PULSER FOR PIEZOELECTRICS TRANSDUCERS USED IN NON-DESTRUCTIVE TESTING

[1]ENG. PAUL ION, [2]ENG. DAN ALEXANDRU STOICHESCU

[1]University POLITEHNICA of Bucharest, [2]Prof.University POLITEHNICA of Bucharest, Faculty of Electronics, Telecomunications and Informations Technology
E-mail: [1]ionpaul11@yahoo.com, [2]dan_stoich@yahoo.com

Abstract- In order to get, at the ultrasonic receiver input, a clear echo pulse, it is very important to apply on the transducer a short high amplitude pulse (hundreds of volts). The pulse frequency is low enough to allow the reception and processing of the informations received from the analysed material between two adjacent pulses, but high enough to ensure an integral control of the material. The piezoceramic disc chattering amplitude is maximum if the pulse frequency spectrum is centered on a frequency f_c equal to the piezoceramic disc frequency. Ideally, the excitation pulse falling edge must be 10% to 30% lower than $\lambda/4$, where λ is the wavelength corresponding to the piezoelectric disc central frequency. The dimensions of the sonic field surface crossed by the controlled piece, the incidence angle of the ultrasonic beam on the piece- environment interface are essential elements ensuring the efficienty of the ultrasonic inspection method. In the paper a high bandwidth pulse generator for ultrasonic transducer excitation is presented. The generated signal frequency may vary between 2MHz and 17MHz, the pulses falling edge is lower than 10ns, their amplitude is U=300V (a slew rate of 30V/ns); VMOS transistors and bipolar transistors are used as switching devices.

Index Terms- Non-Destructive Testing, pulser,ultrasounds

I. INTRODUCTION

The pulse generator design is based on the following: the piezoelectric transducer high impedance requires a high voltage excitation in order to ensure a maximum energy transfer to the examined material. The maximum voltage that can be applied to the ultrasonic transducer depends on the piezoelectric disc width; for the PZT (Plumb- Zirconate-Titanate) a 2kV per millimeter of width is allowed. For a 1MHz, 2,3mm wide disc, a 4,5kV excitation voltage is necessary which is a rathee high voltage for the usual electronic components. For the pulse generator design , high voltage active devices have been used.

II. EXPERIMENTS

A non-destructive ultrasonic equipment consists in a pulse generator exciting the transducer and an echo signal receiver. High amplitude, controlled energy short pulses are generated and then, converted by the transducer in short ultrasonic pulses.

In order to determine the pulse generator efficiency for a certain transducer, the echo pulse method has been used

A3 calibration bloc (ASTM E797) having width stage from 1mm to 10 mm was immersed in a water pail and the transducer has been fixed within an immersed holder on the superior part of the pail, above the calibration block. The holder allows the 3D adjustment of the transducer allowing the ultrasonic beam to penetrate normally its surface. The distance between the transducer and the calibration block surface is adjusted in order to place the focal point within the calibration block. Different circuits for the generator and high banwidth pulse amplifier from the opposite side of the calibration block have been visualized at the amplifier output. All the previously mentioned adjustments were implemented in order to maximize the amplitude of the echo-signals received and visualized on the oscilloscope. A HAMEG oscilloscope, HM305, maximum frequency-35MHz, sensitivity-1mV/div, time base 50ns/div has been used. The measuring probe capacity and the attenuation coefficient are 3pF and 1/10 respectively.

The generator must allow the adjustment of the following signal parameters:

- the time interval within which the pulse is fed to the tranducer;
- the pulse energy, measured by means of the voltage applied to the transducer, considered an unvariable load; the usual values of this voltage vary between 100V and 800V.

Pulse generator circuit selection

In fig.1 the principle of a single MOS generator is presented. For the transducer (the piezoelectric cristal)the Butterworth-Van Dyke [2] model is taken into consideration.

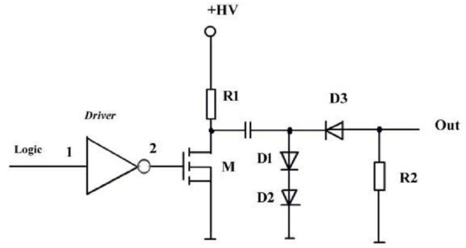

Fig. 1 Pulse generator with a single active component-the MOS transistor[1].

It consists in the transducer capacity C_0 in series with the series resonant circuit Rm, Lm, Cm. The limited mechanical conditions are modeled by Rm and Cm, where as the mechanical system mass is described by the inductance Lm.

In principal pulse load is the piezoelectric transducer capacity C_0, but this capacity is charged during the pulse duration and only the energy taken over by Rm is useful. The capacity charging process must stop before the next transducer excitation cycle. The ultrasonic frequency used in the case of the transmission through the air is rather low (here f=500kHz) and, in order to boost the energy transferred to the transducer, pulse train used.

A piezoceramic transducer with fc=500KHz, Rm=410kΩ, Cm=173Pf,Lm=561µH,C0=480pF has been used.

The resistor R_2 is necessary for reducing to zero the signal after the ending of the excitation pulse. The energy dissipated by this resistor during the excitation pulse is[1]:

$$P_{R2}=f_{PR}\cdot V^2_{HV}\cdot N/2R_2\cdot f_C \qquad (1)$$

where: f_c is the transducer frequency, V_{VH} is the excitation voltage, f_{PR} is the pulse repetition frequency and N is the number of pulses in the train applied to the transducer. The excitation pulses repetition frequency is limited by the high voltage power supply. The circuit performance is limited by the MOS transistor switching speed. Using the transistor RVM60, we obtained t_f=15-20ns (fig2) when U=300V and f_{PR}=1,2KHz.

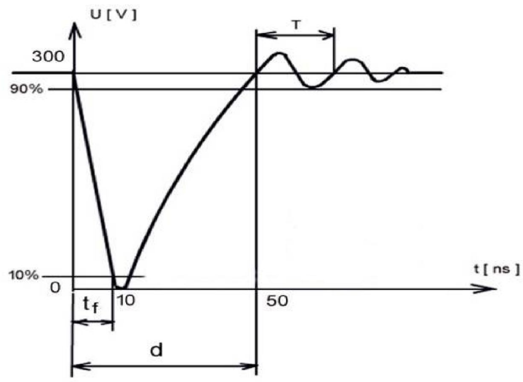

Fig. 2 Pulse diagram: tf=fall time; d= pulse duration; T=decaying oscillation period.

In fig.3 an excitation pulse generator is presented. The constant current through the inductance L is rapidly interrupted; a rapidly growing voltage pulse is generated on the transistorT4 colllector; the value of the pulse rise time is determined especially by the transistor T4.

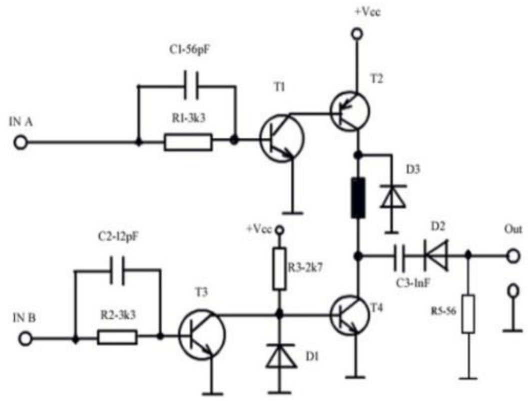

Fig. 3 Pulse generator with bipolar transistors and storage inductance

If L=174µH and Vcc=6,5V, the transducer excitation pulse amplitude is U=92V. The pulse is transmitted through the crossover capacitor C3 to the ultrasonic transducer. For a duration of the output transitory current , t=t_f, the peak value of the current is:

$$I = Uvv/Z0= 92V/35\Omega = 2,7A \qquad (2)$$

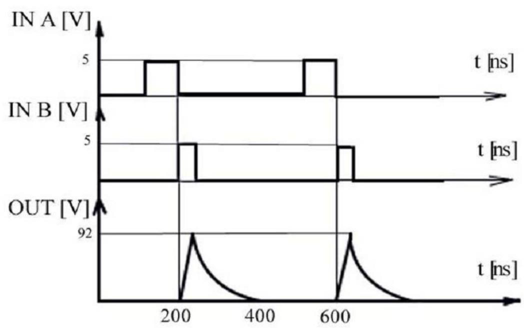

Fig.4 Diagram of the command and the output signals

For the generator circuit in fig.5 the output pulse amplitude is lower than the power supply voltage but interesting experimental results concerning the pulse rise time have been obtained.

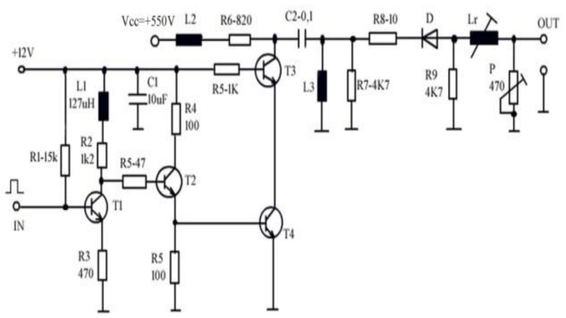

Fig.5 Pulse generator with bipolar transistors and output capacitor

The pulse amplitude is U≤425V on a 50Ω load where as the generator output impedance is ≤ 38Ω. These results can be obtained provided that fast switching transistors are used. We used 2N6654 type transistors for T3 and T4. In this circuit the inductance L4 is important; along with the piezoceramic disc, it constitutes an oscillating circuit whose paramaters are thoroughly computed in order to ensure a maximum energy transfer to the transducer. The pulse generator is optimally working with transducers whose frequencies belog to the 1-15 MHz interval. Using a 2,5MHz frequency transducer after an optimal adjustement, a maximum peak current was obtained:

$$I_{vv}=U/Z_t = 425V/\ 50\Omega = 8{,}5A \qquad (5)$$

A substantial improvement of the final level performance of the previous circuit has been obtained replacing transistor T4 by three parallel devices which ensure a maximum current through T3 during the commutation interval (fig. 6) . Transistors T2,T3,T4 pull the emitter of T1 to the ground. A spherically focalized transducer was used; its frequency and focal distance are 17MHz and 32mm. The transistor T1 is a 2N6655 one, transistors T2,T3 and T4 are BSX12A[3]. The input 0,2μs pulse (IN) determines due to the differentiating cell R12C7 on the base of T6, a short pulse with fast fronts.

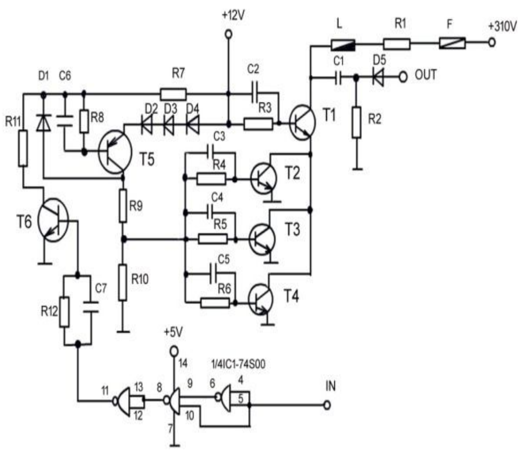

Fig 6.Pulse generator with bipolar transistors connected in parallel.

Through transistor T5 and the differentiating cells C3R4, C4R5, C5R6, this pulse is applied on the T2, T3 and T4 bases. The pulse on the T6 collector is , also, applied to the circuit R3C2 which forms a narrow, fast fronts pulse. The transistors T1,T2,T3 and T4 constitute a fast static switch which generates on the capacitor C1 a 200ns pulse with a fall time ≤ 10ns and an amplitude U= 280V.. The pulse spectrum central frequency is fc= 17MHz. It excites the ultrasonic transducer used for thin wall metallic pipes. By inserting an adjustable inductance at the generator output, other types of transducers may be used with frequencies lower than 17MHz.

III. RESULTS AND DISCUSSIONS

The generator presented in fig. 6 has been implemented using a set of ten inductances connected to a ten positions switch. Each inductance is constructed winding a Φ=0,1mm copper conductor on a Φ=3mm ferrite core. By adjusting the output inductance, different high bandwidth pulses have been obtained , applied to different ultrasonic transducers characterized by different frequencies within 2-17MHz interval.

The same experimental pail described in &2 equipped with an adjustable transducer holder and a calibration block are used.

Assuming that the signal bandwidth is limited only by the pulse fall time, tf , the maximum frequency which can be obtained is [1]:

$$f_{max}=1/\pi \cdot t_f \qquad (6)$$

By adjusting the inductance in series with the load, the generator output impedance has been adapted to several types of ultrasonic transducers having working frequencies between 2MHz and 17MHz. The echo pulse amplitude has been measured by means of an oscilloscope and the series inductance corresponding to the maximum echo signal amplitude has been determined for every transducer. The measurement results for different ultrasonic transducers are given in table1.

Table 1: Correlation between output inductor and transducer frequency

L (μH)	1	3	5,5	8	10,5	13
f (MHz)	17	15	10	6	4	2

CONCLUSIONS

The bipolar transistor pulse generator may be easily adapted to different piezoceramic ultrasonic transducers having working frequencies within the 2-17MHz interval. Very good results have been obtained using a 17MHz spherically focalizes ultrasonic transducer. Compling the generator to a pulse amplifier, a steel pipe dimensions measuring system has been obtained; it used the echo-pulse amplitude damping in steel. The succesive pulse amplifier output signals are identical and have same amplitude; therefore we may conclude that the time interval between two succesive echo pulses received from the opposite side of the measured piece is thoroughly measured.The thickness of piece (d) is determined in terms of the sound velocity through the material (v) :

$$d=v \cdot t/2 \qquad (7)$$

ACKNOWLEDGMENTS

The work has been funded by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU 187/1.5/S/155536.

REFERENCES

[1] Efficient high voltage pulser for piezoelectric air coupled transducer - Linas Svilainis, Andrius Chaziachmetovas, Vytautas Dumbrava, Signal processing department, Kaunas University of Technology, Lithuania, ARTICLE in ULTRASONICS · JUNE 2012

[2] A.Arnau, Y.Jiménez, T.Sogorb, An extended Butterworth-Van Dyke model for quartz crystal microbalance applications in viscoelastic fluid media, IEEE transactions on ultrasonics, ferroelectrics, and frequency control 48 (2001) 1367.82.

[3] Data sheet, T.I.- www.alltransistors.com, 2015

[4] Automatic Dynamic Depth Focusing for NDT-Jorge Camacho, Jorge F. Cruza, Jose Brizuela, and Carlos Fritsch, Senior Member, IEEE-IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 61, no. 4, April 2014.

★★★