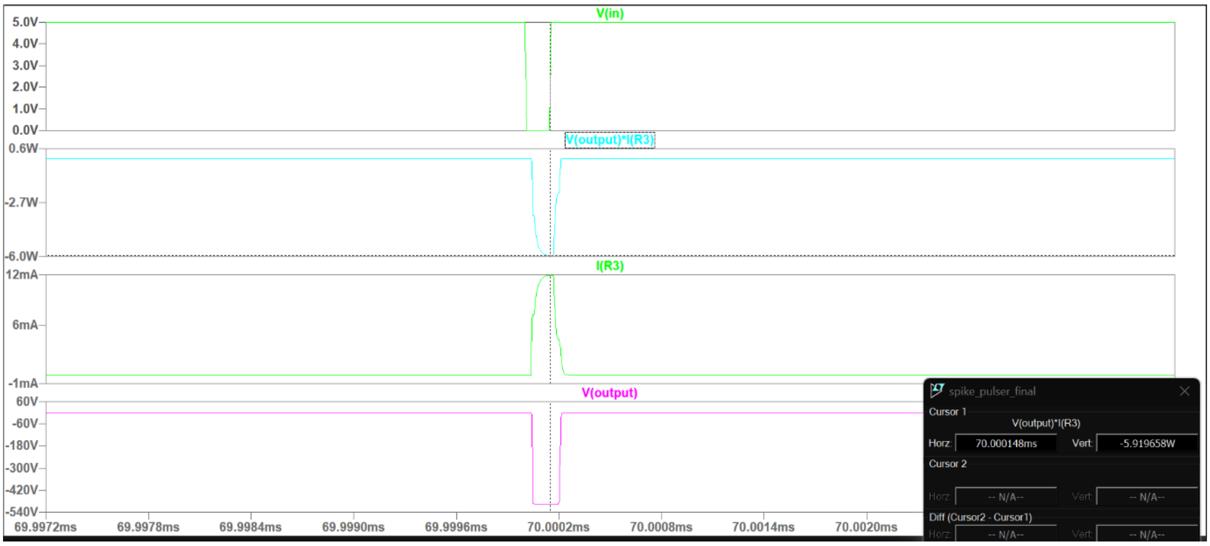


Fig 13: Output pulse response of spike pulser



Cursor 1
V(output)
Horz: 60.000131ms Vert: -496.58897V
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 14: Output pulse amplitude response



Cursor 1
V(output)*I(R3)
Horz: 70.000148ms Vert: -5.919658W
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 15: Power response of spike pulser

Maximum Power consumed by spike pulser at the output =2.465W.

Maximum current at the output load=4.965 mA

Maximum amplitude of negative spike =496.5V

3)+HV=500,C2=12.3nF,R3=100000,Pw=4000ns,PRT=10ms

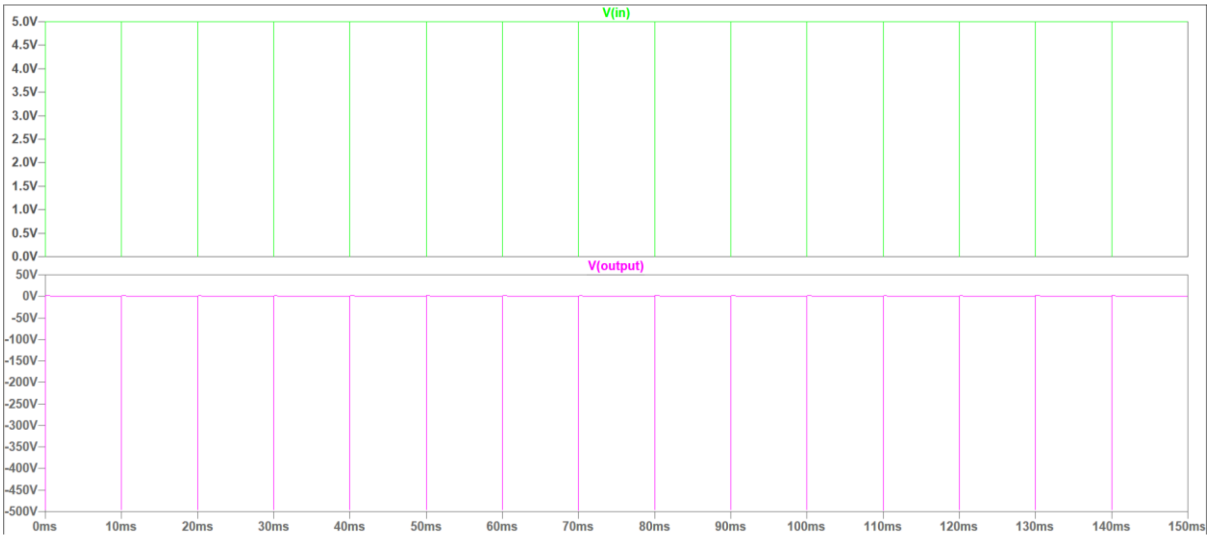


Fig 16: Output pulse response of spike pulser

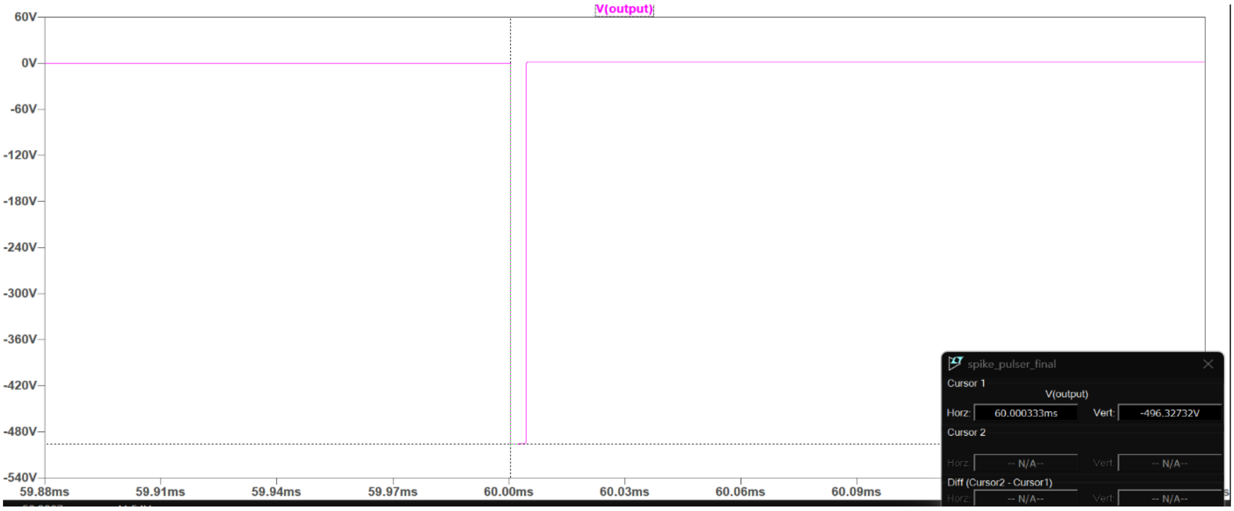


Fig 17: Output pulse amplitude response of spike pulser

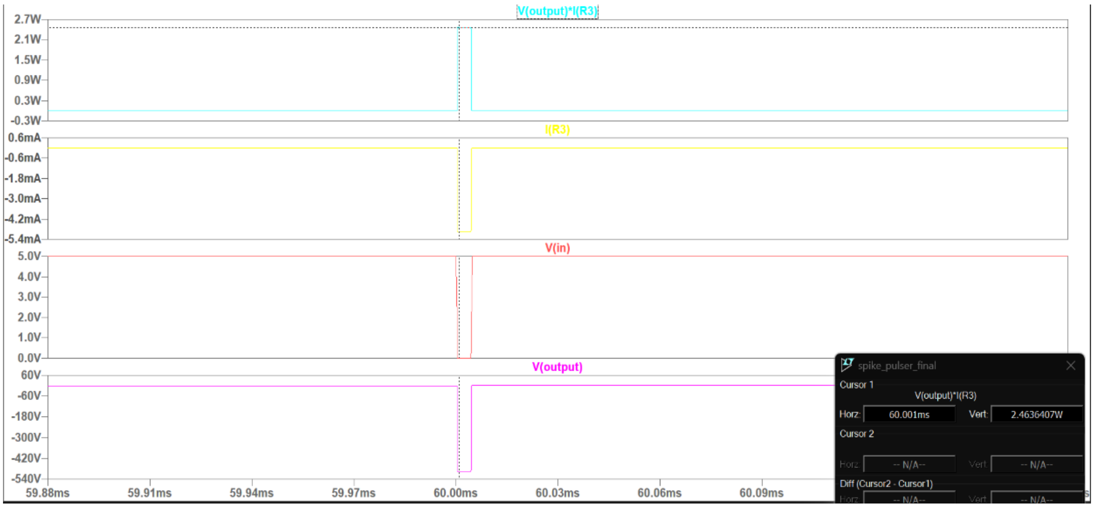


Fig 18: Power response of spike pulser

Maximum Power consumed by spike pulser at the output =2.46 W.

Maximum current at the output load=4.956 mA

Maximum amplitude of negative spike =496.3V

B)SPIKE PULSER using 1ED44173N01B driver and SPA11N60C3 POWER MOSFET

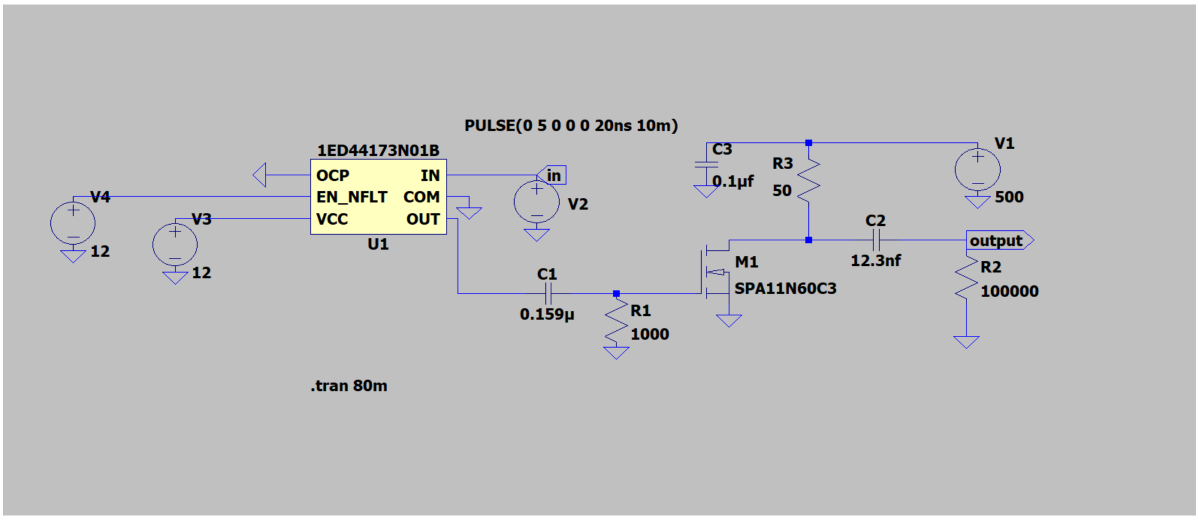


Fig 19: Schematic of spike pulser using 1ED44173N01B driver and SPA11N60C3 POWER MOSFET

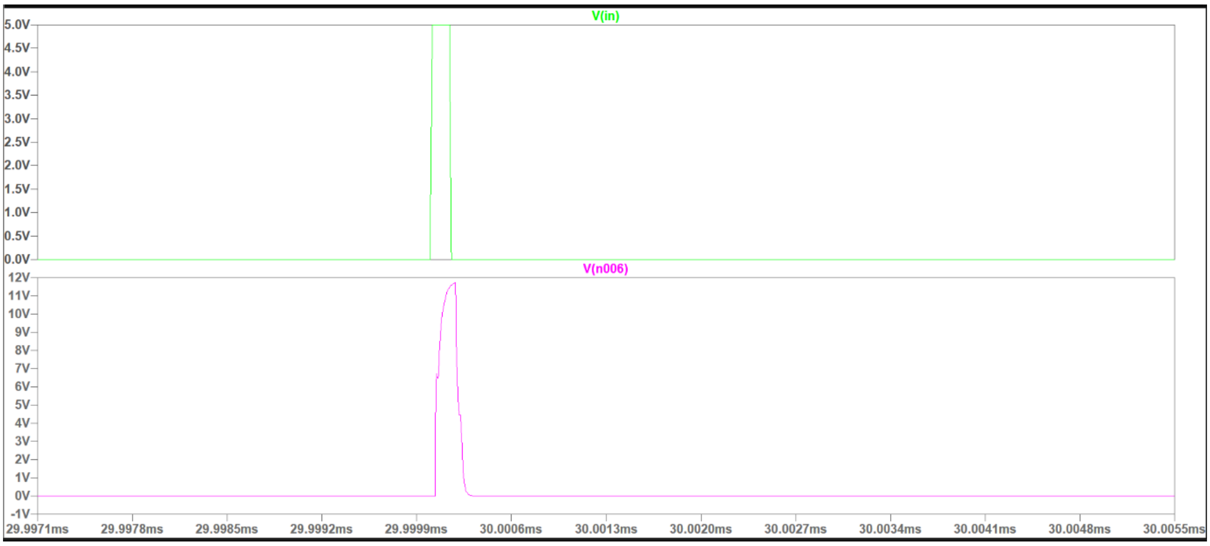


Fig 20: Output pulse response of 1ED44173N01B driver

1) +HV=500,C2=12.3nF,R3=100000,Pw=20ns,PRT=10ms

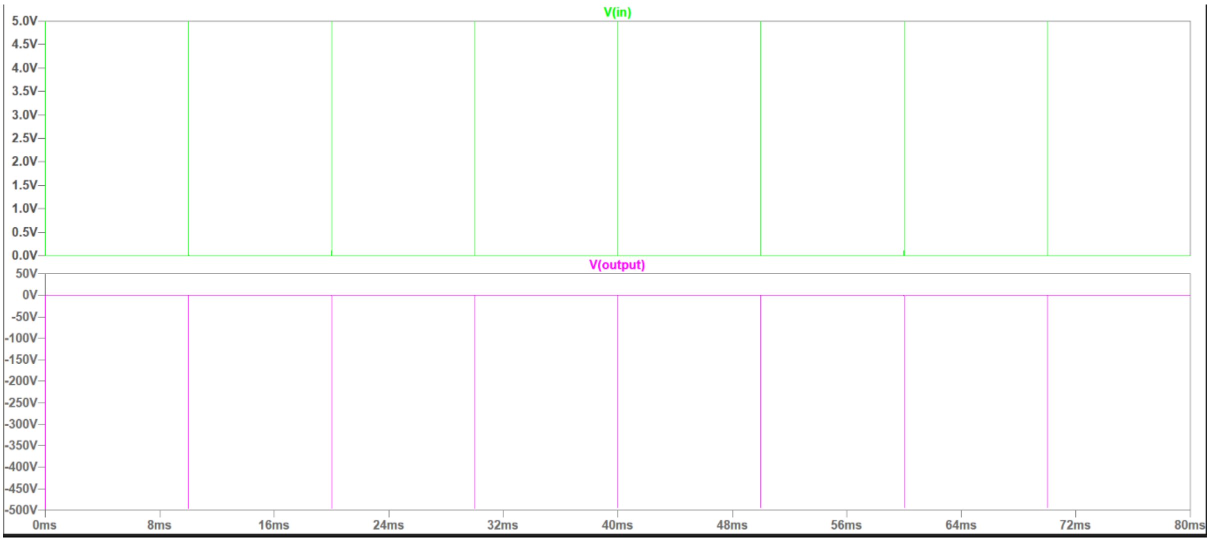
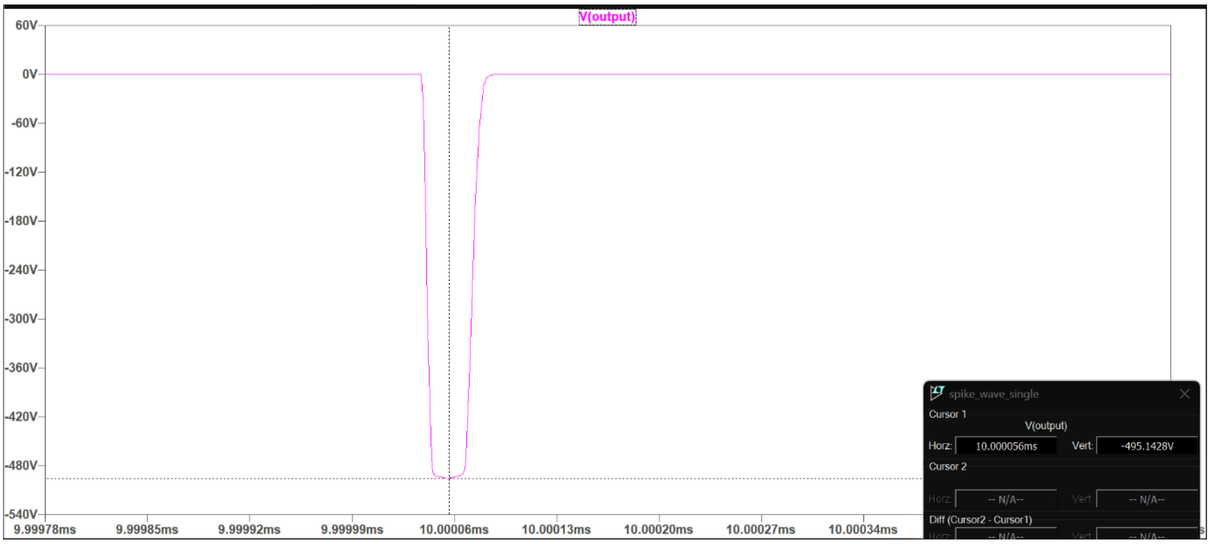
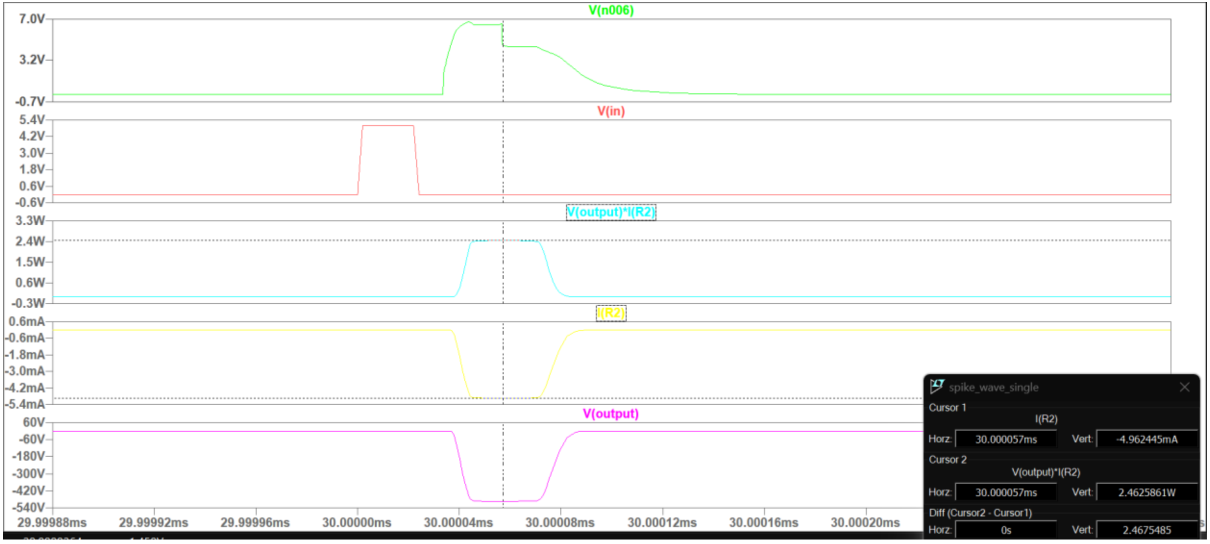


Fig 21 : Output pulse response of spike pulser



Cursor 1
V(output)
Horz: 10.000056ms Vert: -495.1428V
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 22: Output pulse Amplitude response of spike pulser



Cursor 1
I(R2)
Horz: 30.000057ms Vert: -4.962445mA
Cursor 2
V(output)*I(R2)
Horz: 30.000057ms Vert: 2.4625861W
Diff (Cursor2 - Cursor1)
Horz: 0s Vert: 2.4675485

Fig 23: Power response of spike pulser

Maximum Power consumed by spike pulser at the output =2.46 W.

Maximum current at the output load=4.96 mA

Maximum amplitude of negative spike =496V

2)+HV=500,C2=12.3nF,R3=100000,Pw=130ns,PRT=10ms

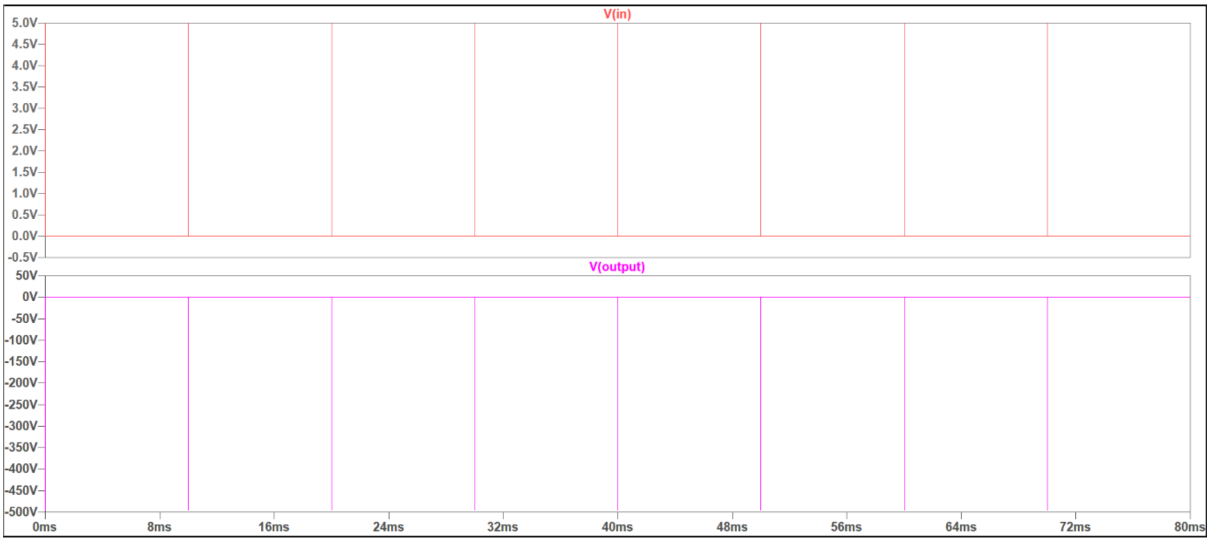
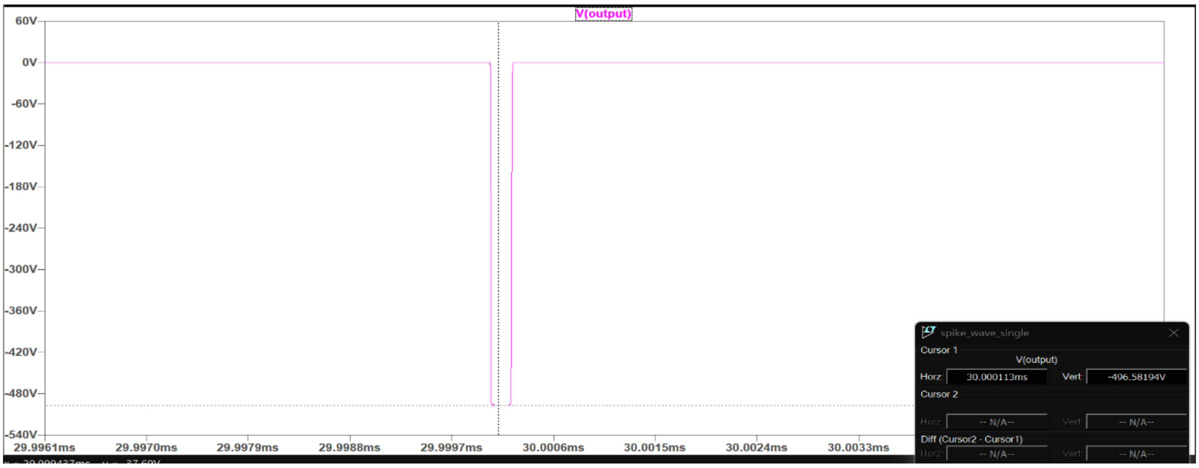
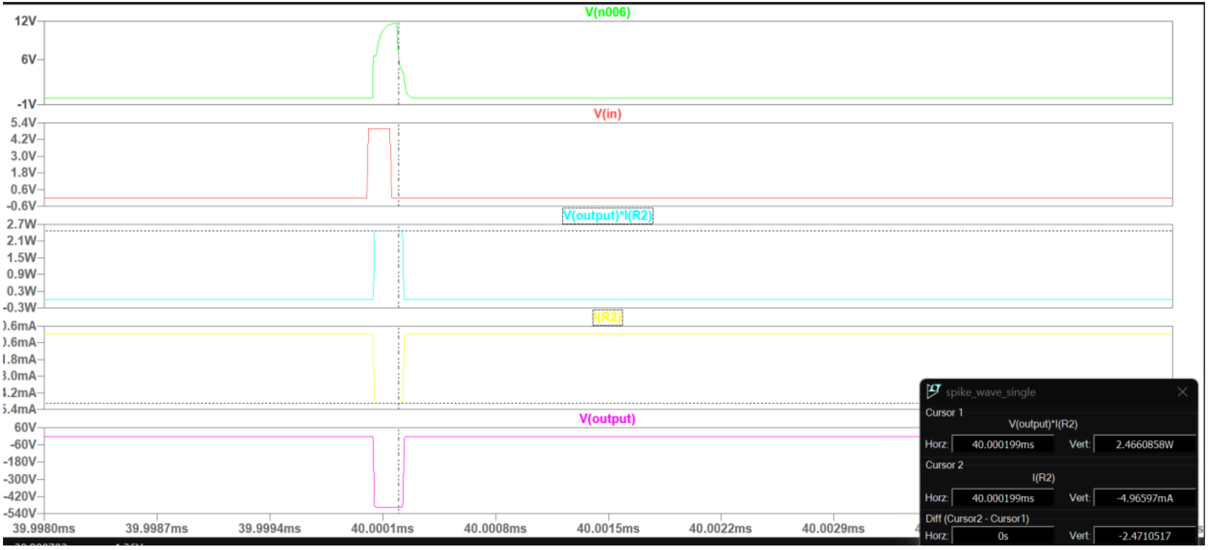


Fig 24 : Output pulse response of spike pulser



Cursor 1
V(output)
Horz: 30.000113ms Vert: -496.58194V
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 25: Output pulse Amplitude response of spike pulser



Cursor 1
V(output)*I(R2)
Horz: 40.000199ms Vert: 2.4660858W
Cursor 2
I(R2)
Horz: 40.000199ms Vert: -4.96597mA
Diff (Cursor2 - Cursor1)
Horz: 0s Vert: -2.4710517

Fig 26: Power response of spike pulser

Maximum Power consumed by spike pulser at the output =2.466 W.

Maximum current at the output load=4.9659 mA

Maximum amplitude of negative spike =496.58V

3)+HV=500,C2=12.3nF,R3=100000,Pw=100000ns,PRT=10ms

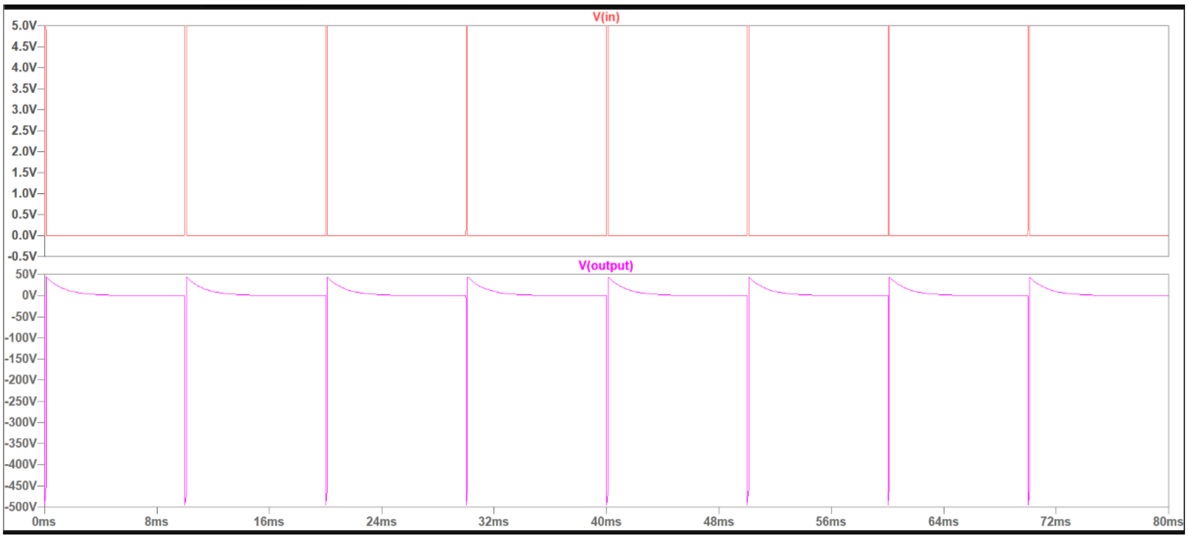
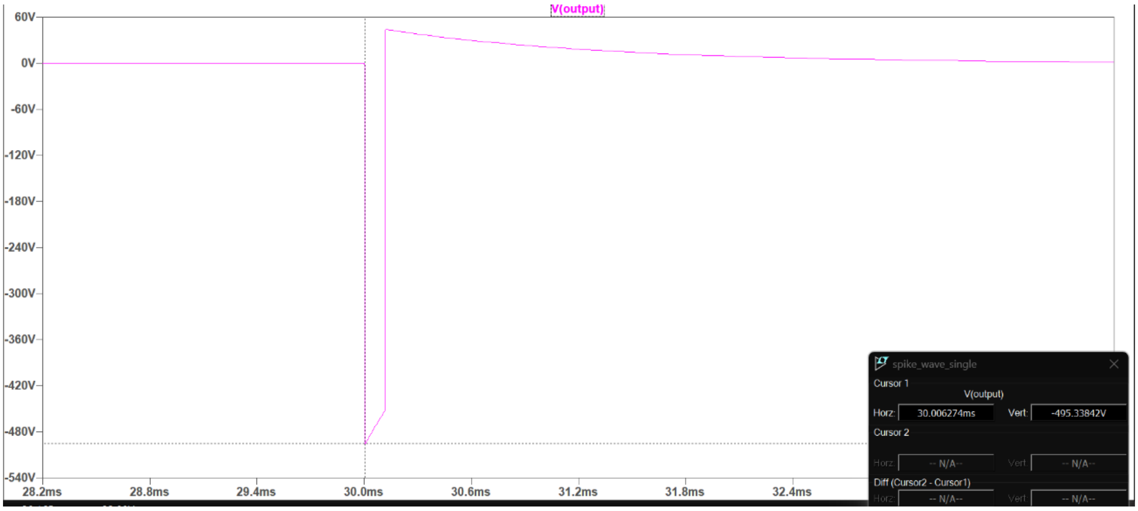
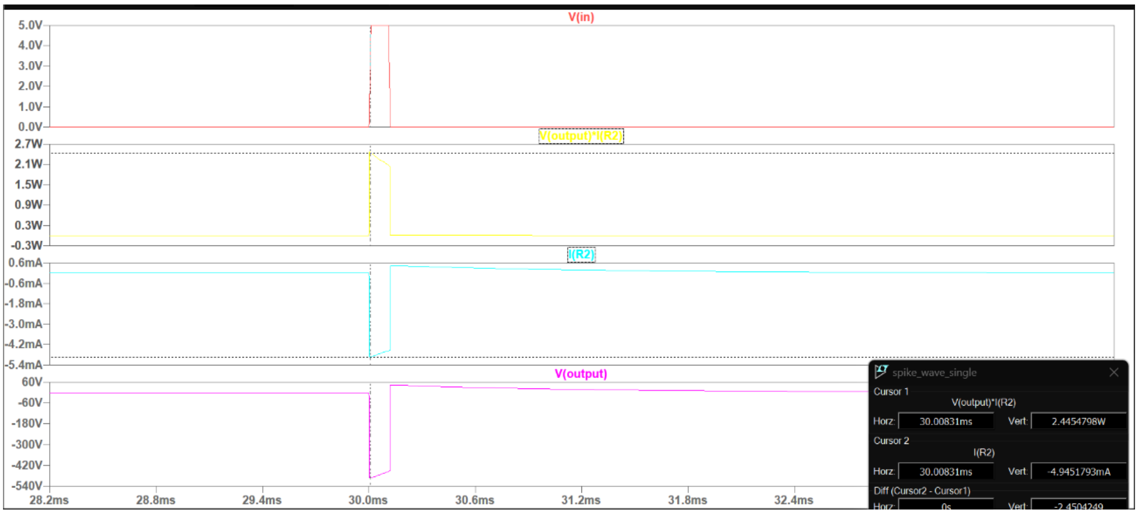


Fig 27 : Output pulse response of spike pulser



Cursor 1
V(output)
Horz: 30.006274ms Vert: -495.33842V
Cursor 2
Horz: -- N/A-- Vert: -- N/A--
Diff (Cursor2 - Cursor1)
Horz: -- N/A-- Vert: -- N/A--

Fig 28:Output pulse Amplitude response of spike pulser



Cursor 1
V(output)*I(R2)
Horz: 30.00831ms Vert: 2.4454798W
Cursor 2
I(R2)
Horz: 30.00831ms Vert: -4.9451793mA
Diff (Cursor2 - Cursor1)
Horz: 0s Vert: -2.4504249

Fig 29: Power response of spike pulser MOSFET

Maximum Power consumed by spike pulser at the output =2.44 W.

Maximum current at the output load=4.945 mA

Maximum amplitude of negative spike =495.33V

CONCLUSION AND FUTURE SCOPE

In this thesis, a high-voltage spike pulser is designed using two types of Drivers. It operates from 20 ns to 100000ns trigger pulse width when 1ED44173N01B driver is used. It operates from 40ns to 4000ns trigger pulse width when EL7212 driver is used. The pulser can provide a negative spike of voltage amplitude up to 650V. Maximum power consumed, the amplitude of the spike, and current at load have been compared for different pulse widths.

FUTURE SCOPE

Future spike pulsers may focus on optimizing power efficiency while maintaining high-energy output. This can contribute to longer battery life in portable devices, reduce power consumption in larger systems, and improve overall energy efficiency.

REFERENCES

1. J. W. Strutt, The Theory of Sound, Ser. Cambridge Library Collection - Physical Sciences. Cambridge, U.K.: Cambridge Univ. Press, 2011, vol. 1.
2. Zhang Y, Demosthenous "A Integrated Circuits for Medical Ultrasound Applications: Imaging and Beyond. IEEE Trans Biomed Circuits Syst". 2021 Oct;15(5):838-858.doi: 10.1109/TBCAS.2021.3120886. Epub 2021 Dec 9. PMID: 34665739.
3. E. G. Tarpara and V. H. Patankar, "Design and development of high voltage ultrasonic spike pulser for immersion applications," *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT),* Kerala, India, 2017, pp. 640-645, doi: 10.1109/ICICICT1.2017.8342638.
4. H. Azhari, Basics of Biomedical Ultrasound for Engineers. Hoboken, NJ, USA: Wiley, 2010
5. KAJAL V. INGALE, Y.B. KALE ,"ULTRASONIC HIGH VOLTAGE PULSER", International Journal of Industrial Electronics and Electrical Engineering, ISSN(p): 2347-6982, ISSN(e): 2349-204X Volume-5, Issue-7, Jul.-2017
6. EL7212, High Speed, Dual Channel Power MOSFET Drivers, Intersil Corporation, USA,2006.
7. 1ED44173N01B, Single-channel low-side MOSFET gate driver IC with fast OCP, Infineon.
8. SPA11N60C3, Cool MOS Power Transistor, Infineon.
9. F. Yamashita, J. Aizawa and H. Honda, "A new compact, low on resistance and high off isolation high voltage analog switch IC without using high voltage power supplies for ultrasound imaging system," *2016 28th International Symposium on Power Semiconductor Devices and ICs (ISPSD)*, 2016, pp. 415-418, doi: 10.1109/ISPSD.2016.7520866.
10. D. Bianchi, F. Quaglia, A. Mazzanti and F. Svelto, "Analysis and Design of a High Voltage Integrated Class-B Amplifier for Ultra-Sound Transducers," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 61, no. 7,

pp. 1942-1951, July 2014, doi: 10.1109/TCSI.2014.2298284.

11. E. Kang *et al.*, "A Variable-Gain Low-Noise Transimpedance Amplifier for Miniature Ultrasound Probes," in *IEEE Journal of Solid-State Circuits*, vol. 55, no. 12, pp. 3157-3168, Dec. 2020, doi: 10.1109/JSSC.2020.3023618.

12. S. Firouz, E. N. Aghdam and R. Jafarnejad, "A Low Power, Low Noise, Single-Ended to Differential TIA for Ultrasound Imaging Probes," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 68, no. 2, pp. 607-611, Feb. 2021, doi: 10.1109/TCSII.2020.3018223.

13. K. Kaviani, O. Oralkan, P. Khuri-Yakub and B. A. Wooley, "A multichannel pipeline analog-to-digital converter for an integrated 3-D ultrasound imaging system," in *IEEE Journal of Solid-State Circuits*, vol. 38, no. 7, pp. 1266-1270, July 2003, doi: 10.1109/JSSC.2003.813294.

14. M. D'Urbino *et al.*, "An Element-Matched Electromechanical $\Delta\Sigma$ ADC for Ultrasound Imaging," in *IEEE Journal of Solid-State Circuits*, vol. 53, no. 10, pp. 2795-2805, Oct. 2018, doi: 10.1109/JSSC.2018.2859961.

15. B. D. Sahoo and B. Razavi, "A fast simulator for pipelined A/D converters," *2009 52nd IEEE International Midwest Symposium on Circuits and Systems*, 2009, pp. 402-406, doi: 10.1109/MWSCAS.2009.5236071.

16. L. Dufort and Mukherjee, “Digitally controlled high-voltage analog switch array for medical ultrasound applications in thin-layer silicon-on-insulator process,” in Proc. IEEE Int. SOI Conf., 2002, pp. 78–79.

17. K. Hara, J. Sakano, M. Mori, S. Tamano, R. Sinomura, and K. Yamazaki, “A new 80V 32×32ch low loss multiplexer LSI for a 3D ultrasound imaging system,” in Proc. 17th Int. Symp. Power Semicond. Devices ICs, 2005, pp. 359–362.

18. Y. Li, R. Wodnicki, N. Chandra, and N. Rao, “An integrated 90V switch array for medical ultrasound applications,” in Proc. IEEE Custom Integr. Circuits Conf., 2006, pp. 269–272.

19. S. Kajiyama et al., “T/R-switch composed of 3 high-voltage MOSFETs with 12.1 μW consumption that can perform per-channel TX to RX self-loopback AC tests for 3D ultrasound imaging with 3072-channel transceiver,” in Proc. IEEE Asian Solid-State Circuits Conf., 2019, pp. 305–308.

20. E. Kang et al., “A variable-gain low-noise transimpedance amplifier for miniature ultrasound probes,” IEEE J. Solid-State Circuits, vol. 55, no. 12, pp. 3157–3168, Dec. 2020.

21. “Capacitive micromachined ultrasonic transducers | Philips Engineering Solutions.”https://www.engineeringsolutions.philips.com/looking-expertise/mems-micro-devices/mems-micro-devices-applications/capacitive-micromachined-ultrasonic-transducers-cmut (accessed May 01, 2022).

22. Y. Qiu et al., “Piezoelectric micromachined ultrasound transducer (PMUT) arrays for integrated sensing, actuation and imaging,” Sensors, vol. 15, no. 4, pp. 8020–8041, 2015. [Online]. Available: https: //www.mdpi.com/1424-8220/15/4/8020.

23. O. Oralkan et al., “Capacitive micromachined ultrasonic transducers: Next-generation arrays for acoustic imaging?” IEEE Trans. Ultrason., Ferroelect., Freq. Control, vol. 49, no. 11, pp. 1596–1610, Nov. 2002.

24. M. C. Chen et al., “A pixel pitch-matched ultrasound receiver for 3- D photoacoustic imaging with integrated delta-sigma beamformer in 28-nm UTBB FD-SOI,” IEEE J. Solid-State Circuits, vol. 52, no. 11, pp. 2843–2856, Nov. 2017.

25. C. Chen et al., “A front-end ASIC with receive sub-array beamforming integrated with a 32 × 32 PZT matrix transducer for 3-D transesophageal echocardiography,” IEEE J. Solid-State Circuits, vol. 52, no. 4, pp. 994–1006, Apr. 2017.

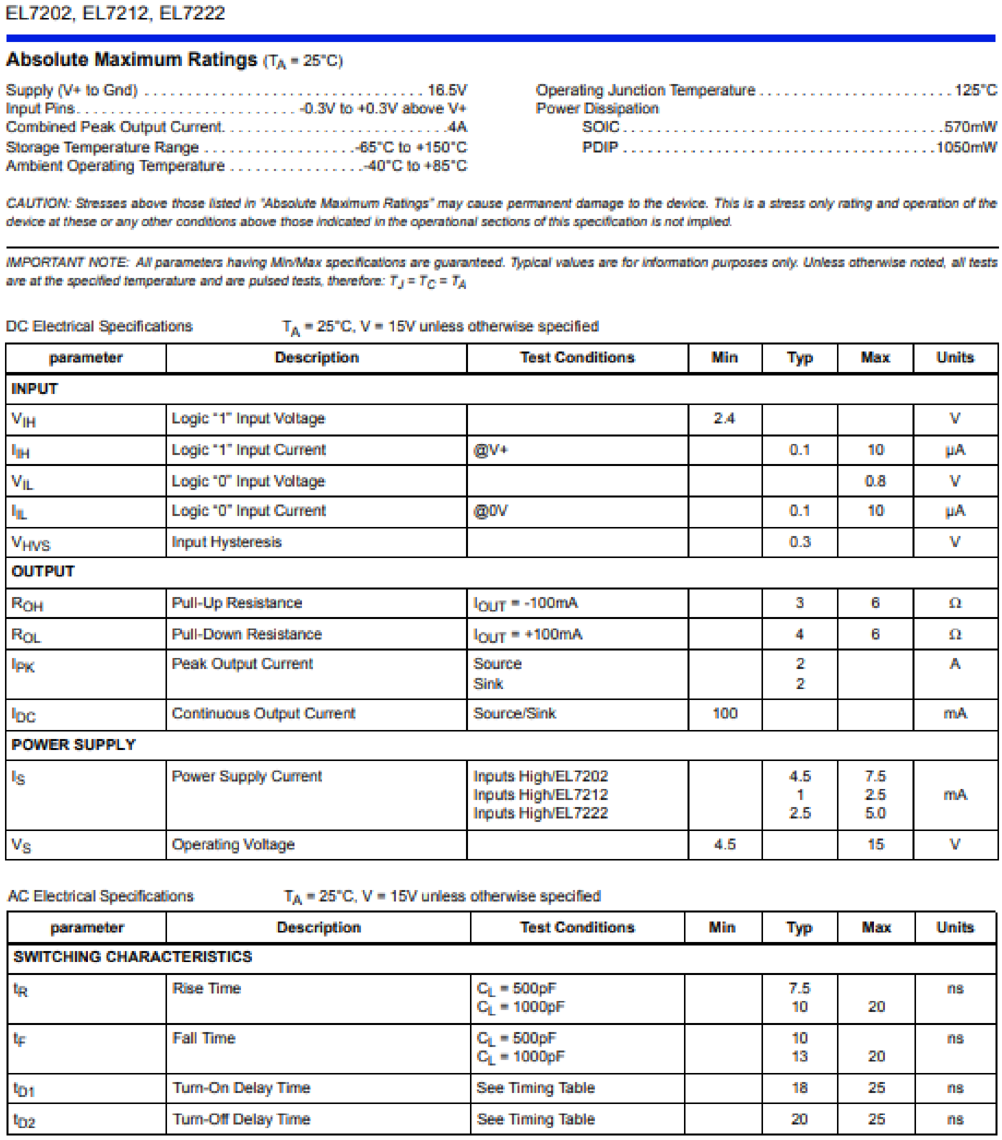
26. Sahoo, B.D. & Razavi, Behzad. (2009), “A Fast Simulator for Pipelined A/D Converters”, Midwest Symposium on Circuits and Systems, 402-406, 10.1109/MWSCAS.2009.5236071**.**

27. Abdominal Ultrasounds: Purpose, Procedure, Uses, Results, Benefits (webmd.com)

28. https://www.wermac.org/others/ndt_ut.html

APPENDICES

A) Datasheet of EL7212



EL7202, EL7212, EL7222

Absolute Maximum Ratings (T_A = 25°C)

Supply (V+ to Gnd)	16.5V	Operating Junction Temperature	125°C
Input Pins	-0.3V to +0.3V above V+	Power Dissipation	
Combined Peak Output Current	4A	SOIC	570mW
Storage Temperature Range	-65°C to +150°C	PDIP	1050mW
Ambient Operating Temperature	-40°C to +85°C		

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

IMPORTANT NOTE: All parameters having Min/Max specifications are guaranteed. Typical values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: $T_J = T_C = T_A$

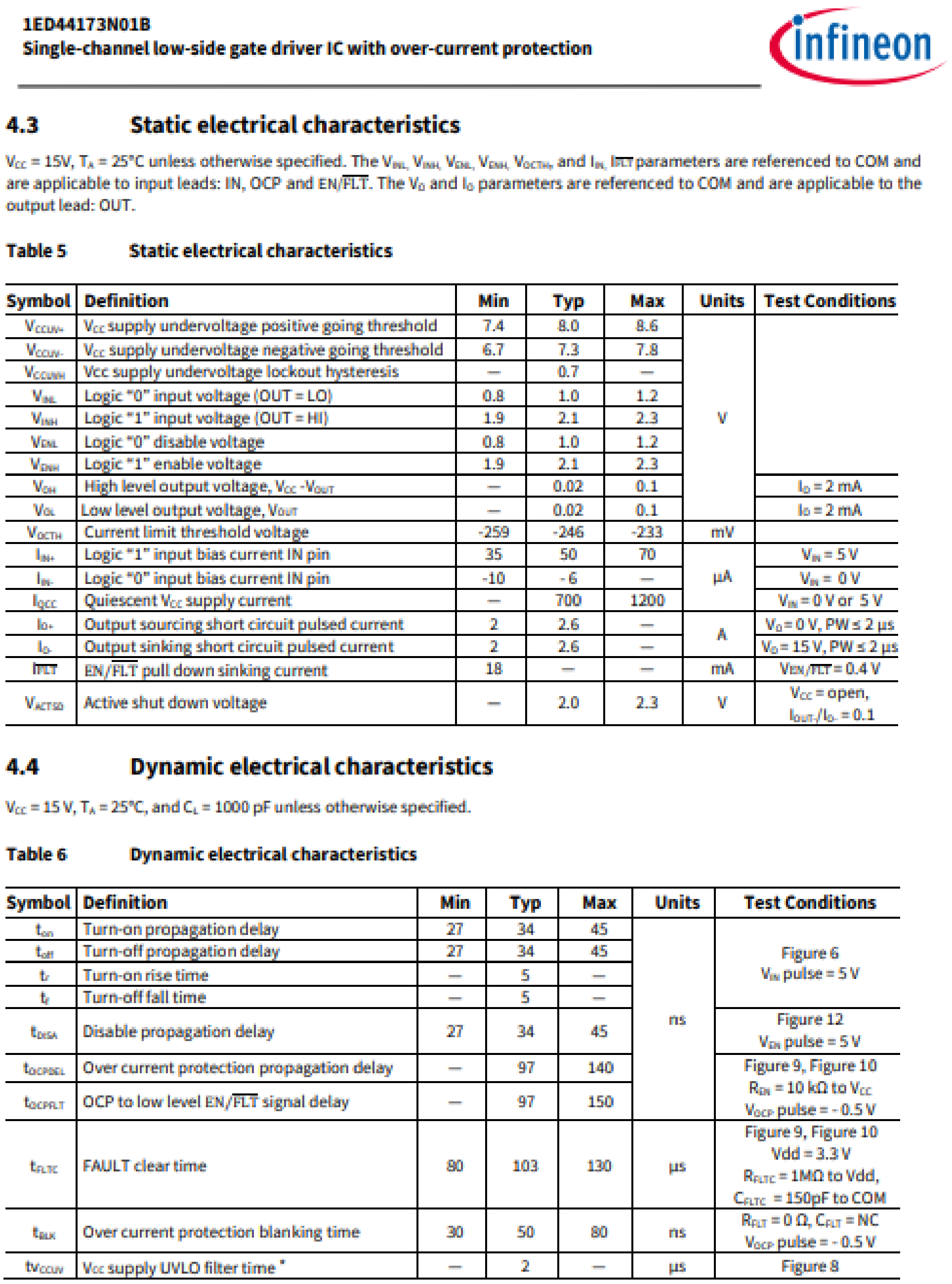
DC Electrical Specifications T_A = 25°C, V = 15V unless otherwise specified

parameter	Description	Test Conditions	Min	Typ	Max	Units
INPUT						
V_{IH}	Logic "1" Input Voltage		2.4			V
I_{IH}	Logic "1" Input Current	@V+		0.1	10	µA
V_{IL}	Logic "0" Input Voltage				0.8	V
I_{IL}	Logic "0" Input Current	@0V		0.1	10	µA
V_{HVS}	Input Hysteresis			0.3		V
OUTPUT						
R_{OH}	Pull-Up Resistance	I_{OUT} = -100mA		3	6	Ω
R_{OL}	Pull-Down Resistance	I_{OUT} = +100mA		4	6	Ω
I_{PK}	Peak Output Current	Source Sink		2 2		A
I_{DC}	Continuous Output Current	Source/Sink	100			mA
POWER SUPPLY						
I_S	Power Supply Current	Inputs High/EL7202 Inputs High/EL7212 Inputs High/EL7222		4.5 1 2.5	7.5 2.5 5.0	mA
V_S	Operating Voltage		4.5		15	V

AC Electrical Specifications T_A = 25°C, V = 15V unless otherwise specified

parameter	Description	Test Conditions	Min	Typ	Max	Units
SWITCHING CHARACTERISTICS						
t_R	Rise Time	C_L = 500pF C_L = 1000pF		7.5 10	 20	ns
t_F	Fall Time	C_L = 500pF C_L = 1000pF		10 13	 20	ns
t_{D1}	Turn-On Delay Time	See Timing Table		18	25	ns
t_{D2}	Turn-Off Delay Time	See Timing Table		20	25	ns

B) Datasheet of 1ED44173N01B



1ED44173N01B
Single-channel low-side gate driver IC with over-current protection

4.3 Static electrical characteristics

V_{CC} = 15V, T_A = 25°C unless otherwise specified. The V_{INL}, V_{INH}, V_{ENL}, V_{ENH}, V_{OCTH}, and I_{IN}, $I_{\overline{FLT}}$ parameters are referenced to COM and are applicable to input leads: IN, OCP and EN/$\overline{\text{FLT}}$. The V_O and I_O parameters are referenced to COM and are applicable to the output lead: OUT.

Table 5 Static electrical characteristics

Symbol	Definition	Min	Typ	Max	Units	Test Conditions
V_{CCUV+}	V_{CC} supply undervoltage positive going threshold	7.4	8.0	8.6	V	
V_{CCUV-}	V_{CC} supply undervoltage negative going threshold	6.7	7.3	7.8		
V_{CCUVH}	Vcc supply undervoltage lockout hysteresis	—	0.7	—		
V_{INL}	Logic "0" input voltage (OUT = LO)	0.8	1.0	1.2		
V_{INH}	Logic "1" input voltage (OUT = HI)	1.9	2.1	2.3		
V_{ENL}	Logic "0" disable voltage	0.8	1.0	1.2		
V_{ENH}	Logic "1" enable voltage	1.9	2.1	2.3		
V_{OH}	High level output voltage, V_{CC} -V_{OUT}	—	0.02	0.1		I_O = 2 mA
V_{OL}	Low level output voltage, V_{OUT}	—	0.02	0.1		I_O = 2 mA
V_{OCTH}	Current limit threshold voltage	-259	-246	-233	mV	
I_{IN+}	Logic "1" input bias current IN pin	35	50	70	µA	V_{IN} = 5 V
I_{IN-}	Logic "0" input bias current IN pin	-10	- 6	—		V_{IN} = 0 V
I_{QCC}	Quiescent V_{CC} supply current	—	700	1200		V_{IN} = 0 V or 5 V
I_{O+}	Output sourcing short circuit pulsed current	2	2.6	—	A	V_O = 0 V, PW ≤ 2 µs
I_{O-}	Output sinking short circuit pulsed current	2	2.6	—		V_O = 15 V, PW ≤ 2 µs
$I_{\overline{FLT}}$	EN/$\overline{\text{FLT}}$ pull down sinking current	18	—	—	mA	$V_{EN/\overline{FLT}}$ = 0.4 V
V_{ACTSD}	Active shut down voltage	—	2.0	2.3	V	V_{CC} = open, I_{OUT-}/I_{O-} = 0.1

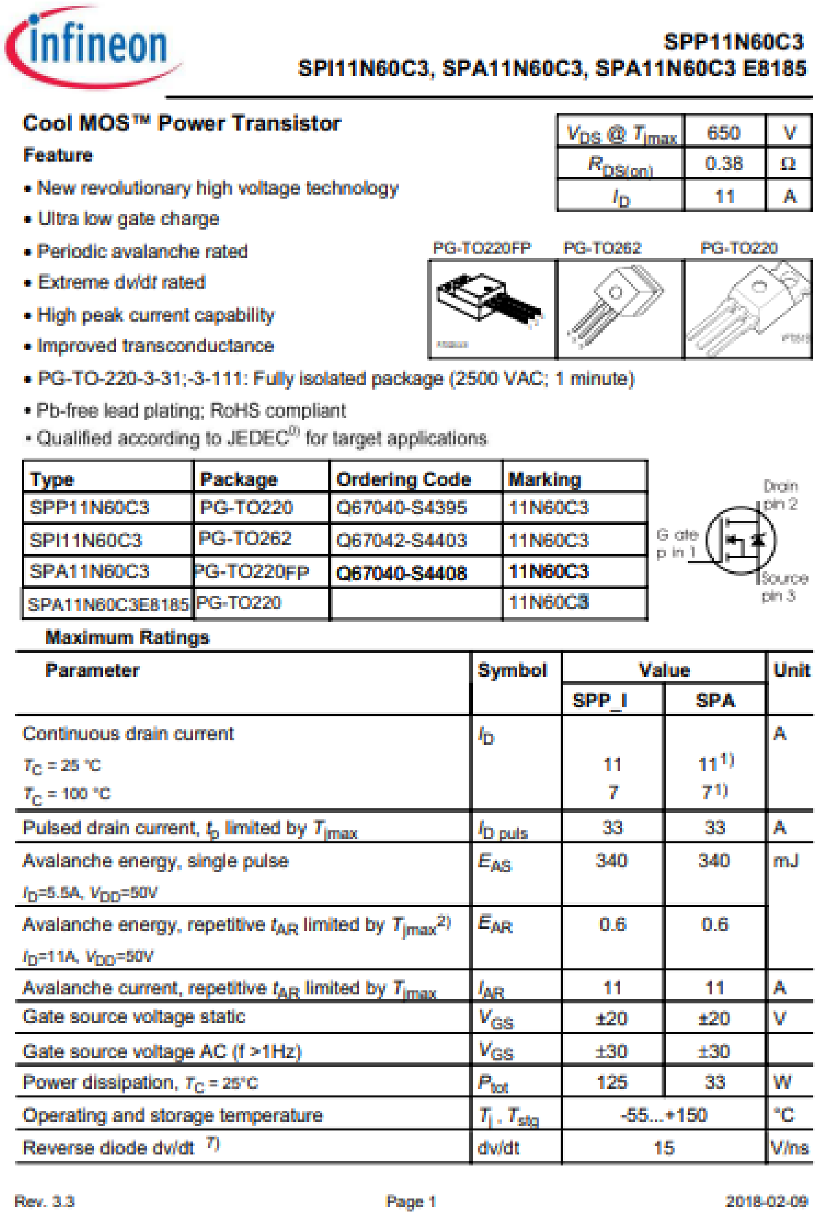
4.4 Dynamic electrical characteristics

V_{CC} = 15 V, T_A = 25°C, and C_L = 1000 pF unless otherwise specified.

Table 6 Dynamic electrical characteristics

Symbol	Definition	Min	Typ	Max	Units	Test Conditions
t_{on}	Turn-on propagation delay	27	34	45	ns	Figure 6 V_{IN} pulse = 5 V
t_{off}	Turn-off propagation delay	27	34	45		
t_r	Turn-on rise time	—	5	—		
t_f	Turn-off fall time	—	5	—		
t_{DISA}	Disable propagation delay	27	34	45		Figure 12 V_{EN} pulse = 5 V
t_{OCPDEL}	Over current protection propagation delay	—	97	140		Figure 9, Figure 10 R_{EN} = 10 kΩ to V_{CC} V_{OCP} pulse = - 0.5 V
t_{OCPFLT}	OCP to low level EN/$\overline{\text{FLT}}$ signal delay	—	97	150		
t_{FLTC}	FAULT clear time	80	103	130	µs	Figure 9, Figure 10 Vdd = 3.3 V R_{FLTC} = 1MΩ to Vdd, C_{FLTC} = 150pF to COM
t_{BLK}	Over current protection blanking time	30	50	80	ns	R_{FLT} = 0 Ω, C_{FLT} = NC V_{OCP} pulse = - 0.5 V
tV_{CCUV}	V_{CC} supply UVLO filter time *	—	2	—	µs	Figure 8

C) Datasheet of SPA11N60C3



SPP11N60C3
SPI11N60C3, SPA11N60C3, SPA11N60C3 E8185

Cool MOS™ Power Transistor

Feature

- New revolutionary high voltage technology
- Ultra low gate charge
- Periodic avalanche rated
- Extreme dv/dt rated
- High peak current capability
- Improved transconductance
- PG-TO-220-3-31;-3-111: Fully isolated package (2500 VAC; 1 minute)
- Pb-free lead plating; RoHS compliant
- Qualified according to JEDEC1) for target applications

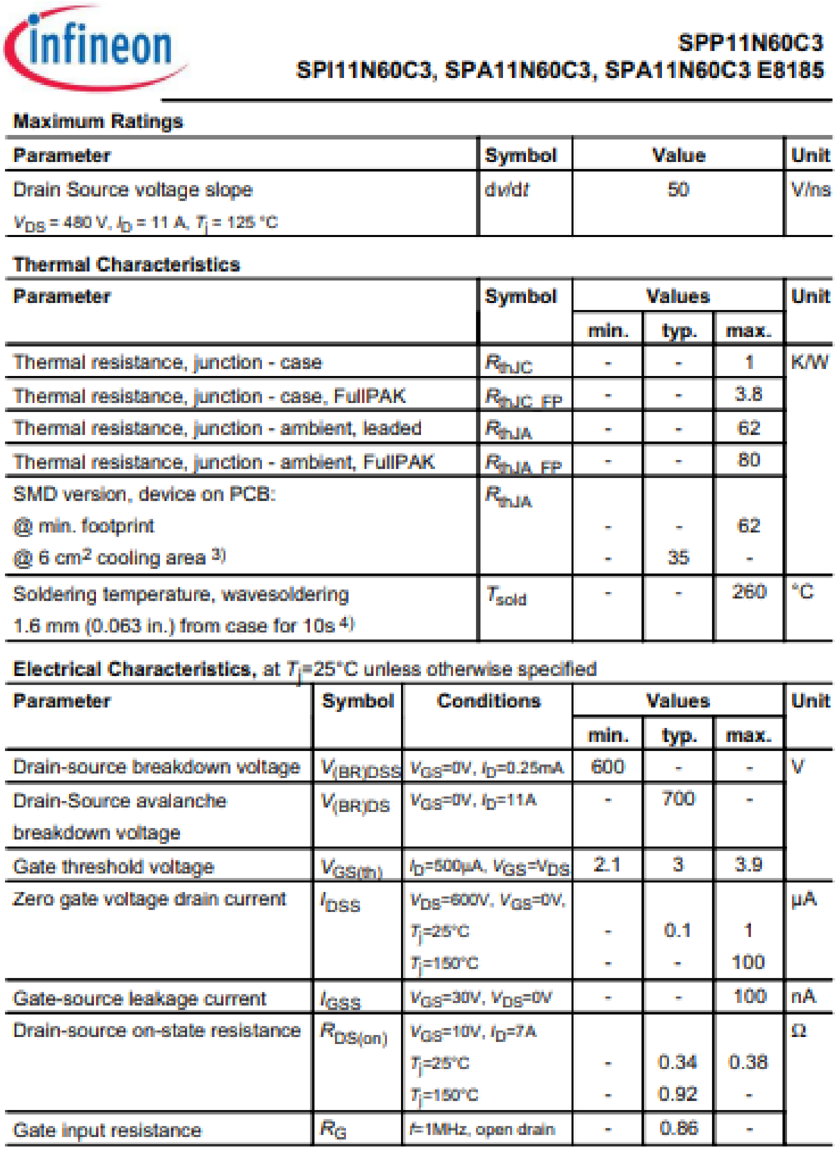
V_{DS} @ T_{jmax}	650	V
$R_{DS(on)}$	0.38	Ω
I_D	11	A

Type	Package	Ordering Code	Marking
SPP11N60C3	PG-TO220	Q67040-S4395	11N60C3
SPI11N60C3	PG-TO262	Q67042-S4403	11N60C3
SPA11N60C3	PG-TO220FP	Q67040-S4408	11N60C3
SPA11N60C3E8185	PG-TO220		11N60C3

Maximum Ratings

Parameter	Symbol	Value		Unit
		SPP_I	SPA	
Continuous drain current	I_D			A
T_C = 25 °C		11	11 1)	
T_C = 100 °C		7	7 1)	
Pulsed drain current, t_p limited by T_{jmax}	$I_{D\ puls}$	33	33	A
Avalanche energy, single pulse I_D=5.5A, V_{DD}=50V	E_{AS}	340	340	mJ
Avalanche energy, repetitive t_{AR} limited by T_{jmax} 2) I_D=11A, V_{DD}=50V	E_{AR}	0.6	0.6	
Avalanche current, repetitive t_{AR} limited by T_{jmax}	I_{AR}	11	11	A
Gate source voltage static	V_{GS}	±20	±20	V
Gate source voltage AC (f >1Hz)	V_{GS}	±30	±30	
Power dissipation, T_C = 25°C	P_{tot}	125	33	W
Operating and storage temperature	T_j , T_{stg}	-55...+150		°C
Reverse diode dv/dt 7)	dv/dt	15		V/ns

Rev. 3.3 Page 1 2018-02-09



SPP11N60C3
SPI11N60C3, SPA11N60C3, SPA11N60C3 E8185

Maximum Ratings

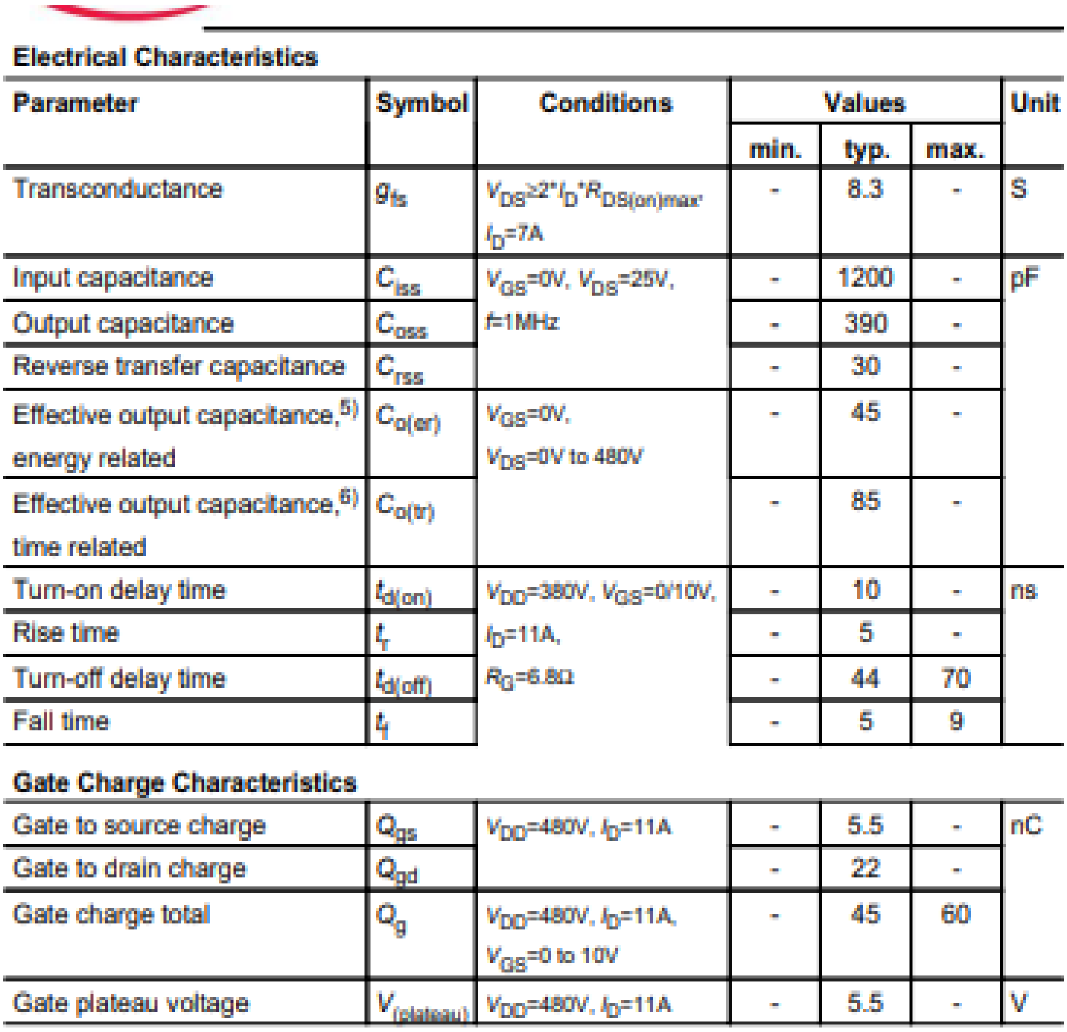
Parameter	**Symbol**	**Value**	**Unit**
Drain Source voltage slope V_{DS} = 480 V, I_D = 11 A, T_j = 125 °C	dv/dt	50	V/ns

Thermal Characteristics

Parameter	**Symbol**	**Values**			**Unit**
		min.	**typ.**	**max.**	
Thermal resistance, junction - case	R_{thJC}	-	-	1	K/W
Thermal resistance, junction - case, FullPAK	R_{thJC_FP}	-	-	3.8	
Thermal resistance, junction - ambient, leaded	R_{thJA}	-	-	62	
Thermal resistance, junction - ambient, FullPAK	R_{thJA_FP}	-	-	80	
SMD version, device on PCB:	R_{thJA}				
@ min. footprint		-	-	62	
@ 6 cm² cooling area [3]		-	35	-	
Soldering temperature, wavesoldering 1.6 mm (0.063 in.) from case for 10s [4]	T_{sold}	-	-	260	°C

Electrical Characteristics, at T_j=25°C unless otherwise specified

Parameter	**Symbol**	**Conditions**	**Values**			**Unit**
			min.	**typ.**	**max.**	
Drain-source breakdown voltage	$V_{(BR)DSS}$	V_{GS}=0V, I_D=0.25mA	600	-	-	V
Drain-Source avalanche breakdown voltage	$V_{(BR)DS}$	V_{GS}=0V, I_D=11A	-	700	-	
Gate threshold voltage	$V_{GS(th)}$	I_D=500µA, V_{GS}=V_{DS}	2.1	3	3.9	
Zero gate voltage drain current	I_{DSS}	V_{DS}=600V, V_{GS}=0V,				µA
		T_j=25°C	-	0.1	1	
		T_j=150°C	-	-	100	
Gate-source leakage current	I_{GSS}	V_{GS}=30V, V_{DS}=0V	-	-	100	nA
Drain-source on-state resistance	$R_{DS(on)}$	V_{GS}=10V, I_D=7A				Ω
		T_j=25°C	-	0.34	0.38	
		T_j=150°C	-	0.92	-	
Gate input resistance	R_G	f=1MHz, open drain	-	0.86	-	



Electrical Characteristics

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Transconductance	g_{fs}	$V_{DS} \geq 2 * I_D * R_{DS(on)max}$, I_D=7A	-	8.3	-	S
Input capacitance	C_{iss}	V_{GS}=0V, V_{DS}=25V, f=1MHz	-	1200	-	pF
Output capacitance	C_{oss}		-	390	-	
Reverse transfer capacitance	C_{rss}		-	30	-	
Effective output capacitance,[5] energy related	$C_{o(er)}$	V_{GS}=0V, V_{DS}=0V to 480V	-	45	-	
Effective output capacitance,[6] time related	$C_{o(tr)}$		-	85	-	
Turn-on delay time	$t_{d(on)}$	V_{DD}=380V, V_{GS}=0/10V, I_D=11A, R_G=6.8Ω	-	10	-	ns
Rise time	t_r		-	5	-	
Turn-off delay time	$t_{d(off)}$		-	44	70	
Fall time	t_f		-	5	9	

Gate Charge Characteristics

Parameter	Symbol	Conditions	min.	typ.	max.	Unit
Gate to source charge	Q_{gs}	V_{DD}=480V, I_D=11A	-	5.5	-	nC
Gate to drain charge	Q_{gd}		-	22	-	
Gate charge total	Q_g	V_{DD}=480V, I_D=11A, V_{GS}=0 to 10V	-	45	60	
Gate plateau voltage	$V_{(plateau)}$	V_{DD}=480V, I_D=11A	-	5.5	-	V

report

by manisha jain

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