Is it worth purchasing a capacitive-feedback amplifier?
Advantages and Trade Offs

The higher the resistance of the feedback resistor in an IV converter the lower the noise. When driving this statement to the limit, one comes up with an infinity resistance, having just a capacitor as a feedback element. This approach has been taken in the design of the capacitive-feedback current to voltage converter (CIV) also known as an "integrating heastage". Indeed, the capacitor feedback design has important advantages over the conventional resistor-feedback IV converter that **can** result in "better" recordings. Although we honor the development of the CIV, we would like to focus on the little word "can".

In the AXON GUIDE, Chapter 3 an important statement can be found regarding the noise performance/benefit of a capacitive-feedback design.

The lower noise of the CIV can be realized only in situations where all other noise sources are minimized. That is, the experimenter should use a low-noise glass[1] and pipette holder[2], Sylgard coating, and a high-resistance seal[3]. By carefully removing other sources of noise, the reduced noise of the CIV can be realized in real patches, not just in theory.

[1]) means using e.g. Quartz-glass pipettes
[2]) a design of a low noise pipette holder with a capacitance of 0.52 pF is given by Benndorf (1993)
[3]) larger than 100 GOhm might become desirable in order to keep this noise source at negligible levels (see Benndorf in Chapter 5 of Single-Channel Recording)

Details of all the precautions and requirements for low-noise recordings are summarized by Benndorf in chapter 5 of the book Single-Channel Recording.

In case you are planning to use borosilicate glass for your recordings, then your measurements will not benefit by using a capacitive-feedback amplifier. The noise introduced by the pipette and holder predominates the noise of the amplifier as pointed out by Sigworth in chapter 4 of the book Single-Channel Recording...*In recordings using a conventional borosilicate-glass pipette the spectral density caused by the pipette and other sources is considerably larger than the EPC 7[4] noise.*

[4]) same applies for EPC 8, EPC 9 and EPC 10 patch clamp amplifiers

Another point is that ... *The advantage of the capacitor-feedback amplifier is seen greatest at low frequencies, ... but at frequencies above 10 kHz the disparity between resistor and capacitor-feedback amplifier becomes smaller as the amplifier's e_nC_t noise predominates.* (from Sigworth, chapter 4 of Single-Channel Recording)

In summary, revealing the advantages of an capacitive-feedback amplifier in a real patch recording requires the use of low-noise glass pipettes and low-noise pipette holders. And even then, the advantages are most prominent at small bandwidths below 10 kHz.

Many laboratories, however, lack the equipment such as a laser-based pipette puller for fabrication of quartz-glass micropipettes and special pipette holders or do not intend to spend all the additional effort required to take advantage of the capacitive-feedback amplifier.

Although many laboratories will not benefit by the capacitive-feedback amplifier, they tend to purchase it because of this feature. This is the point that we are not understanding.

At this point, please consider the trade offs you will be making by purchasing a capacitive-feedback amplifier.

With respect to noise:
E.g. the Axopatch 200B lacks a 50 GOhm feedback resistor for low noise whole-cell recordings. The noise of the Axopatch 200B in the 500 MOhm range is up to 20% larger than that of the EPC 10 Patch Clamp Amplifier at comparable bandwidth.

Other features:
The fully computer controlled, self-calibrating patch clamp amplifier EPC 10 features the highest degree of data integrity and gives the experimenter the most flexibility. Standardization and automation of the experimental protocol is fully supported due to complete software control of the entire amplifier and all its settings. Please refer to our brochures "EPC 10 Patch Clamp Amplifier" and "PATCHMASTER Software" as well as our manuals and tutorials for a detailed description of the feature of the HEKA patch clamp system.

References

Benndorf, K., 1993, Multiple levels of native cardiac Na^+ channels at elevated temperature measured with high-bandwidth/low noise patch clamp. Pflügers Arch. **422**:506-515.

Benndorf, K., Low-Noise Recording, in *Single-Channel Recording*, 2nd Edition, Edited by Bert Sackmann and Erwin Neher*, Plenum Press*, 1995

Sigworth, F., Design of the Patch Clamp, in *Single-Channel Recording*, 2nd Edition, Edited by Bert Sackmann and Erwin Neher*,* Plenum Press, 1995

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