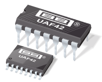


 SBFS002B – JULY 1992 – REVISED OCTOBER 2010

UNIVERSAL ACTIVE FILTER

Check for Samples: UAF42

FEATURES

- **VERSATILE:**
  - **Low-Pass, High-Pass**
  - **Band-Pass, Band-Reject**
- **SIMPLE DESIGN PROCEDURE**
- **ACCURATE FREQUENCY AND Q:**
  - **Includes On-Chip 1000pF ±0.5% Capacitors**

APPLICATIONS

- **TEST EQUIPMENT**
- **COMMUNICATIONS EQUIPMENT**
- **MEDICAL INSTRUMENTATION**
- **DATA ACQUISITION SYSTEMS**
- **MONOLITHIC REPLACEMENT FOR UAF41**

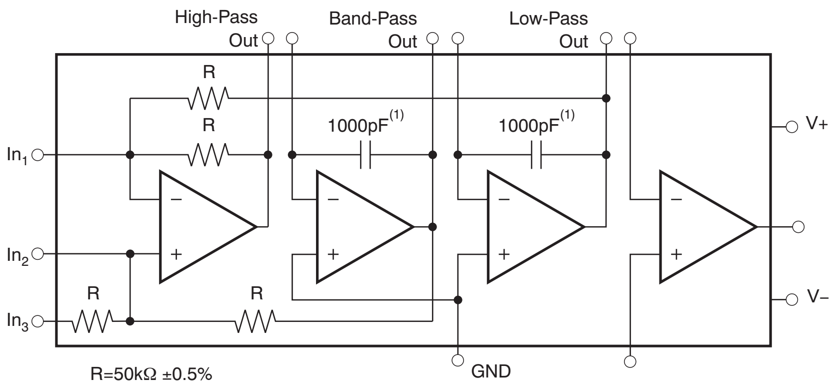
DESCRIPTION

The UAF42 is a universal active filter that can be configured for a wide range of low-pass, high-pass, and band-pass filters. It uses a classic state-variable analog architecture with an inverting amplifier and two integrators. The integrators include on-chip 1000pF capacitors trimmed to 0.5%. This architecture solves one of the most difficult problems of active filter design—obtaining tight tolerance, low-loss capacitors.

A DOS-compatible filter design program allows easy implementation of many filter types, such as Butterworth, Bessel, and Chebyshev. A fourth, uncommitted FET-input op amp (identical to the other three) can be used to form additional stages, or for special filters such as band-reject and Inverse Chebyshev.

The classical topology of the UAF42 forms a time-continuous filter, free from the anomalies and switching noise associated with switched-capacitor filter types.

The UAF42 is available in 14-pin plastic DIP and SOIC-16 surface-mount packages, specified for the –25°C to +85°C temperature range.



NOTE: (1) ±0.5%.

ELECTRICAL CHARACTERISTICS

At T_A = +25°C, and V_S = ±15V, unless otherwise noted.

PARAMETER	CONDITIONS	UAF42AP, AU			UNIT
		MIN	TYP	MAX	
FILTER PERFORMANCE					
Frequency Range, f_n			0 to 100		kHz
Frequency Accuracy	f = 1kHz			1	%
vs Temperature			0.01		%/°C
Maximum Q			400		—
Maximum (Q • Frequency) Product			500		kHz
Q vs Temperature	$(f_O \cdot Q) < 10^4$		0.01		%/°C
	$(f_O \cdot Q) < 10^5$		0.025		%/°C
Q Repeatability	$(f_O \cdot Q) < 10^5$		2		%
Offset Voltage, Low-Pass Output				±5	mV
Resistor Accuracy			0.5	1	%
OFFSET VOLTAGE(1)					
Input Offset Voltage			±0.5	±5	mV
vs Temperature			±3		μV/°C
vs Power Supply	V_S = ±6V to ±18V	80	96		dB
INPUT BIAS CURRENT(1)					
Input Bias Current	V_{CM} = 0V		10	50	pA
Input Offset Current	V_{CM} = 0V		5		pA
NOISE					
Input Voltage Noise					
Noise Density: f = 10Hz			25		nV/√Hz
Noise Density: f = 10kHz			10		nV/√Hz
Voltage Noise: BW = 0.1Hz to 10Hz			2		μV_{PP}
Input Bias Current Noise					
Noise Density: f = 10kHz			2		fA/√Hz
INPUT VOLTAGE RANGE(1)					
Common-Mode Input Range			±11.5		V
Common-Mode Rejection	V_{CM} = ±10V	80	96		dB
INPUT IMPEDANCE(1)					
Differential			10^{13} || 2		Ω || pF
Common-Mode			10^{13} || 6		Ω || pF
OPEN-LOOP GAIN(1)					
Open-Loop Voltage Gain	V_O = ±10V, R_L = 2kΩ	90	126		dB
FREQUENCY RESPONSE					
Slew Rate			10		V/μs
Gain-Bandwidth Product	G = +1		4		MHz
Total Harmonic Distortion	G = +1, f = 1kHz		0.1		%
OUTPUT(1)					
Voltage Output	R_L = 2kΩ	±11	±11.5		V
Short Circuit Current			±25		mA

(1) Specifications apply to uncommitted op amp, A_4. The three op amps forming the filter are identical to A_4 but are tested as a complete filter.

APPLICATION INFORMATION

The UAF42 is a monolithic implementation of the proven state-variable analog filter topology. This device is pin-compatible with the popular UAF41 analog filter, and it provides several improvements.

The slew rate of the UAF42 has been increased to 10V/µs, versus 1.6V/µs for the UAF41. Frequency • Q product of the UAF42 has been improved, and the useful natural frequency extended by a factor of four to 100kHz. FET input op amps on the UAF42 provide very low input bias current. The monolithic construction of the UAF42 provides lower cost and improved reliability.

DESIGN PROGRAM

Application report SBFA002 (available for download at www.ti.com) and a computer-aided design program also available from Texas Instruments, make it easy to design and implement many kinds of active filters. The DOS-compatible program guides you through the design process and automatically calculates component values.

Low-pass, high-pass, band-pass and band-reject (notch) filters can be designed. The program supports the three most commonly-used all-pole filter types: Butterworth, Chebyshev and Bessel. The less-familiar inverse Chebyshev is also supported, providing a smooth passband response with ripple in the stop band.

With each data entry, the program automatically calculates and displays filter performance. This feature allows a spreadsheet-like *what-if* design approach. For example, a user can quickly determine, by trial and error, how many poles are required for a desired attenuation in the stopband. Gain/phase plots may be viewed for any response type.

The basic building element of the most commonly-used filter types is the second-order section. This section provides a complex-conjugate pair of poles. The natural frequency, ω_n, and Q of the pole pair determine the characteristic response of the section. The low-pass transfer function is shown in Equation 1:

$$\frac{V_O(s)}{V_I(s)} = \frac{A_{LP}\omega_n^2}{s^2 + s\,\omega_n/Q + \omega_n^2} \qquad (1)$$

The high-pass transfer function is given by Equation 2:

$$\frac{V_{HP}(s)}{V_I(s)} = \frac{A_{HP}s^2}{s^2 + s\,\omega_n/Q + \omega_n^2} \qquad (2)$$

The band-pass transfer function is calculated using Equation 3:

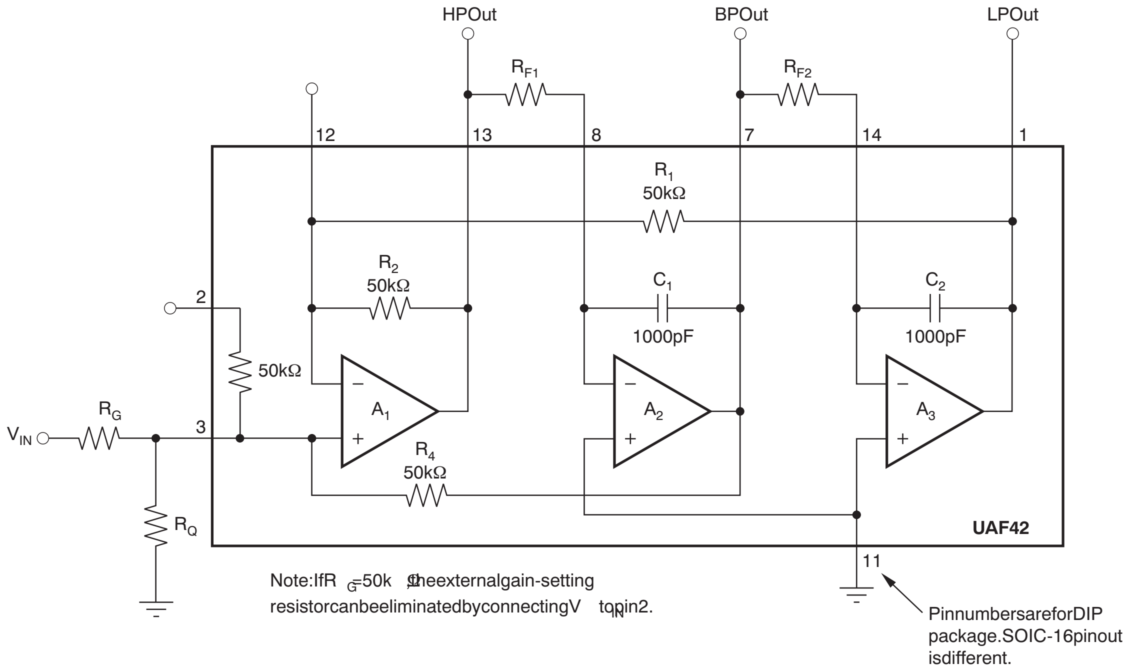
$$\frac{V_{BP}(s)}{V_I(s)} = \frac{A_{BP}(\omega_n/Q)s}{s^2 + s\,\omega_n/Q + \omega_n^2} \qquad (3)$$

A band-reject response is obtained by summing the low-pass and high-pass outputs, yielding the transfer function shown in Equation 4:

$$\frac{V_{BR}(s)}{V_I(s)} = \frac{A_{BR}(s^2 + \omega_n^2)}{s^2 + s\,\omega_n/Q + \omega_n^2} \qquad (4)$$

The most common filter types are formed with one or more cascaded second-order sections. Each section is designed for ω_n and Q according to the filter type (Butterworth, Bessel, Chebyshev, etc.) and cutoff frequency. While tabulated data can be found in virtually any filter design text, the design program eliminates this tedious procedure.

Second-order sections may be noninverting (Figure 1) or inverting (Figure 2). Design equations for these two basic configurations are shown for reference. The design program solves these equations, providing complete results, including component values.



Design Equations

1. $$\omega_n^2 = \frac{R_2}{R_1 R_{F1} R_{F2} C_1 C_2}$$

2. $$Q = \frac{1 + \frac{R_4 (R_G + R_Q)}{R_G R_Q}}{1 + \frac{R_2}{R_1}} \left(\frac{R_2 R_{F1} C_1}{R_1 R_{F2} C_2}\right)^{1/2}$$

3. $$Q A_{LP} = Q A_{HP} \left(\frac{R_1}{R_2}\right) = A_{BP} \left(\frac{R_1 R_{F1} C_1}{R_2 R_{F2} C_2}\right)^{1/2}$$

4. $$A_{LP} = \frac{1 + \frac{R_1}{R_2}}{R_G \left(\frac{1}{R_G} + \frac{1}{R_Q} + \frac{1}{R_4}\right)}$$

5. $$A_{HP} = \frac{R_2}{R_1} A_{LP} = \frac{1 + \frac{R_2}{R_1}}{R_G \left(\frac{1}{R_G} + \frac{1}{R_Q} + \frac{1}{R_4}\right)}$$

6. $$A_{BP} = \frac{R_4}{R_G}$$

Figure 1. Noninverting Pole-Pair

