

Programmable virtually-zero-noise polarization voltage supply for condenser microphones

Tomasz Starecki*

Institute of Electronic Systems, Warsaw University of Technology,
Nowowiejska 15/19, 00-665 Warsaw, Poland

ABSTRACT

The paper describes a design of a +200 V polarization voltage supply for condenser microphones, dedicated for use in photoacoustic applications. Due to very low signal levels, typical for photoacoustic experiments, the design was optimized towards minimum electromagnetic and acoustic emission. In addition output voltage can be digitally adjusted in a relatively wide range.

Keywords: photoacoustic equipment, polarization voltage supply, condenser microphone, DC/DC converter

1. INTRODUCTION

Condenser microphones are used in many common applications like noise measurements, vibration testing, acoustics measurements of buildings, etc., but also in some more sophisticated applications e.g. in photoacoustics. The main advantages of condenser microphones are:¹

- high stability under various environmental conditions,
- flat frequency response over a wide frequency range,
- low distortion,
- very low internal noise,
- wide dynamic range (typically 140 dB),
- high sensitivity.

A very important feature is extremely low influence of aging effects, static pressure, temperature and humidity on characteristics of condenser microphones,² while in case of many other sensors such effects cannot be neglected.

2. PRINCIPLE OF OPERATION AND TYPICAL APPLICATION CIRCUIT OF CONDENSER MICROPHONE

Structure of a condenser microphone is shown at fig. 1.³ It can be easily noticed, that due to the insulator that separates contact pin from the housing, there is no electrical contact between the diaphragm and the backplate, which in result form a capacitor. In response to pressure changes, the diaphragm is moving and thus changing its distance from the backplate, which in turn results in capacitance variations. Capacitance variations can be converted into corresponding electrical signal in number of ways, but the most common approach is based on a constant electrical charge. It should be noted that there are other methods (e.g. use of bridge circuits powered from AC voltage, use of resonance circuits, etc.), but the one mentioned first seems to be the simplest, most stable and producing lowest inherent noise level. Main point of the constant electrical charge method is providing that the charge on the capacitor formed by the diaphragm and the backplate is held virtually constant, so that every variation of the capacitance will be reflected as a change of the voltage across the capacitor, due to:

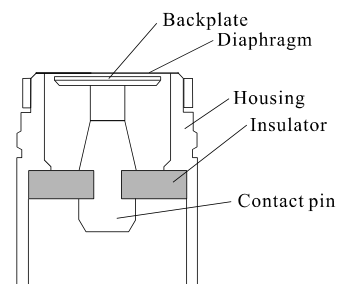


Fig. 1. Sketch of a condenser microphone.

*tomi@ise.pw.edu.pl

$$Q = U \times C \quad (1)$$

Typical circuit diagram of a microphone preamplifier based on a constant charge principle is illustrated at fig. 2, at which capacitance of the microphone is represented by the capacitor C. The microphone is charged from polarization voltage, which in the given example is +200 V, via resistor R₁. Value of this resistor must be high enough, so that corner frequency resulting from the R₁C time constant is significantly below operational bandwidth of the whole equipment. Taking into consideration that 1" condenser microphones have capacitances of approx. 50 pF, R₁ resistance is usually in the range of 1 to 20 Gohms. As working with signal sources of very high impedance is troublesome, the AC signal resulting from microphone capacitance variations, is fed into a voltage follower input. It is clear from eq. 1, that in order to maximize sensitivity of the circuit, polarization voltage should be as high as possible. Nominal polarization voltage for most of condenser microphones is set at +200 V. As forcing the follower to work at such voltage levels is not very comfortable, the follower is separated from this DC voltage by means of a capacitor C₁. Resistor R₂ sets working point of the follower. In order not to decrease significantly input impedance of the preamplifier, its value is usually similar to R₁.

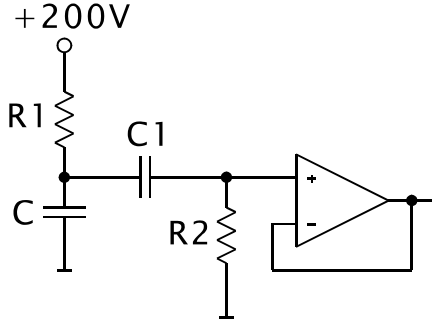


Fig. 2. Typical circuit diagram of a microphone preamplifier based on a constant charge principle.

Assuming constant charge of the capacitor results in:

$$Q = U_0 \times C_0 = (U_0 + u) \times (C_0 + c), \quad (2)$$

where:

- U₀ ! polarization voltage,
- u ! voltage change resulting from the diaphragm deflection,
- C₀ ! nominal capacitance of the microphone,
- c ! microphone capacitance change resulting from the diaphragm deflection,
- Q ! charge of the capacitor.

Taking into consideration that:

$$C = \frac{\varepsilon \times S}{D}, \quad (3)$$

where:

- g ! dielectric constant of the air,
- S ! area of the backplate/diaphragm forming capacitor,
- D ! distance between the backplate and the diaphragm,
- C ! capacitance of the microphone,

formula (2) can be converted into:

$$U_0 \times \frac{\varepsilon \times S}{D_0} = (U_0 + u) \times \frac{\varepsilon \times S}{(D_0 + d)} \quad (4)$$

which finally gives:

$$u = d \frac{U_0}{D_0}, \quad (5)$$

which clearly indicates, that in spite of nonlinear relationship between microphone capacitance and its voltage, change of microphone voltage *u* is proportional to the diaphragm deflection *d*.

3. DESIGN OF THE POLARIZATION VOLTAGE SUPPLY

Polarization voltage supply presented in the paper was optimized for photoacoustic applications. It should be noted, that the most important difference between typical and photoacoustic applications of condenser microphones is very low signal level. Assuming that average photoacoustic setup should be capable of signal detection at the level of $0.5 \mu\text{V}$, and that microphone sensitivity is 50 mV/Pa , means that the system detection level is set at 10^{-5} Pa (compared to atmospheric pressure of approx. 10^5 Pa), which corresponds to the diaphragm deflection of 10^{-14} m (in comparison to diameter of an electron of 10^{-15} m). The mentioned numbers indicate level of overall sensitivity of photoacoustic setups to any external influence, including electric, acoustic and electromagnetic noise, etc.

As the designed polarization voltage supply was to be also used in battery-powered equipment, it had to be a small size DC/DC converter, powered from a +4.8 V to +12 V battery. Due to the fact that after performing initial charge at powering the instrument on, microphone draws virtually no static current from the polarization voltage, output current capabilities didn't have to be greater than 1 mA. The only additional requirement was output voltage adjustment capability. The requirement resulted from the fact that frequency response of the microphone depends on the polarization voltage⁴ and that sensitivity of the microphone depends directly on the polarization voltage (see eq. 5), so that use of 240 V instead of nominal 200 V should increase sensitivity of the photoacoustic setup by approx. 20 percent.

For test purposes a standard DC/DC converter based on MAX 1523 was built. The supply was working fine, however some preliminary tests showed that despite from relatively high switching frequency, careful PCB design, shielding and filtering, sensitivity of the photoacoustic instrument was limited by acoustic and electromagnetic interferences produced by the DC/DC converter. A solution to the problem seemed to be using the DC/DC to produce the polarization voltage and initially charge the microphone, and then switching it off for the time of measurements. Certainly, switching off the converter will result in decrease of its output voltage due to discharge of the output capacitor. However, it should be noticed that the only discharge current in a circuit shown at fig. 2 can result from microphone and capacitor leakage currents, which are negligible. Hence the main discharge of the output capacitor is due to the internal circuit of the DC/DC converter. Limiting this internal discharge current to the value of 100 nA would result in the output voltage drop of 1 percent (which is a value that can be easily accepted in many applications) after 10 seconds, which in many applications is long enough to perform necessary measurements.

Circuit diagram of the improved version of the DC/DC converter is presented at fig. 1. MAX 1523 is powered from +5.0 V (+4.8 V) and works in a standard configuration, driving TN2404K MOSFET (Vishay, SOT-23, breakdown voltage:

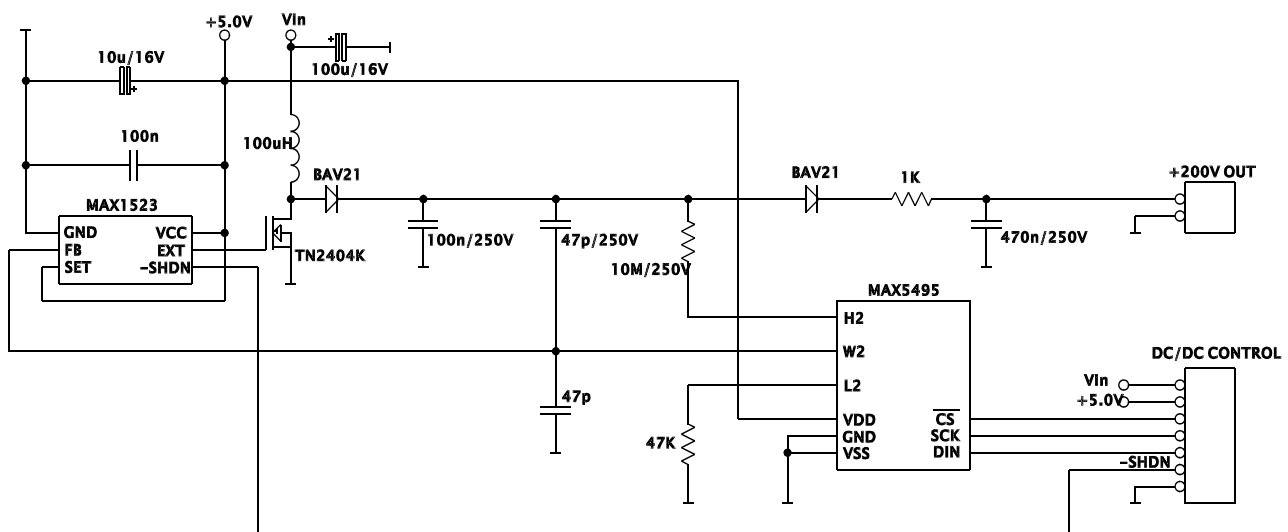


Fig. 1. Polarization voltage supply circuit diagram.

240 V). Diodes BAV 21 used in the circuit have maximum reverse voltage of 250 V (note that reverse voltage and maximum forward current of BAV 21 may vary in a relatively wide range depending on a manufacturer). Depending on application, V_{in} can be tied to VCC (+5 V) or can be connected to another (higher) voltage. In particular V_{in} can be powered from some unregulated voltage source in order to increase power efficiency of the circuit. MAX 5495 used in the feedback loop of the DC/DC controller is a digital potentiometer used for output voltage adjustment. The potentiometer has 10-bit resolution, that results in the output voltage adjustment step of approx. 0.1 V, and is programable via SPI interface. Wiper setting of the potentiometer can be stored in the internal non-volatile (EEPROM) memory of MAX 5495, so that it does not require reprogramming at every power-on sequence. Series resistor 1k Ω at the voltage supply output has double function - protects the circuit from being damaged by accidental output short-circuit, and together with the 470 nF capacitor forms a low-pass filter that cuts off some of the voltage noise at the voltage supply output. The circuit should be powered on with the shutdown feature of the MAX 1523 active, so that MAX 5495 is started up first. The second BAV 21 diode prevents the 470 nF capacitor from being discharged during MAX 1523 shutdown through its 10 Mohm feedback loop. Taking into consideration that typical reverse current of BAV 21 at room temperature and reverse voltage of 200 V is about 30 nA (maximum at these conditions is 100 nA),⁵ output voltage drop of 1 percent during MAX 1523 shutdown should take approx. 30 s, which is a very reasonable result. The time could be longer if a diode with lower reverse current is used. It should be mentioned that there are so-called "low-leakage diodes", that have extremely low reverse current levels. However, such diodes cannot be used in the described circuit, as they are rated for much lower reverse voltages.

4. RESULTS AND CONCLUSIONS

The circuit presented at fig. 1 was assembled on a 32.5 x 20 mm printed board. Taking into consideration that the circuit was relatively simple and preliminary checked, correct operation of the circuit in further tests wasn't surprising. Use of shutdown feature resulted in complete removal of acoustic and electromagnetic interferences from the DC/DC converter. Due to the digital potentiometer it was possible to precisely adjust output polarization voltage from about 140 V to over 240 V (as the switching transistor used in the circuit was rated for 240 V, the circuit wasn't tested at higher voltages).

Small size of the circuit, high quality, digitally adjusted output voltage, and shutdown feature resulting in no acoustic and electromagnetic emission, make the designed condenser microphone polarization voltage supply ideally suited for applications in photoacoustic measurements.

5. REFERENCES

1. *Lecture note: Measuring microphones*, pp. 19-26, Brüel & KjFr, NFrüm.
2. *Measurement microphones*, pp. 19-26, Brüel & KjFr, NFrüm, 1994.
3. *Microphone handbook: Theory*, ch. 2, Brüel & KjFr, NFrüm 1996.
4. *Microphone handbook: Theory*, ch. 3, Brüel & KjFr, NFrüm 1996.
5. *BAV21 Datasheet*, rev. C, Fairchild Semiconductor, 2001.