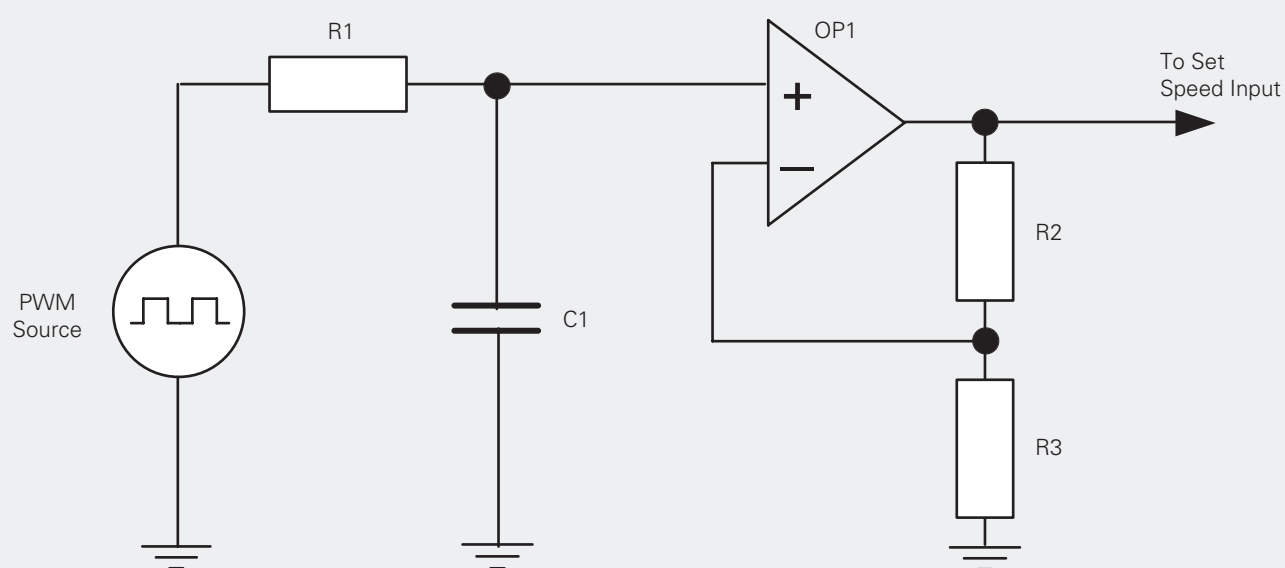


Application Note

PWM Signal to Analog Set Speed



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1. Introduction

Most Micronel blowers equipped with integrated driver electronics can be controlled by applying an analog voltage to the Set Speed pin. The input range is typically limited to 0 to 4 V_{DC}. However, in many applications, analog voltage sources may not be readily accessible. Fortunately, most consumer electronics incorporate a microcontroller or another device capable of outputting a digital PWM signal.

It is possible to convert the PWM signal to an analog voltage by incorporating an intermediate circuit in the form of an RC low-pass filter before connecting it to the blower's Set Speed input. A more comprehensive explanation of the RC-filter circuit can be found in chapter 2.1: 'PWM Signal with Passive RC Filter'. All subsequent solutions presented in this document are built upon the foundation of this RC filter. Table 1 displays the recommended values of R and C for various PWM input frequencies. The delay time (T_{Delay}) determines how fast the analog output voltage reacts to a change of the input duty cycle.

Input Frequency [Hz]	Capacitor Value [uF]	Resistor Value [Ohm]	T _{Delay} [ms]
1000	47.0	330	46.5
5000	10.0	330	9.9
10000	4.7	330	4.7
15000	4.7	220	3.1

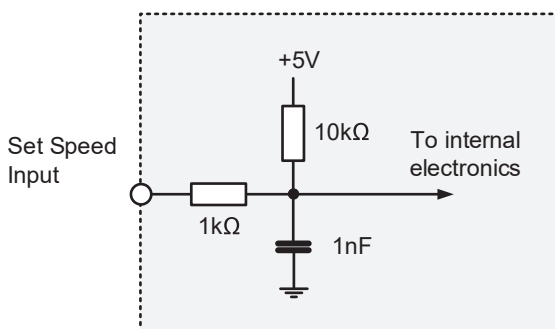
Table 1: Recommended RC Filter Values

1.1 Set Speed Input Circuit

In order to construct a reliable circuit for converting a PWM signal into an appropriate Set Speed voltage, it is essential to examine the Set Speed circuitry within Micronel blowers. There are two distinct circuits employed for the Set Speed input in Micronel blowers, which are illustrated in Figure 1. The type of internal pullup resistor at hand can impact the behavior of the subsequently described circuits. It thereby determines which of the presented solutions is appropriate to be implemented.

To identify which of the two pullup resistor circuits is used in a specific blower, you can consult to the product's datasheet.

Weak internal pullup resistor:



Strong internal pullup resistor:

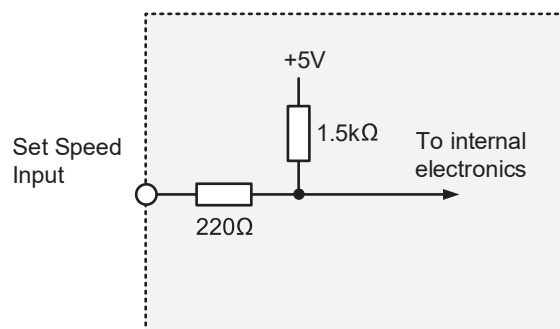


Figure 1: Internal Pullup Resistor Variations for Micronel Products

Note: The term 'weak' or 'strong' depends on the value of the pullup resistor. A 'weak' pullup resistor has a high resistance value and a 'strong' pullup resistor has a low resistance value.

2. Possible Solutions

The values in Table 1 have been used to verify the functionality and behavior of the circuits presented in the following chapters.

Any values that deviate from these recommendations must be evaluated and verified with a complete test setup by the customer themselves. A detailed explanation and an example on how to carry out the calculations can be found in chapter 3: 'RC-Filter Calculation Example'.

2.1 PWM Signal with Passive RC Filter

An RC lowpass filter, such as displayed in Figure 2, is an electrical circuit that allows low frequency signals to pass through while blocking high frequency signals. With the right setup, this can be utilized to convert an AC-Voltage (such as a PWM signal) to a DC-Voltage. The filter consists of a resistor (R1) and a capacitor (C1) connected in series. It is one of the simplest approaches to convert a PWM signal to an analog voltage in proportion to its duty cycle. The recommended values for the components can be found in Table 1.

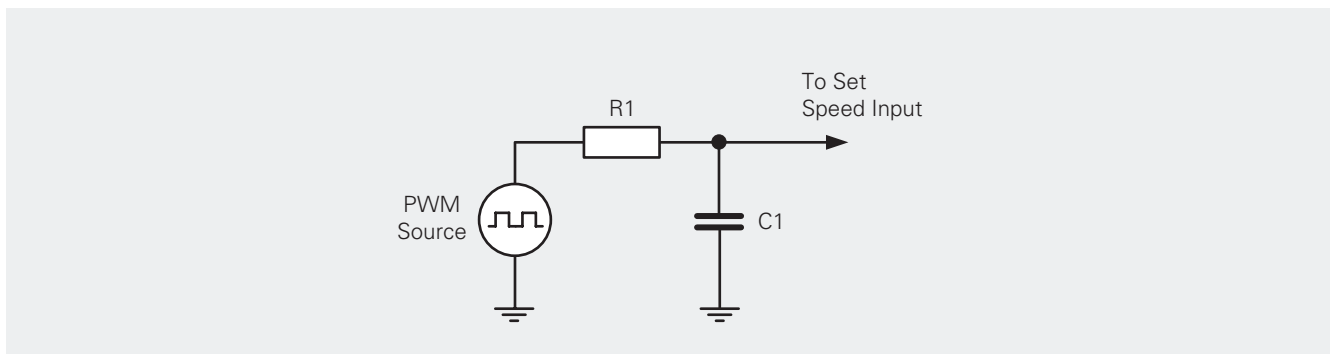


Figure 2: RC filter

Note: While the RC filter is simple and works well under no-load conditions, it can also show problematic behavior under load. If R1 is chosen to be larger than 500 Ω , the output of the RC filter becomes significantly influenced by the internal pullup resistor of the blower's Set Speed input. This is especially the case, if the Micronel blower has a Set Speed input with a strong pullup resistor. At the same time, a low value for R1 will put a larger strain on the PWM source. This may cause the PWM voltage to drop and consequently decreases the generated Set Speed voltage. To counter these phenomena, it is recommended to decouple the RC filter from the Set Speed input by adding an operation amplifier circuit in between (See chapter 2.2 or 2.3).

Moreover, the passive RC filter lacks the ability to increase its output voltage beyond the level set by the PWM source. Therefore, if the PWM source has a voltage level of $3.3 V_{DC}$, then the maximum analog output level of the passive RC filter will also be limited to a maximum $3.3 V_{DC}$. As a result, a blower with a $0-4.0 V_{DC}$ analog input will not be able to reach its maximum speed. On the other hand, if the PWM source has a high voltage level of $5.0 V_{DC}$, the analog output voltage already reaches $4.0 V_{DC}$ at a duty cycle of 80%. Increasing the duty cycle beyond 80% will increase the analog output voltage, but it will not result in higher blower speed.

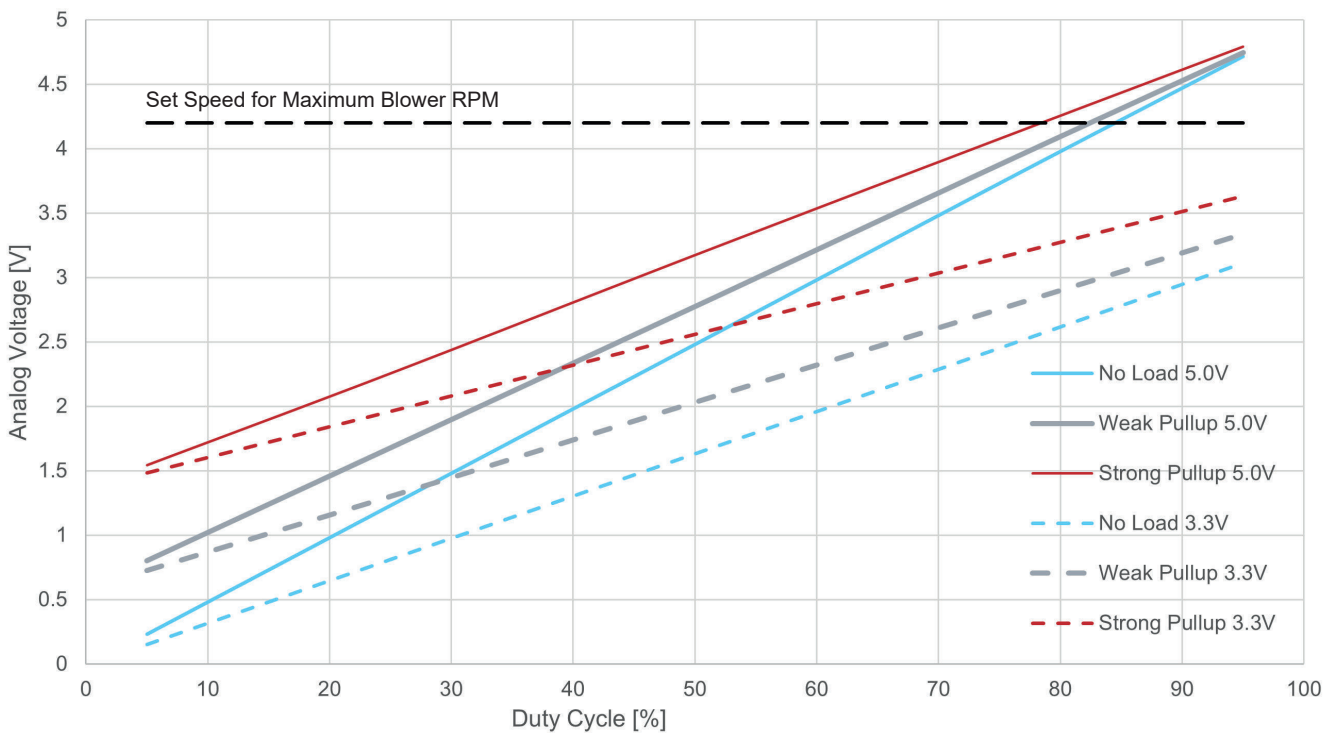


Figure 3: Behavior of the RC Filter for a 3.3 V_{DC} and 5.0 V_{DC} Square Wave PWM Input Signal

2.2 5 V_{DC} PWM Signal With RC Filter and Operational Amplifier

The circuit in Figure 4 employs an operation amplifier (OPAMP) to form an impedance converter between the RC filter and the internal pullup resistor of the Set Speed input. This allows the filter to be decoupled from the blower input and solves the issues presented in chapter 2.1: ‘PWM Signal with Passive RC Filter’. The recommended components can be found in Table 2, and the circuit’s behavior is visualized in Figure 5.

Note: A duty cycle above 80% will cause the output voltage of this circuit to exceed 4.0 V_{DC}. The Set Speed input is capped at 4.0 V_{DC} for 100% blower speed. Higher Set Speed voltages will not increase the blower’s speed any further.

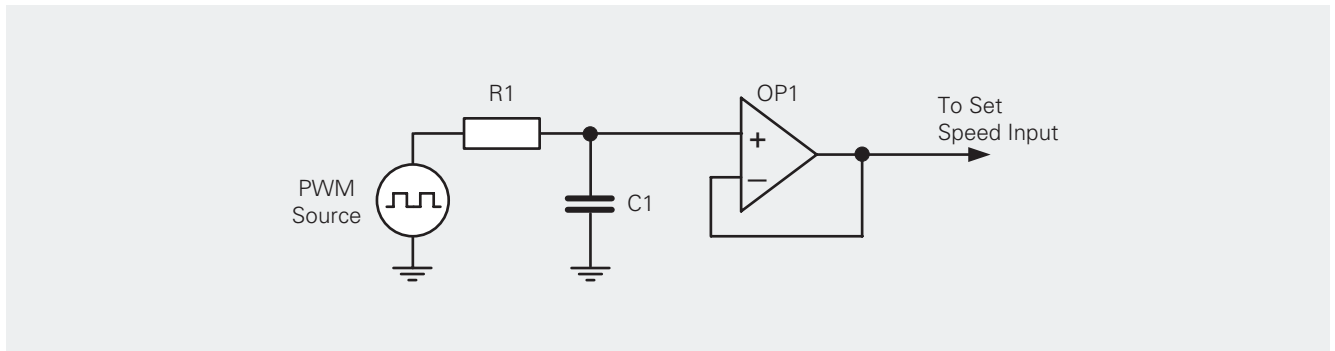


Figure 4: RC-Filter With Impedance Converter

Component	Value / Type
OP1	Operational amplifier e.g. MCP6001 (Rail-to-Rail type, supply voltage 5.0 – 6.0 V _{DC})
R1 / C1	Low pass filter according to Table 1: Recommended RC Filter Values’

Table 2: Component Values for Impedance Converter OPAMP Solution

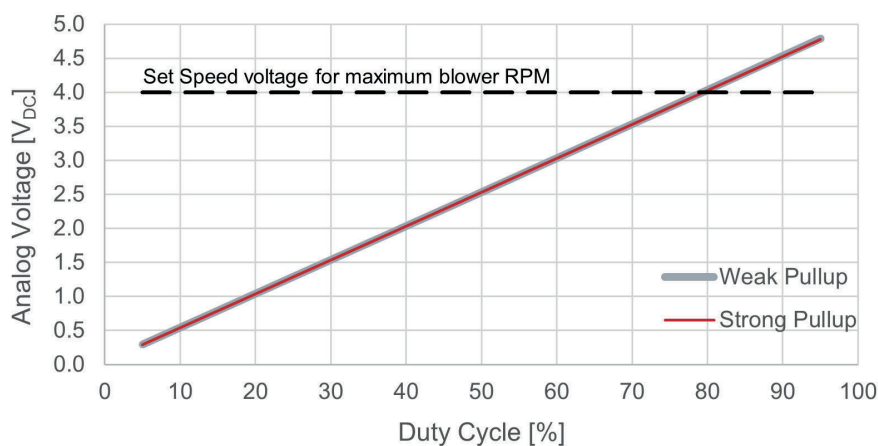


Figure 5: Behavior of the RC Filter With Impedance Converter for a 5 V_{DC} Square Wave PWM Input Signal

2.3 3.3 V_{DC} PWM Signal With RC Filter and Operational Amplifier

In addition to decoupling the RC filter from the Set Speed input like the impedance converter in chapter 2.2: ‘5 V_{DC} PWM Signal With RC Filter and Operational Amplifier’, the non-inverting operational amplifier circuit in Figure 6 allows the output voltage to be scaled depending on the values of R2 and R3. With the component values listed in Table 3, this circuit is designed to scale a 3.3 V_{DC} PWM signal to a 0 ... 4.4 V_{DC} analog voltage. The behavior of the circuit is visualized in Figure 7.

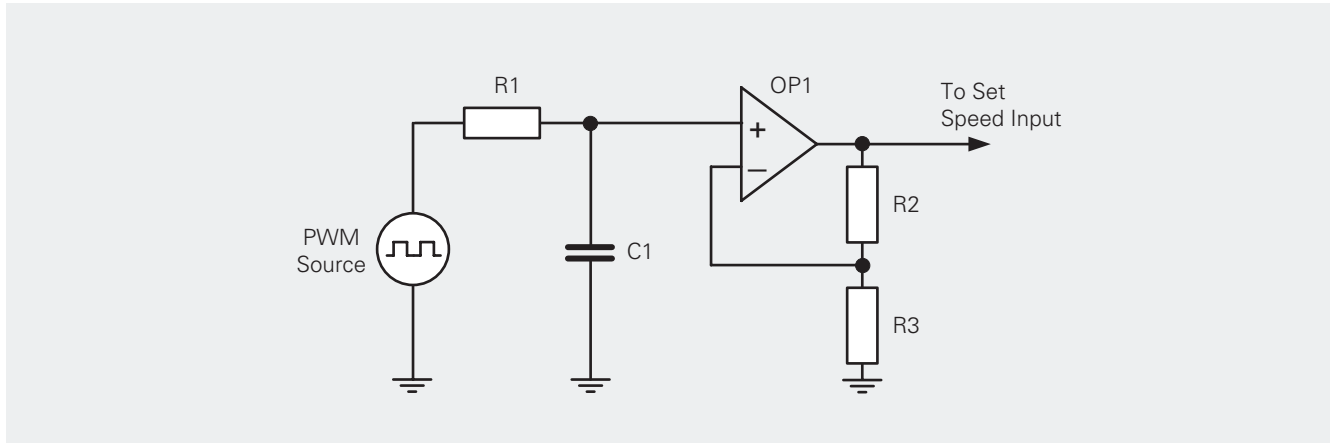


Figure 6: RC-Filter With Non-Inverting Operational Amplifier

Component	Value / Type
OP1	Operational amplifier e.g. MCP6001 (Rail-to-Rail type, supply voltage 5.0 – 6.0 V _{DC})
R1 / C1	Low pass filter according to Table 1: Recommended RC Filter Values'
R2	1.2 kΩ
R3	3.6 kΩ

Table 3: Component Values for Non-Inverting OPAMP Solution

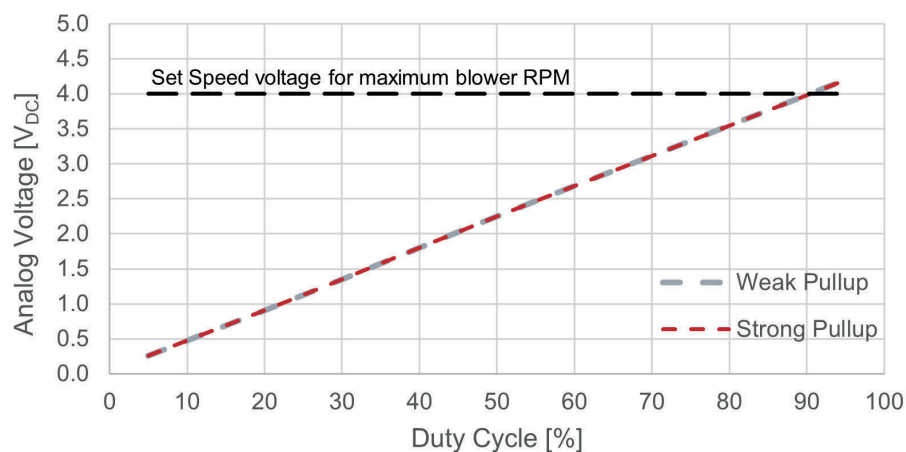


Figure 7: Behavior of the RC Filter With Non-Inverting OPAMP for a 3.3 V_{DC} Square Wave PWM Input Signal

3. RC-Filter Calculation Example

The dimensioning of an RC filter is based on the formula for its cutoff frequency, which calculates to:

$$f_c = \frac{1}{2\pi \cdot R \cdot C}$$

If there are no clear conditions for any of the components, the dimensioning starts with the capacitor as the choice of the capacitor is usually more restrictive than the choice of the resistor. The usage of X7R types is preferred, due to their availability, wide ranges of values and good temperature behavior. As the capacity of a capacitor changes with the applied voltage, it is also recommended to use a capacitor with a minimum nominal voltage of 16 V_{DC} for this application. A convenient value would be $C = 4.70 \mu F$.

For a square wave input signal of 10 kHz, we recommend the cutoff frequency of the filter to be at $f_c = 100 \text{ Hz}$. Choosing the cutoff frequency to be notably higher than input frequency divided by 100 may cause fluctuations in the output signal of the filter.

With the above chosen values for f_c and C , the required resistor value can be calculated as following:

$$R = \frac{1}{2\pi \cdot f_c \cdot C} = 338.6 \Omega$$

The calculated resistor value usually does not fit with components available on the market, which are divided into defined increments. To keep things simple, we can choose the next closest resistor-value of the very common E24 resistor line, which would be 330 Ohm. With this value we arrive at a final cutoff frequency of

$$f_c = \frac{1}{2\pi \cdot R \cdot C} = \frac{1}{2\pi \cdot 330\Omega \cdot 4.7\mu F} = 102.6 \text{ Hz}$$

Depending on the values of R and C , the filter will need a certain amount of time to reach a stable output voltage. This is expressed through the time constant τ , which is calculated as following:

$$\tau = R \cdot C$$

The filter can be expected to reach approximately 95% of its stable output voltage value within $3 \cdot \tau$ (this corresponds to T_{Delay} from the chapter's introduction). For the above calculated filter, this results in:

$$3 \cdot \tau = T_{\text{Delay}} = 3 \cdot 330\Omega \cdot 4.7\mu F = 4.7 \text{ msec}$$

A few example values for RC filters can be found in the table below. All values are aimed at receiving resistor values below 500 Ohm so they can be expected to work with weak and strong pullup resistors at the Set Speed input. Depending on the internal pullup resistor of the blower, the accuracy of the filtered signal will vary. If higher resistor values are desired for the filter, the value of C must be decreased and vice-versa.

Square-Wave Input Frequency [Hz]	RC Filter Cut-Off Frequency [Hz]	Capacitor Value [uF]	Calculated Resistor Value [Ohm]	E24 Resistor Value [Ohm]	Real Cut-Off Frequency [Hz]	T _{Delay} (3 · τ) [ms]
1000	10	47	339	330	10.3	46.5
5000	50	10	318	330	48.2	9.9
10000	100	4.7	339	330	102.6	4.7
15000	150	4.7	226	220	153.9	3.1

Table 4: Resulting Values for the RC-Filter Calculation Example

Revision Table

Revision	Date	Name	Remarks
01	23.06.2023	BA / KE	Creation of document

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