Ultra-low output noise: ~50µVrms with DC – 100kHz large signal bandwidth; ~20µVrms with DC – 500Hz using the supplied load capacitor box

- High voltage: 20.0x precision amplification up to +175V and -175V output voltage with respect to ground
- Short-circuit protected output with 275mA output current capability
- No overshoot with capacitive loads: bandwidth changes automatically to ensure stability
- 2 inputs: a standard BNC connector, and a differential connector to reject interference (mating connector supplied)
- BNC monitor out connector provides 1:100 replica of the output signal

About this manual

This user manual is an integral part of the Falco Systems WMA-200 high voltage amplifier product. Please read it carefully and pay attention to the recommendations and instructions for safe use.

The WMA-200 high voltage amplifier: getting started

The Falco Systems WMA-200 model is a high quality, high voltage, linear laboratory amplifier optimized for experiments requiring world-class, ultra-low output noise. The excellent noise performance, combined with the wide bandwidth and large voltage range make this amplifier the preferred choice for the most demanding precision positioning systems. The amplifier will routinely enable sub-atomic positioning resolution with piezo positioning systems and MEMS devices, and is the ultimate ultra low noise driver for EO-modulators, (particle) beam steering, ultrasonics, dielectric studies, and many other loads requiring a high voltage drive.

The output noise level of the high voltage amplifier is only ~50µVrms with its standard large signal bandwidth of DC – 100kHz. For even lower noise in experiments where this large bandwidth is not required, a capacitor load box is supplied with the amplifier. It cuts the bandwidth to DC – 500Hz, at the same time reducing the output noise level to an unprecedented ~20µVrms. Keep input and output cables as short as possible to prevent picking up interference from the surroundings. For
more information on how to connect the amplifier for the lowest possible noise level, please read the 'Noise' section later in this manual.

The WMA-200 high voltage amplifier is designed to be fully stable and free of spurious signals with any capacitive load. The amplification is a precise 20.0x (fixed, defined by 0.1% precision resistors). The amplifier has an output range of −175V to +175V, a large signal bandwidth of 100kHz @ -3dB, and a slew rate of 80V/µs. The short-circuit protection with a fast current limit of ±275mA make this amplifier suitable for both normal daily laboratory use and for implementing automated measurement systems.

Recommendations:
- Never apply more than +15V (or less than -15V) to the amplifier input to prevent damage.
- Do not connect separate signal sources to both the BNC and differential inputs simultaneously, as the signal sources are be connected together inside the amplifier.
- A short voltage spike may appear at the output, when the amplifier is turned on or off. Pay attention not to damage sensitive circuitry or equipment already connected.
- The amplifier cannot be damaged by a short-circuit condition or capacitive loading, but two situations should be avoided:
  ● Connecting a charged capacitor to the input or output.
  ● Connecting a highly inductive load to the output (such as a coil).
- Do not connect anything to the output that can act as an antenna.
- This product should only be cleaned with a soft, slightly moist cloth. Unplug the WMA-200 amplifier from the mains power before cleaning.

Safety

- This product is able to produce over 175V at more than 275mA at its output, which is a very high level (risk of electric shock). Safety measures should be taken accordingly. This is indicated by the sign ⚠ above the output connector of the amplifier.
- This product is a Class I appliance which requires a mains connection with protective earth.

- Always position the WMA-200 amplifier such that the on/off power switch is easily accessible.
- The airflow to and from the WMA-200 amplifier should not be blocked or impeded, at the front, sides and the back.
- The internal circuitry of the amplifier operates at high voltage. Only qualified personnel from Falco Systems should service this amplifier.
- Only replace fuses with the correct type:
  ● 230V version of the WMA-200: 250V 800mA 5x20mm slow blow.
  ● 115V version of the WMA-200: 250V 1.6A 5x20mm slow blow.
- The Falco Systems WMA-200 amplifier is only suitable for indoor use in a class II environment (domestic, light industrial).
- Non-sinusoidal mains power generators cannot be used to power this product.

Detailed properties of the WMA-200 high voltage amplifier

Inputs

Two inputs are available on the WMA-200 front panel: a standard BNC input for easy interfacing to existing setups, and a differential connector (TE Connectivity T01-0560-S03) to reject interference. Such interference is almost always present on the incoming cable, picked up from the environment external to the amplifier. A mating cable connector for the differential input (TE Connectivity T01-0550-S03) is supplied with the amplifier.

The input impedance of both inputs of the WMA-200 high voltage amplifier is defined by a 1kΩ resistor to ground, in parallel with 100pF to prevent electrostatic discharge (ESD) input damage. These resistors add some noise to the output voltage unless a low-impedance source (e.g. the output of a preamplifier) is connected to the input. The noise will be slightly higher when the amplifier input is left open.

The 1kΩ resistors will form a voltage divider with the output resistance of the signal source which is used to drive the WMA-200. If this impedance is very low, no change in gain will be observable, but if this source has e.g. a (commonly encountered) 50Ω output resistance, the apparent gain will change from 20x to a lower but very well-defined 19.05x due to this voltage divider effect.
The 1kΩ resistors also add to the output offset voltage because the offset current of the input amplifier generates a voltage over these resistors. This output offset voltage is ~3mV if the BNC input is used with a 50Ω signal generator. When both inputs are shorted together or connected to a low-impedance source, the offset is reduced to ~700 µV.

Using the BNC connector, the amplifier will amplify 20.0x, up to the maximum output voltage. To obtain the lowest possible noise performance possible, it is highly recommended to use the differential input instead of the BNC. For this purpose, a mating connector is supplied with the amplifier. The BNC input is internally connected to the positive input of the differential connector (see Fig 1 for the connections). The negative input of the differential connector should be supplied with the same input signal as the positive input, but this signal should have the opposite polarity. Both of the differential inputs amplify 20.0x, which means that the absolute amplitude of either input should be only half of the value that would be used to drive the BNC input.

![Figure 1. Signals to be supplied to the BNC and differential connector](image)

A low noise amplifier like the WMA-200 model can never be made fully insensitive to input overload conditions, as this would limit the performance of the amplifier significantly. For normal operation, input voltages should remain in the –8.75V to +8.75V range when using the BNC input, and half this value when using the differential connector. This will result, with an amplification of 20.0x, in an output voltage swing of –175V to +175V. Below -15V and above +15V, the input protection circuitry will limit the voltage fed to the amplifier, but the amplifier (or the signal source) may be permanently damaged if the current of the source is not limited.

**Outputs**

The WMA-200 model has a 50Ω output resistance, and has been designed to be fully stable with all capacitive loads. It has been optimized for a perfect step-response, but it is also a very good linear and sine-wave amplifier. The WMA-200 amplifier has a clever feedback system, which ensures that no significant overshoot occurs at any capacitive load. The bandwidth of the amplifier is automatically reduced to ensure stability. Instability under capacitive loading conditions is a common problem of other high-speed negative feedback amplifiers, often resulting in unwanted output overshoot voltages, and, in extreme cases, oscillations. Short-circuiting this amplifier will not break down the amplifier, due to the extremely fast current limiting circuit that has been employed. A monitor out signal is available on a separate BNC connector, which provides a 1:100 replica of the output signal as seen by the load.
Cabling

The WMA-200 high voltage amplifier has been designed for use in the most demanding low noise experiments. As such, the noise generated by the amplifier is so low, that the actual performance of the set-up in which it is used can easily be dominated by interference picked up from the surroundings. For optimal performance use the differential input, with a high quality differential cable such as STP (shielded twisted pair), and keep the cable as short as possible. As the output connector is a single-ended BNC, all interference picked up by the output cable will be directly appear across the connected load. The noise performance of the amplifier has been assessed with the inputs shorted, and the output of the amplifier connected with a direct coaxial connection to a low-noise oscilloscope front end. Fig. 2 shows the arrangement. Even a 10 centimetre output cable increases the attainable noise level by a few microvolts in a typical setup due to interference pick-up. But this may not be a problem in many applications; the performance is still excellent by conventional standards when a longer coaxial cable is used. It is recommended not to make a ground connection to the load in any other way than via the WMA-200 amplifier output connector ground, to prevent ground loops. The optimal arrangement of connections is given in Fig. 3.

Noise

The noise of the amplifier is lowest when a low-impedance source is used, because then the 1kΩ input resistors cannot contribute to the overall noise level. Such a source is e.g. a pre-amplifier output or a 50Ω function generator output. To assess the noise performance of the amplifier without picking up interference, connect the two input pins of the differential
connector together while leaving the ground pin in the middle open (Fig. 2). The output noise will be lowered further when the bandwidth of the amplifier is reduced, which happens when a significant capacitive load is connected to the output. This will happen automatically when a high-capacitance piezo is connected to the output. For all other cases, a shielded 1uF load capacitor box is supplied with the amplifier, which is connected parallel to the load (Fig 4). This will bring the noise down from its value of ~50\(\mu\)Vrms (with a DC - 100kHz bandwidth) to only ~20\(\mu\)Vrms (with a DC – 500Hz bandwidth). If used, always connect the capacitor box directly next to the load, so that the box also filters away the interference picked up by the output cable before this interference reaches the load. For a comprehensive treatment on the subject of noise and interference, the reader is referred to the Falco Systems application note 'High voltage amplifiers: so you think you have noise!', online at www.falco-systems.com.

![Image of capacitor box](image_url)

Figure 4. When the bandwidth- and noise reducing capacitor box is connected to the load, the noise reduces to ~20\(\mu\)Vrms, while the bandwidth is simultaneously reduced to DC – 500Hz.

**The load**

The output impedance of the WMA-200 model is 50\(\Omega\), to ensure stability with all capacitive loads. The amplifier is generally used for high-impedance applications where the load is capacitive. This is the case for MEMS devices, EO-modulators and piezo’s alike. It should be noted that a coaxial cable itself also presents a capacitive load of approximately 100pF/m.

Matched loading with a 50\(\Omega\) load circuit is possible by connecting a 50\(\Omega\) resistor in series with the output to ground, but is not recommended. The advantage is that excessively long cables will not distort the waveforms. The disadvantage is a highly reduced voltage range (275mA in 50\(\Omega\) gives 13.75V maximum instead of 175V maximum).

With sensitive and/or high-frequency measurements, coaxial or shielded twisted pair (STP) cable should be used for the input, and a coaxial cable for the output. The length of the cables should be minimized. Otherwise the cables will cause overshoot due to cable reflections (an effect related to the finite speed of light), and current limiting due to the cable capacitance. Although the amplifier itself remains fully stable, using less than 3 meter of input and output cable is recommended for the WMA-200 amplifier to obtain optimal results without cable reflections, even if obtaining the lowest possible noise performance is not required.

**Transmitter mode**

This amplifier can generate a significant amount of power at frequencies used for radio transmission and reception. The amplifier should not be used for telecommunication as described in the R&TTE directive 95/5/EC. Also for this reason always use coaxial cables.

**Amplifier characteristics**

In the following pages, several amplifier characteristics are illustrated:
- Frequency response as a function of capacitive load (Fig. 5, 6)
- Rms output noise voltage versus capacitive load (Fig. 7)
- Noise and offset without capacitor box (Fig. 8)
- Noise and offset with capacitor box (Fig. 9)
- Noise spectrum with and without capacitor box (Fig. 10)

- Sine and triangle wave responses (Fig. 11, 12)
- Square wave response (Fig. 13, 14, 15)
- Step response (Fig. 16)
- Capacitive load dependency of square wave output (Fig. 17)

Figure 5. Frequency response at 300V\textsubscript{pp} output voltage with different capacitive loads

Figure 6. Frequency response at 1V\textsubscript{pp} output voltage with different capacitive loads
Figure 7. Rms output noise voltage versus capacitive load

Figure 8. Noise without output loading, and with the 1µF capacitor box connected, plus typical offset. The noise, as measured with a true rms voltmeter in a 1MHz bandwidth, is 48µV_{rms} with no load, and 18µV_{rms} with the 1µF load connected. The corresponding signal bandwidths of the amplifier are DC – 100kHz and DC – 500Hz. The noise and offset may appear to be slightly higher than shown here if the amplifier input is not differentially connected to a low-impedance source.

Figure 9. Sine wave 300V_{pp} 1kHz
Figure 10. Triangle wave 300V_{pp} 1kHz

Figure 11. Square wave 300V_{pp} 1kHz

Figure 12. Square wave 300V_{pp} 20kHz
Figure 13. Square wave $1V_{pp}$ 20kHz (small signal response)

Figure 14a. $300V_{pp}$ step response 10-90%: up in 4.4µs

Figure 14b. $300V_{pp}$ step response 10-90%: down in 4.2µs
Figure 14c. 0 to 150V step response 10-90%: up in 3.5µs

Figure 14d. 150 - 0V step response 10-90%: down in 3.8µs

Figure 14. Unipolar and bipolar step response

Figure 15a. 0pF load
Figure 15. 300V_{pp} square wave response under different capacitive loading conditions. The 275mA current limit limits the speed at which the capacitor can be charged. The bandwidth adjustments of the amplifier with different capacitive loads preventing overshoot are clearly visible. Note the difference of the horizontal timescale in the figures.
Technical specifications

**Amplification: precision 20.0x, fixed**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tr>
<td>Bandwidth: DC – 100kHz @ -3dB large signal bandwidth</td>
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<tr>
<td>Noise and offset: 50μVrms output noise typical without capacitor box, 20μVrms with capacitor box connected to the output, 700μV offset typical</td>
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<tr>
<td>Output voltage: -175V to +175V</td>
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<tr>
<td>Current: 275mA typical with limiter</td>
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<tr>
<td>Slew rate: 80V/μs typical</td>
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<tr>
<td>Input impedance: 1kΩ // 100pF</td>
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<tr>
<td>Output impedance: 50Ω</td>
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<tr>
<td>Stability: stable with all capacitive and resistive loads, no overshoot &gt; 5%</td>
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<td>Power: 230V 50Hz AC, 140W or 115V 60 Hz AC, 140W</td>
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<td>Mains fuse: 2x 800mA 250V slow blow (230V version) or 2x 1.6A 250V slow blow (115V version)</td>
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<td>Safety: Class I - requires mains power connector with protective earth</td>
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<tr>
<td>Specifications may be subject to change</td>
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Harmonized standards

This product complies with the following standards:

Safety: EN61010-1
EMC: EN61326
FCC: 47 CFR 15

WEEE and RoHS

Do not dispose of the WMA-200 amplifier as standard waste, but bring it to a WEEE electronic waste collection point. The amplifier has been built in compliance with the RoHS directive.

Warranty

Falco Systems products are guaranteed against malfunction due to defects in materials or workmanship for a period of 1 year from the date of shipment.

If a malfunction occurs during this period, the product will be repaired or replaced without charge. The product will be returned to the customer prepaid. The warranty does not apply to:
- Exterior finish or appearance
- Malfunction resulting from use or operation of the product in other ways than specified in the user manual
- Malfunctioning due to misuse or abuse of the product
- Malfunctioning occurring after changes or repairs have been made by anyone other than Falco Systems.

To obtain warranty service, the customer has to inform Falco Systems first via info@falco-systems.com to receive further instructions.

Falco Systems will not be liable for any consequential damages, including, without limitation, devices or equipment connected to the product, injury to persons or property or loss of use. See for more details the Falco Systems Standard Terms and Conditions of Sale, which can also be obtained via info@falco-systems.com.