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## Low-BOM Microphone Interface Using the Analog Signal Conditioning (OPAMP) Peripheral

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### Introduction

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An electret microphone produces an audio output signal in the millivolt range. To interface an electret microphone with a microcontroller (MCU), it is necessary to amplify the signal up to the 100-millivolt range so that it can be detected by an analog comparator in the MCU or converted to a digital signal by the MCU's analog-to-digital converter (ADC). Conventionally, it has been necessary to add one or two operational amplifier (op amp) integrated circuits and several passive components to a hardware design to perform this amplification. An MCU containing the Analog Signal Conditioning (OPAMP) peripheral can be interfaced with an electret microphone using minimal external circuitry because the OPAMP peripheral is capable of linear amplification. In addition to the microphone, only one resistor and one capacitor are required. The OPAMP peripheral also provides the ability to adjust the gain under firmware control.

### Features

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- Electret Microphone Amplifier Using Microcontroller's Analog Signal Conditioning (OPAMP) Peripheral
- Adjustable Gain Under Firmware Control
- Low Bill of Materials – Only Two External Components Required in Addition to Microphone:
  - One resistor
  - One capacitor

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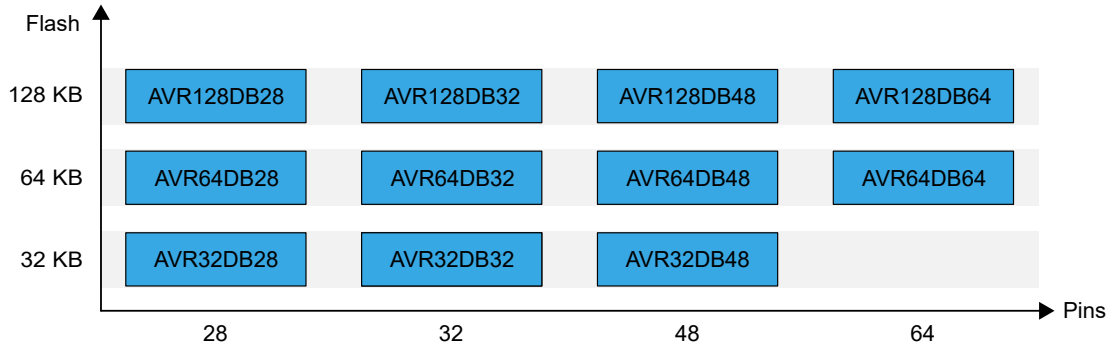
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## 1. Relevant Devices

This section lists the relevant devices for this document. The following figures show the different family devices, laying out pin count variants and memory sizes:

- Vertical migration upwards is possible without code modification, as these devices are pin-compatible and provide the same or more features
- Horizontal migration to the left reduces the pin count and, therefore, the available features
- Devices with different Flash memory sizes typically also have different SRAM and EEPROM

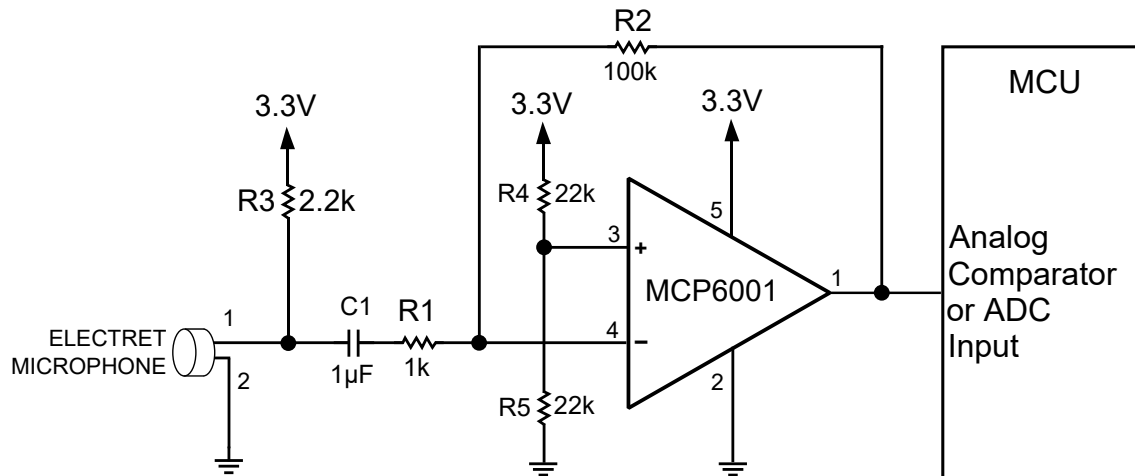
**Figure 1-1. AVR® DB Family Overview**



## 2. Conventional Electret Microphone Interface

To interface an electret microphone with a microcontroller (MCU), it has conventionally been necessary to use one or two op amp integrated circuits and some resistors to amplify the signal.

**Figure 2-1. Schematic Diagram of Conventional Microphone Interface**



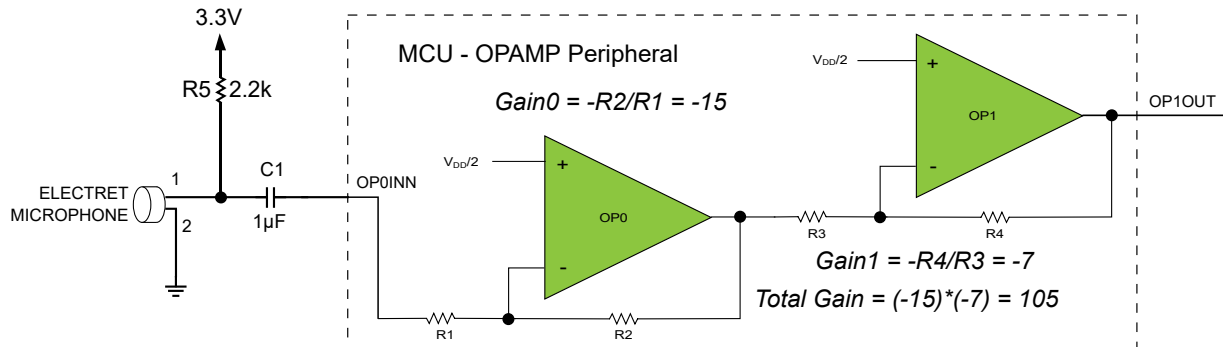
The schematic diagram of a conventional electret microphone interface is shown in the figure above. An electret microphone requires a pullup resistor to  $V_{DD}$  to bias it – this function is provided by resistor R3. The millivolt audio output signal appears at pin 1 of the electret microphone, but it is superimposed on a DC voltage. Capacitor C1 blocks the DC voltage from the rest of the circuit to prevent saturation, and the capacitor value is sized to allow audio frequencies to pass through it. The MCP6001 op amp is wired in an inverting amplifier configuration, with the gain determined by the ratio  $-R2/R1$ . A voltage divider consisting of R4 and R5 biases the non-inverting (+) input of the op amp at  $V_{DD}/2$ . This causes the amplified audio output at pin 1 of the op amp to be centered around a DC voltage of  $V_{DD}/2$ . This output is suitable for direct connection to either an analog comparator input or analog-to-digital converter (ADC) input of an MCU.

The conventional electret microphone interface has a few drawbacks. Not only does it require several passive and active components to be added to the hardware design, but it also does not provide a mechanism for the MCU to adjust the gain of the amplifier under firmware control.

### 3. Electret Microphone Interface Using OPAMP Peripheral

The microcontroller's (MCU's) OPAMP peripheral can be configured to linearly amplify millivolt-level signals. This capability can be used to greatly simplify the hardware interface with an electret microphone.

**Figure 3-1. Schematic Diagram of Microphone Interface Using OPAMP Peripheral**



The schematic diagram of the electret microphone interface with the MCU is shown in the figure above. Only two components are required in addition to the microphone and MCU: Resistor R5 for biasing the microphone, and capacitor C1 for blocking the DC voltage and allowing the audio signal to pass through. The remainder of the amplification circuit is provided by the OPAMP peripheral inside the MCU.

As shown in the schematic diagram, op amps OP0 and OP1 inside the MCU's OPAMP peripheral are configured as cascaded inverting amplifiers, using resistors that are also inside the OPAMP peripheral. The gain of the OP0 stage is determined by the ratio  $-R2/R1$ , and the gain of the OP1 stage is determined by the ratio  $-R4/R3$ . In the schematic, the first stage is shown with a gain of -15 and the second stage is shown with a gain of -7 for an overall gain of 105. Because the resistor ratios can be changed under firmware control, it is possible for the MCU to adjust the gain if needed. For example, in a high-noise environment, a gain of 105 might be too large, causing the output signal to saturate and distort. In this case, the gain of one or both op amps could be reduced as needed.

Depending on the requirements of the application, output pin OP1OUT can be connected via a circuit board trace to external circuitry, or it can be used as either an analog comparator input or an analog-to-digital converter (ADC) input on the same pin of the MCU.

## 4. OPAMP Configuration Code

Just a few lines of code are required to configure the OPAMP peripheral to implement the electret microphone amplifier in [Figure 3-1](#):

```
// Set up the timebase of the OPAMP peripheral
OPAMP.TIMEBASE = 3; // Number of CLK_PER cycles that equal one us, minus one (4-1=3)

//Make OP0 an inverting PGA with gain of -15
OPAMP.OP0INMUX = OPAMP_OP0INMUX_MUXPOS_VDDDIV2_gc | OPAMP_OP0INMUX_MUXNEG_WIP_gc;
OPAMP.OP0RESMUX = OPAMP_OP0RESMUX_MUXB0T_INN_gc | OPAMP_OP0RESMUX_MUXWIP_WIP7_gc |
OPAMP_OP0RESMUX_MUXTOP_OUT_gc;
// Configure OP0 Control A
OPAMP.OP0CTRLA = OPAMP_OP0CTRLA_OUTMODE_NORMAL_gc | OPAMP_ALWAYS_ON_bm;

//Make OP1 an inverting PGA with gain of -7
OPAMP.OP1INMUX = OPAMP_OP1INMUX_MUXPOS_VDDDIV2_gc | OPAMP_OP1INMUX_MUXNEG_WIP_gc;
OPAMP.OP1RESMUX = OPAMP_OP1RESMUX_MUXB0T_LINKOUT_gc | OPAMP_OP1RESMUX_MUXWIP_WIP6_gc |
OPAMP_OP1RESMUX_MUXTOP_OUT_gc;
// Configure OP1 Control A
OPAMP.OP1CTRLA = OPAMP_OP1CTRLA_OUTMODE_NORMAL_gc | OPAMP_ALWAYS_ON_bm;

// Enable the OPAMP peripheral
OPAMP.CTRLA = OPAMP_ENABLE_bm;
```

After this code has been executed, the op amps stay active, and no further CPU intervention is required.



[View Code Example on GitHub](#)  
Click to browse repository

**5. Revision History**

Doc. Rev.	Date	Comments
A	09/2020	Initial document release

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