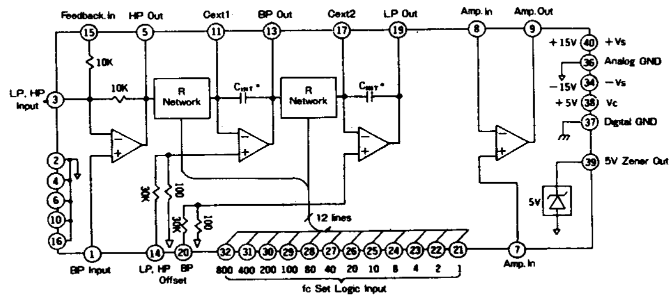
FLJ-D1,D2,DC DIGITAL PROGRAMMABLE FILTER

FEATURES

- **Cutoff frequency is set by logic inputs.**
- **Lowpass, Highpass and Bandpass output functions are available simultaneously.**
- **Gain and Q are set by external components.**
- **High accuracy, high stability**

GENERAL DESCRIPTION

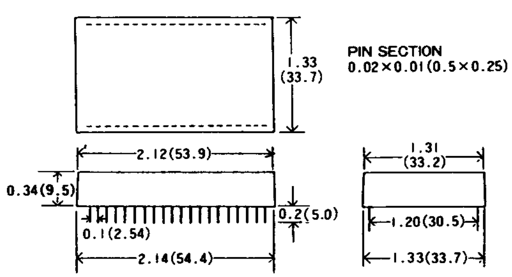
FLJ-D1, -D2 and -DC are digital programmable filters which can set the cutoff frequency and center frequency with 3 digit BCD inputs.
Two-pole lowpass, bandpass and highpass output functions are available simultaneously from three different outputs and notch function is available by combining these outputs to the uncommitted op amp.
To realize higher order filters, several filters can be cascaded. And to obtain higher performance of higher order filters, both Gain and Q are designed to be set with external components.



$*C_{INT}$ FLJ-D1 50,000pF
FLJ-D2 500pF
FLJ-DC None. Need Cext.

BLOCK DIAGRAM (Fig. 1)

MECHANICAL DIMENSIONS (Fig. 2) INCHES(mm)



PIN CONNECTIONS (Table 1)

FUNCTION	PIN	PIN	FUNCTION
INPUT (BP)	1	40	+Vs (+15V)
ANALOG GND	2	39	5V ZENER OUTPUT
INPUT (HP, LP)	3	38	Vc(+5V)
ANALOG GND	4	37	DIGITAL GND
OUTPUT (HP)	5	36	ANALOG GND
ANALOG GND	6	35	NC
AMP. (+) INPUT	7	34	-Vs(-15V)
AMP. (−) INPUT	8	33	NC
AMP. OUTPUT	9	32	LOGIC 800
ANALOG GND	10	31	LOGIC 400
Cext 1.	11	30	LOGIC 200
NC	12	29	LOGIC 100
OUTPUT (BP)	13	28	LOGIC 80
ZERO ADJ. (HP, LP)	14	27	LOGIC 40
NEG. FEEDBACK IN	15	26	LOGIC 20
ANALOG GND	16	25	LOGIC 10
Cext 2.	17	24	LOGIC 8
NC	18	23	LOGIC 4
OUTPUT (LP)	19	22	LOGIC 2
ZERO ADJ. (BP)	20	21	LOGIC 1

DO NOT CONNECT NC PINS TO OTHERS.

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SPECIFICATIONS (Table 2)

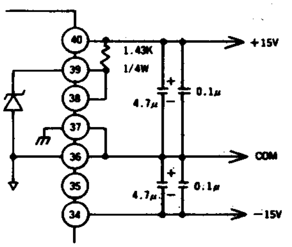
Typical at 25°C, ±15V and +5V supplies, gain of -1, $Q = \sqrt{2}/2$ unless otherwise specified.

ABSOLUTE RATINGS

Power Supplies .... ±Vs : ±20V, Vc : +5.5V
Control Logic Input .... Vc+0.5V
Analog Input .... ±Vs

FILTER CHARACTERISTICS	
Frequency Program Range : FLJ-D1 ...	1Hz ~ 1.599KHz
FLJ-D2 ...	100Hz ~ 159.9KHz
FLJ-DC ...	Determined by external capacitors
Frequency Program	BCD 3 digits, MSD is hexa-decimal (0~15)
Frequency Program Accuracy	±0.1%
Q Range	$1/3 \leq Q \leq 1 \times 10^6$ /fc
Rolloff	12dB/oct (LP, HP), 6dB/octBW (BP)
Number of poles	2pole (1 pole pair)
Voltage Gain	1 ~ 10
Pass Band Gain Variance	Depends on external resistors
Resonant Frequency T.C.	0.01%/°C
Gain T.C.	0.2dB Full Temperature Range
Distortion	0.002%
Noise	35μVrms (LP), 100μVrms (HP), 30μVrms (BP)
Load Resistance	2KΩ
AMPLIFIER CHARACTERISTICS	
Input Voltage Range	±10V min.
Input Impedance	300KΩ
Input Offset Voltage	0.5mV
Input Bias Current	200nA
Input Offset Drift	5μV/°C
Output Voltage/Current	±10V/5mA min.
Output Impedance	5Ω max.
Output Short Circuit Current	38mA
Small Signal Frequency Bandwidth ...	10MHz
Slew Rate	8V/μSec
POWER SUPPLIES AND ENVIRONMENT	
Supply Voltages	±Vs : ±15V ±10%, Vc : +5V ±10%
Supply Current	+15mA, -18mA +2.2mA
Operating Temperature Range	-20°C ~ +70°C
Operating Humidity Range	10% ~ 95% RH
Storage Temperature Range	-30°C ~ +80°C
Storage Humidity Range	10% ~ 80% RH

ZENER OUTPUT (Fig. 3)



TECHNICAL NOTES

1. The cutoff frequency of lowpass and highpass, and the center frequency of bandpass filters can be set with three digit BCD, TTL compatible logic inputs. The MSD is hexadecimal. See table 1.
2. The cutoff frequency is shown as either one equation of the following:

   $fc = \frac{N}{20 \cdot C}$ Hz, C : μF, N : Digital Number

   $fc = \frac{N}{2\pi \cdot C \cdot Rf}$ Hz, C : F, Rf : Ω, N : Digital Number

   C = 50,000pF is contained in FLJ-D1 and C = 500pF is contained in FLJ-D2 respectively, while no capacitor is contained in FLJ-DC.

   The fc's of each model are:

   FLJ-D1 : fc = N or $fc = \frac{N}{2\pi \cdot 5 \times 10^{-8} \cdot Rf}$

   FLJ-D2 : fc=100N or $fc = \frac{N}{2\pi \cdot 5 \times 10^{-10} \cdot Rf}$

   FLJ-DC : $fc = \frac{N}{20 \cdot C}$ or $fc = \frac{N}{2\pi \cdot Cext \cdot Rf}$

   The value of Rf is 3.183KΩ for the programmed fc logic is 1,000.
   The value of Cext is calculated taking these factors into consideration.
3. Each logic input is connected to CMOS4000 series internally. Then each input is pulled down with 100KΩ resistors. The use of 10KΩ pull-up resistors to +5V is recommended when filters are programmed with TTL logic.
4. An independent +5V zener diode is contained in the filter. The output voltage range of this diode is +4.87V ~ +5.12V. The connection shown in Figure 3 is recommended if a filter is driven by ±15V supplies only.
5. Analog GND (Pin36) and logic GND (Pin37) are separated to be useful for universal applications. Connect grounds of ±15V and +5V externally. No return current of the digital power supply should flow through the analog ground.
6. The use of 4.7μF and 0.1μF bypass capacitors for both ±15V and +5V lines close to the module is highly recommended.

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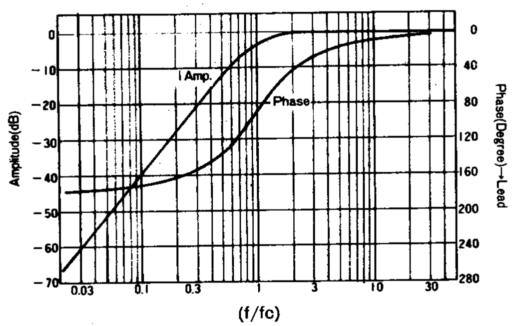
LOGIC INPUT CODING TABLE (Table 3)

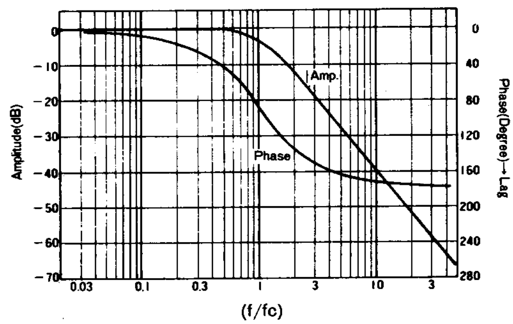
Logic Input *1 (MSD)		(LSD)	Decimal Number	fc (Cutoff Frequency) FLJ-D1	FLJ-D2	FLJ-DC *2
0 0 0 0	0 0 0 0	0 0 0 1	1	1Hz	100Hz	0.1Hz
0 0 0 0	0 0 0 0	0 0 1 0	2	2	200	0.2
0 0 0 0	0 0 0 0	0 1 0 0	4	4	400	0.4
0 0 0 0	0 0 0 0	1 0 0 0	8	8	800	0.8
0 0 0 0	0 0 0 1	0 0 0 0	10	10	1KHz	1
0 0 0 0	0 0 1 0	0 0 0 0	20	20	2	2
0 0 0 0	0 1 0 0	0 0 0 0	40	40	4	4
0 0 0 0	1 0 0 0	0 0 0 0	80	80	8	8
0 0 0 1	0 0 0 0	0 0 0 0	100	100	10	10
0 0 1 0	0 0 0 0	0 0 0 0	200	200	20	20
0 1 0 0	0 0 0 0	0 0 0 0	400	400	40	40
1 0 0 0	0 0 0 0	0 0 0 0	800	800	80	80
1 0 0 1	0 0 0 0	0 0 0 0	900	900	90	90
1 0 1 0	0 0 0 0	0 0 0 0	1000	1000	100	100
1 1 0 0	0 0 0 0	0 0 0 0	1200	1200	120	120
1 1 1 0	0 0 0 0	0 0 0 0	1400	1400	140	140
1 1 1 1	0 0 0 0	0 0 0 0	1500	1500	150	150
1 1 1 1	1 0 0 1	1 0 0 1	1599	1599Hz	159.9KHz	159.9Hz

Note: *1. Logic 1 = +5V
Logic 0 = GND or OPEN
*2. FLJ-DC needs external capacitors.
These values are ones when two 0.5μF are used as external capacitors.

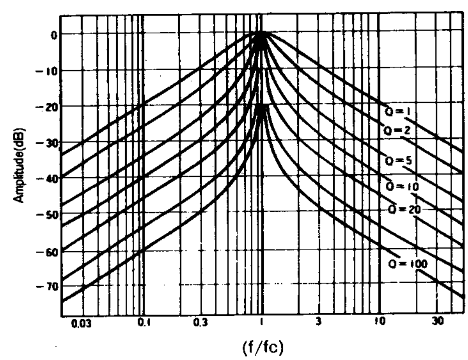
BUTTERWORTH HIGHPASS (Fig. 4)



BUTTERWORTH LOWPASS (Fig. 5)



BANDPASS (Fig. 6)



GAIN AND Q

The gain and Q of this filter are set with the following equations.

1. Lowpass and highpass filters

Gain: $G = \frac{-1}{Rg} \times 10^4 \ (Rg : \Omega)$

Q: $Q = \frac{Rg \cdot (Rq + 10^4)}{Rq \cdot (2Rg + 10^4)}$

Rg = 10KΩ when G = -1. Then, $Rq = \frac{10^4}{3Q-1}$

Then, the following values are obtained:

	Q	Rq
Butterworth	0.70711	8.918KΩ
Bessel	0.57735	13.66KΩ

See Figure 4 and 5 for "Amplitude/Phase vs. Frequency" characteristics.

2. Bandpass filter

Gain: $G = \frac{-1}{Rg} \times 10^4 \ (Rg : \Omega)$

Q: $Q = \frac{1 + (1/Rg + 1/Rq) \cdot 10^4}{2}$

Rg = 10KΩ when G = -1. Then, $Rq = \frac{10^4}{2(Q-1)}$

Then, the following values are obtained:

Q	Rq
2	5.00KΩ
5	1.25KΩ
10	556Ω

See Figure 6 for reference.

APPLICATIONS

I. HIGHER ORDER LOWPASS AND HIGHPASS FILTERS

Several units of FLJ-D Series filters can be cascaded to realize higher order filters. Any model can be used to make Butterworth filters as the cutoff frequency of each stage is equal.

The use of FLJ-DC is recommended for other type of filters such as Chebyshev and Bessel because the cutoff frequency of each stage is different.

The value of external components are different at each stage. The Tables 7 and 8 show the values of fn and Qn at each stage.

= Design Example 1. =

● Higher Order Lowpass Filter/Basic Theory

Following points should be understood referring to the Figure 9.

a. Connections are the same either for Butterworth, Bessel or Chebyshev.
b. Each module is used as a two-pole filter in case of even order.
c. The first module is used as a one-pole filter and the rest are used as two-pole in case of odd order.
d. Even order filter : Input is given to Input #2 of Fig. 9. Output is either Output #3, #4 or #5 depending on the number of order.
   In case of sixth order filter, for example, 3 pieces of FLJ-D are used, input and output are Input #2 and Output #4 respectively.
   Proper values of Rg1 ~ Rg4, Rq1 ~ Rq4 and Cext1 ~ Cext 4 are to be selected depending on filter type. See Table 4, 5, 6.
e. Odd order filter : Input is given to Input #1 of Fig. 9. Output is either Output #2, #3, #4. In case of fifth order filter, 3 pieces of FLJ-D are used, input is given to Input #1, Output #1 and Input #2 are connected, output is taken from Output #3.
f. The fc program logic lines are connected to each other of filter in equal ways.

● Higher Order Lowpass Filter/Calculation Example

To build 8th order, 0.05dB ripple, Chebyshev filter using four FLJ-DC's.

Here, gain=+1, the cutoff frequency should be programmed between 10Hz and 15.99KHz.

a. Use 4 pieces of FLJ-DC.
b. Output is inverted at every 2nd order. Output becomes in phase with input at the final stage, in this case.
c. The relationship between the cutoff frequency and the external capacitors of FLJ-DC is shown in the following equation.

   $fc = \frac{N}{20\ Cext}$ N: Digital Number (1~1,599) Cext: µF, fc:Hz

   If digital range of 10Hz ~ 15.99KHz is desired, fc is equal to 10N.

   $10N = \frac{N}{20\ Cext}$ then, Cext = 0.005µF = 5000pF
d. Gain of each stage is -1, then $G=-1/Rg \times 10^4$, then Rg=10KΩ.
e. Refer to Table 7 and find out fn=0.42170 and Qn=0.57503 at the crossing point of "8 Poles, 1st stage" and "Chebyshev, 0.05dB ripple".
   These figures mean that the cutoff frequency of the 1st stage should be 0.42170 times of the total cutoff frequency, and that the Q of 1st stage should be 0.57503 respectively.

   $0.42170fc = \frac{N}{20Cext}$ here substitute fc=10N

   then, $4.2170N = \frac{N}{20Cext}$ therefore, Cext = 0.011857µF = 11857pF

   $Rq = \frac{10^4}{3Q-1}$ here Q = 0.57503, therefore, Rq1 = 13.7KΩ.
f. Rqn and Cextn of 2nd, 3rd and 4th stages are calculated in similar ways. The Table 6 shows the results of the calculations.

= Design Example 2 =

● Higher Order Highpass Filter/Calculation Example

To build 8th order Butterworth highpass filter using FLJ-DC.

Gain should be +1, the cutoff frequency range should be 10Hz ~ 15.99KHz.

a. Use 4 pieces of FLJ-DC. Gain of each stage is -1 and it becomes +1 at the final stage.

   $G = \frac{-1}{Rg} \times 10^4$, therefore, Rg = 10KΩ.
b. See table 4 and obtain values of fn and Qn of each stage under 8th Butterworth.

   $fc = \frac{N}{20Cext}$ N: Digital Number (1 ~ 1,599) Cext: µF fc:Hz

   The fn of each stage is 1.

   Therefore, $10N = \frac{N}{20Cext}$ then, Cext = 5000pF
c. Gain is -1 at each stage.

   $Rq = \frac{10^4}{3Q-1}$ substitute values of Qn to obtain Rq of each stage.

   The results are shown in Table 9. See Table 10 for Chebyshev highpass filter.

II. BANDPASS FILTER

One-pole pair, two-pole pair and three-pole pair connections are shown in Figure 11. The values of external components are shown in Table 11.

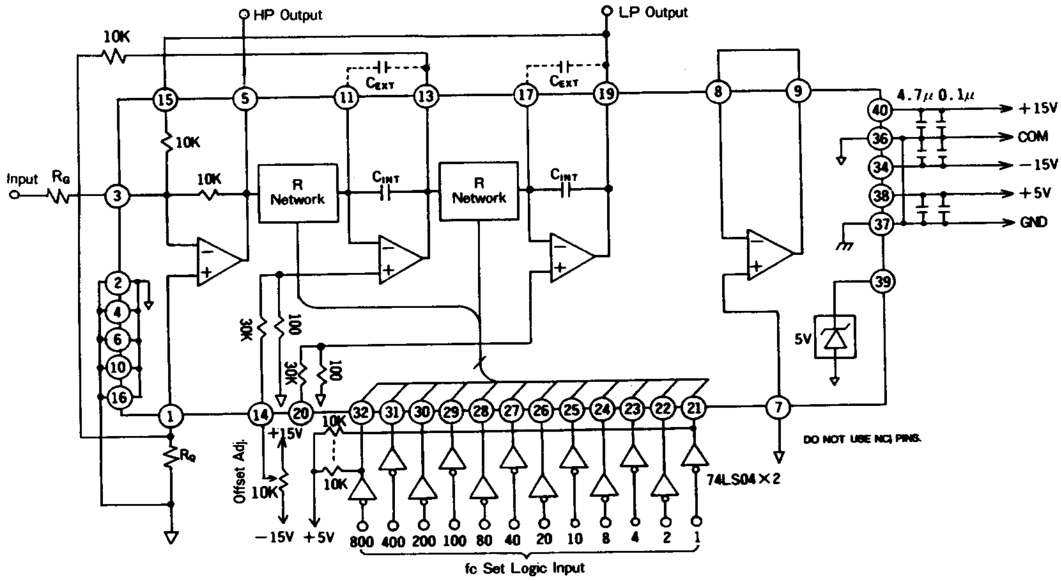
III. BAND ELIMINATION FILTER

A band elimination (=notch) filter can be made using FLJ-D Series filters.

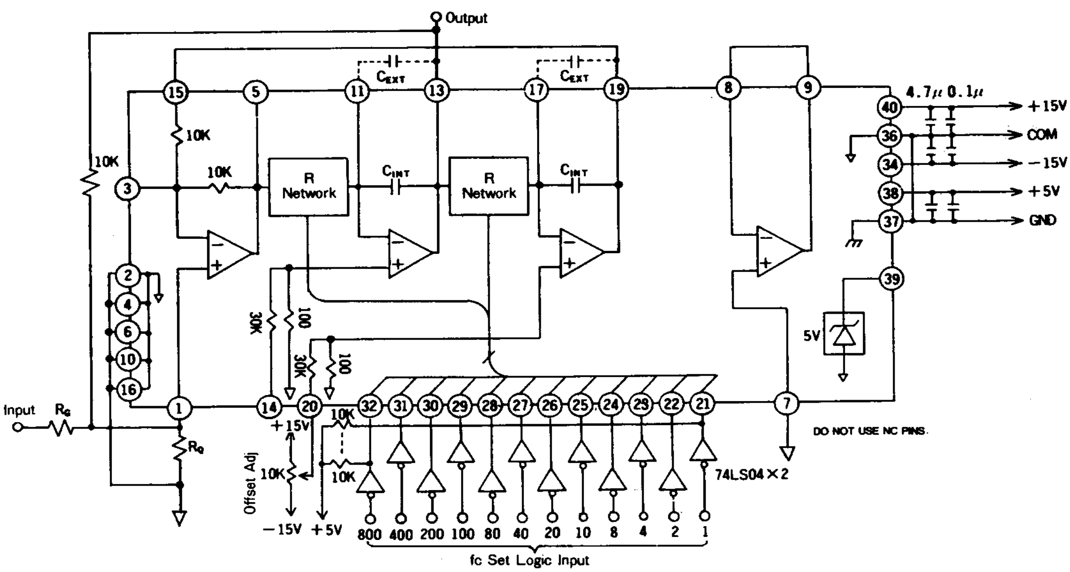
A non-inverting type which employs LP + HP method is shown in Figure 12.

An inverting type which employs 1-BP method is shown in Figure 13. It is recommended to use a non-inverting type for Q ≦ 1 and inverting type for Q ≧ 1 applications. A bandpass filter of higher order is shown in Figure 14.

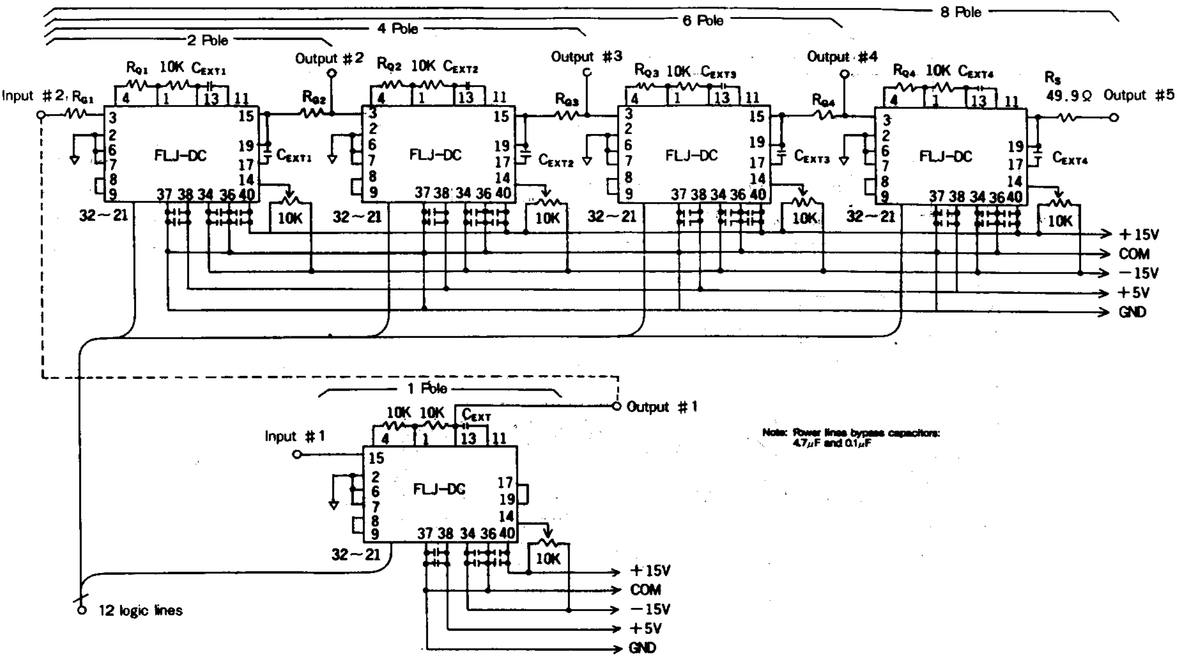
LOWPASS & HIGHPASS CONNECTIONS (Fig. 7)



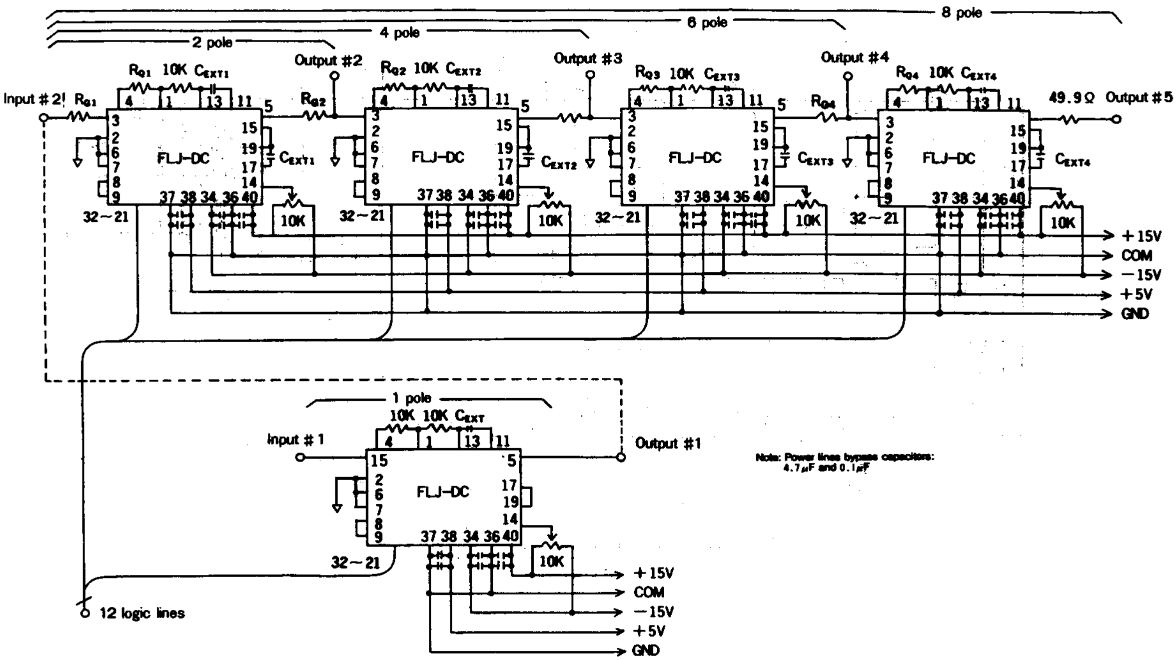
BANDPASS FILTER CONNECTIONS (Fig.8)



HIGHER ORDER LOWPASS FILTER (Fig. 9)



HIGHER ORDER HIGHPASS FILTER (Fig. 10)



BUTTERWORTH, LOWPASS EXTERNAL COMPONENTS (Table 4)

(FLJ-DC, fc:10Hz~15.99KHz, IGI=1) (See Fig. 9)

	2 pole	3 pole	4 pole	5 pole	6 pole	7 pole	8 pole
C_{EXT}		5000pF		5000pF		5000pF	
C_{EXT1}	5000pF	5000pF	5000pF	5000pF	5000pF	5000pF	5000pF
C_{EXT2}			5000pF	5000pF	5000pF	5000pF	5000pF
C_{EXT3}					5000pF	5000pF	5000pF
C_{EXT4}							5000pF
R_{G1}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G2}	Rs	Rs	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G3}			Rs	Rs	10KΩ	10KΩ	10KΩ
R_{G4}					Rs	Rs	10KΩ
R_{Q1}	8.87KΩ	4.99K	16.2KΩ	11.8KΩ	18.2KΩ	15KΩ	18.7KΩ
R_{Q2}			3.4KΩ	2.61KΩ	8.87KΩ	6.98KΩ	12.4KΩ
R_{Q3}					2.10KΩ	1.74KΩ	5.90KΩ
R_{Q4}							1.50KΩ
Input	#2	#1	#2	#1	#2	#1	#2
Output	#2	#2	#3	#3	#4	#4	#5

Rs=49.9Ω

BUTTERWORTH, HIGHPASS (Table 9)

(FLJ-DC, fc:10Hz~15.99KHz, IGI=1) (See Fig.10)

	2pole	3pole	4pole	5pole	6pole	7pole	8pole
C_{EXT}		5000pF		5000pF		5000pF	
C_{EXT1}	5000pF	5000pF	5000pF	5000pF	5000pF	5000pF	5000pF
C_{EXT2}			5000pF	5000pF	5000pF	5000pF	5000pF
C_{EXT3}					5000pF	5000pF	5000pF
C_{EXT4}							5000pF
R_{G1}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G2}	49.9Ω	49.9Ω	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G3}			49.9Ω	49.9Ω	10KΩ	10KΩ	10KΩ
R_{G4}					49.9Ω	49.9Ω	10KΩ
R_{Q1}	8.87KΩ	4.99KΩ	16.2KΩ	11.8KΩ	18.2KΩ	15.0KΩ	18.7KΩ
R_{Q2}			3.4KΩ	2.61KΩ	8.87KΩ	7.15KΩ	12.4KΩ
R_{Q3}					2.10KΩ	1.74KΩ	5.9KΩ
R_{Q4}							1.50KΩ
Input	#2	#1	#2	#1	#2	#1	#2
Output	#2	#2	#3	#3	#4	#4	#5

BESSEL, LOWPASS EXTERNAL COMPONENTS (Table 5)

(FLJ-DC, fc:10Hz~15.99KHz, IGI=1) (See Fig.9)

	2pole	3pole	4pole	5pole	6pole	7pole	8pole
C_{EXT}		3774pF		3323pF		2964pF	
C_{EXT1}	3924pF	3448pF	3491pF	3208pF	3112pF	2908pF	2807pF
C_{EXT2}			3113pF	2844pF	2955pF	2739pF	2725pF
C_{EXT3}					2621pF	2436pF	2556pF
C_{EXT4}							2281pF
R_{G1}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G2}	Rs	Rs	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G3}			Rs	Rs	10KΩ	10KΩ	10KΩ
R_{G4}					Rs	Rs	10KΩ
R_{Q1}	13.7KΩ	9.31KΩ	17.8KΩ	14.3KΩ	18.7KΩ	16.9KΩ	19.1KΩ
R_{Q2}			6.98KΩ	5.76KΩ	12.1KΩ	10.2KΩ	14.7KΩ
R_{Q3}					4.87KΩ	4.22KΩ	8.87KΩ
R_{Q4}							3.74KΩ
Input	#2	#1	#2	#1	#2	#1	#2
Output	#2	#2	#3	#3	#4	#4	#5

Rs=49.9Ω

CHEBYSHEV, HIGPASS (Table 10)

(FLJ-DC, fc:10Hz~15.99KHz, IGI=1) (See Fig.10)

	4pole(0.5dB)	5pole(0.5dB)	6pole(0.1dB)	7pole(0.1dB)	8pole(0.05dB)
C_{EXT}		1812pF		1884pF	
C_{EXT1}	2985pF	3452pF	2566pF	2873pF	2109pF
C_{EXT2}	5156pF	5089pF	4172pF	4339pF	3348pF
C_{EXT3}			5314pF	5226pF	4558pF
C_{EXT4}					5248pF
R_{G1}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G2}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G3}	49.9Ω	49.9Ω	10KΩ	10KΩ	10KΩ
R_{G4}			49.9Ω	49.9Ω	10KΩ
R_{Q1}	8.87KΩ	3.92KΩ	12.4KΩ	6.49KΩ	13.7KΩ
R_{Q2}	1.27KΩ	787Ω	3.32KΩ	2.21KΩ	4.53KΩ
R_{Q3}			768Ω	562Ω	1.78KΩ
R_{Q4}					487Ω
Input	#2	#1	#2	#1	#2
Output	#3	#3	#4	#4	#5

CHEBYSHEV, LOWPASS EXTERNAL COMPONENTS (Table 6)

(FLJ-DC, fc:10Hz~15.99KHz, IGI=1) (See Fig.9) ( ):Ripple

	4pole(0.5dB)	5pole(0.5dB)	6pole(0.1dB)	7pole(0.1dB)	8pole(0.05dB)
C_{EXT}		13800pF		13270pF	
C_{EXT1}	8375pF	7241pF	9743pF	8701pF	11857pF
C_{EXT2}	4848pF	4913pF	5992pF	5761pF	7467pF
C_{EXT3}			4705pF	4784pF	5485pF
C_{EXT4}					4764pF
R_{G1}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G2}	10KΩ	10KΩ	10KΩ	10KΩ	10KΩ
R_{G3}	Rs	Rs	10KΩ	10KΩ	10KΩ
R_{G4}			Rs	Rs	10KΩ
R_{Q1}	8.87KΩ	3.92KΩ	12.4KΩ	6.49KΩ	13.7KΩ
R_{Q2}	1.27KΩ	787Ω	3.32KΩ	2.21KΩ	4.54KΩ
R_{Q3}			768Ω	562Ω	1.78KΩ
R_{Q4}					487Ω
Input	#2	#1	#2	#1	#2
Output	#3	#3	#4	#4	#5

Rs=49.9Ω

6

HIGHER ORDER BUTTERWORTH(LP, HP), BESSEL(LP), CHEBYSHEV(LP)···fn, Qn Table (Table 7)

No. of Pole	Butterworth		Bessel(LP)		Chebyshev(LP)											
					0.05dB(Ripple)		0.1dB		0.2dB		0.25dB		0.3dB		0.5dB	
	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn
2	1.0	0.707107	1.2742	0.57735												
3 1st	1.0	0.5	1.32475	0.5												
3 2nd	1.0	1.000000	1.44993	0.69104												
4 1st	1.0	0.541196	1.43241	0.52193	0.88526	0.60017	0.78926	0.61880	0.70111	0.64590	0.67442	0.65725	0.65324	0.66778	0.59700	0.70511
4 2nd	1.0	1.306563	1.60594	0.80554	1.22098	1.99842	1.15327	2.18293	1.09483	2.43501	1.07794	2.53611	1.06482	2.62790	1.03127	2.94055
5 1st	1.0	0.5	1.50470	0.5	0.61901	0.5	0.53891	0.5	0.46141	0.5	0.43695	0.5	0.41713	0.5	0.36232	0.5
5 2nd	1.0	0.618034	1.55876	0.56354	0.85362	0.85227	0.79745	0.91452	0.74726	1.00091	0.73241	1.03593	0.72076	1.06790	0.69048	1.17781
5 3rd	1.0	1.618034	1.75812	0.91652	1.13476	2.96615	1.09313	3.28201	1.05708	3.70686	1.04663	3.87568	1.03851	4.02836	1.01773	4.54496
6 1st	1.0	0.517638	1.60653	0.51032	0.56933	0.58116	0.51319	0.59946	0.46032	0.62595	0.44406	0.63703	0.43103	0.64729	0.39623	0.68364
6 2nd	1.0	0.707107	1.69186	0.61120	0.87014	1.21335	0.83449	1.33157	0.80306	1.49172	0.79385	1.55565	0.78666	1.61360	0.76812	1.81038
6 3rd	1.0	1.931852	1.90782	1.0233	1.09094	4.15611	1.06273	4.63290	1.03823	5.26890	1.03112	5.52042	1.02560	5.74741	1.01145	6.51285
7 1st	1.0	0.5	1.68713	0.5	0.43017	0.5	0.37678	0.5	0.32431	0.5	0.30760	0.5	0.29400	0.5	0.25617	0.5
7 2nd	1.0	0.554958	1.71911	0.53235	0.61098	0.78823	0.57464	0.84640	0.54170	0.92694	0.53186	0.95956	0.52411	0.98931	0.50386	1.09155
7 3rd	1.0	0.801938	1.82539	0.66083	0.89236	1.66357	0.86788	1.84721	0.84643	2.09299	0.84017	2.19039	0.83528	2.27837	0.82273	2.57555
7 4th	1.0	2.246980	2.05279	1.1263	1.06561	5.56621	1.04520	6.23324	1.02745	7.11866	1.02230	7.46782	1.01829	7.78256	1.00802	8.84180
8 1st	1.0	0.509796	1.78143	0.50599	0.42170	0.57503	0.38159	0.59318	0.34344	0.61944	0.33164	0.63041	0.32219	0.64058	0.29674	0.67657
8 2nd	1.0	0.601345	1.83514	0.55961	0.66965	1.07710	0.64514	1.18296	0.62334	1.32615	0.61692	1.38326	0.61189	1.43501	0.59887	1.61068
8 3rd	1.0	0.899976	1.95645	0.71085	0.91166	2.19456	0.89381	2.45282	0.87820	2.79620	0.87365	2.93174	0.87011	3.05398	0.86101	3.46567
8 4th	1.0	2.562915	2.19237	1.2257	1.04963	7.19539	1.03416	8.08190	1.02070	9.25500	1.01679	9.71678	1.01375	10.1327	1.00595	11.5308

HIGH ORDER CHEBYSHEV(HP)···fn, Qn Table (Table 8)

No. of Pole	Chebyshev(HP)											
	0.05dB(Ripple)		0.1dB		0.2dB		0.25dB		0.3dB		0.5dB	
	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn	fn	Qn
4 1st	1.129612	1.99842	1.267010	2.18293	1.426310	2.43501	1.482756	2.53611	1.530831	2.62790	1.675042	2.94055
4 2nd	0.819014	0.60017	0.867100	0.61880	0.913384	0.64590	0.927695	0.65725	0.939126	0.66778	0.969678	0.70511
5 1st	1.615483	2.96615	1.855597	3.28201	2.167270	3.70686	2.28859	3.87568	2.397334	4.02836	2.759991	4.54496
5 2nd	1.171481	0.85227	1.253997	0.91452	1.338222	1.00091	1.365355	1.03593	1.387424	1.06790	1.448268	1.17781
5 3rd	0.881244	0.5	0.914804	0.5	0.946002	0.5	0.955447	0.5	0.962918	0.5	0.982579	0.5
6 1st	1.756451	4.15611	1.948596	4.63290	2.172402	5.26890	2.25195	5.52042	2.320024	5.74741	2.523787	6.51285
6 2nd	1.149240	1.21335	1.198337	1.33157	1.245237	1.49172	1.259684	1.55565	1.271197	1.61360	1.301880	1.81038
6 3rd	0.916641	0.58116	0.940973	0.59946	0.963178	0.62595	0.969819	0.63703	0.975039	0.64729	0.98868	0.68364
7 1st	2.324662	5.56621	2.654069	6.23324	3.083470	7.11866	3.25098	7.46782	3.401361	7.78256	3.903658	8.84180
7 2nd	1.636715	1.66357	1.740220	1.84721	1.846040	2.09299	1.880194	2.19039	1.907996	2.27837	1.984678	2.57555
7 3rd	1.120624	0.78823	1.152233	0.84640	1.181433	0.92694	1.19024	0.95956	1.197203	0.98931	1.215466	1.09155
7 4th	0.938430	0.5	0.956755	0.5	0.973283	0.5	0.97819	0.5	0.982039	0.5	0.992044	0.5
8 1st	2.371354	7.19539	2.620614	8.08190	2.911717	9.25500	3.015318	9.71678	3.103759	10.1327	3.369953	11.5308
8 2nd	1.483317	2.19456	1.550051	2.45282	1.604261	2.79620	1.620956	2.93174	1.634281	3.05398	1.669811	3.46567
8 3rd	1.096900	1.07710	1.118806	1.18296	1.138693	1.32615	1.144623	1.38326	1.149280	1.43501	1.161427	1.61068
8 4th	0.952717	0.57503	0.966968	0.59318	0.97972	0.61944	0.98349	0.63041	0.986436	0.64058	0.994085	0.67657

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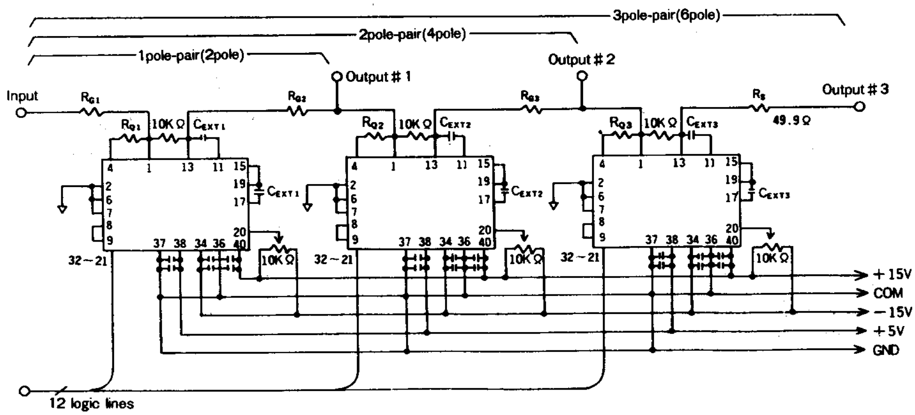
HIGHER ORDER BANDPASS FILTER (Fig. 11)



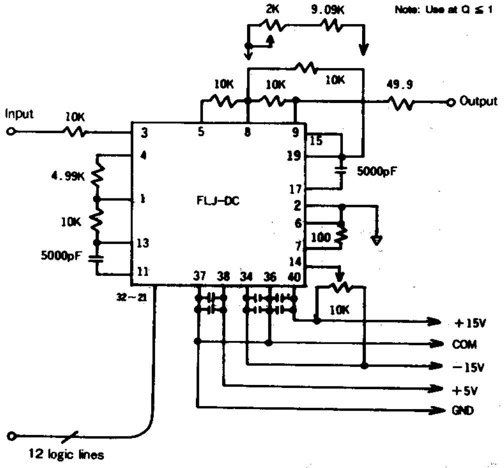
BANDPASS FILTER (1 POLE-PAIR, 2 POLE-PAIR, 3 POLE-PAIR) (Table 11)

(Total |G| = 1, Q = 2, 5, 4.32, 10 fo = 10 ~ 15.99KHz) (See Fig. 11)

	1 pole-pair, Inverting			2pole-pair, Non-Inverting			3pole-pair, Inverting			
Q	2	5	10	2	5	10	2	4.32 (1/3oct)	5	10
C_{EXT1}	5000pF	5000pF	5000pF	4182pF	4658pF	4826pF	4027pF	4523pF	4585pF	4788pF
C_{EXT2}				5978pF	5367pF	5180pF	5000pF	5000pF	5000pF	5000pF
C_{EXT3}							6208pF	5527pF	5452pF	5221pF
R_{G1}	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω	10K Ω
R_{G2}	49.9 Ω	49.9 Ω	49.9 Ω	4.87K Ω	4.99K Ω	4.99K Ω	10K Ω	10K Ω	10K Ω	10K Ω
R_{G3}				49.9 Ω	49.9 Ω	49.9 Ω	2.37K Ω	2.49K Ω	2.49K Ω	2.49K Ω
R_{Q1}	4.99K Ω	1.24K Ω	562Ω	2.67K Ω	825Ω	383Ω	1.62K Ω	649Ω	549Ω	261Ω
R_{Q2}				3.74K Ω	887Ω	392Ω	4.99K Ω	1.5K Ω	1.24K Ω	549Ω
R_{Q3}							3.40K Ω	806Ω	665Ω	287Ω
f_1	1.0	1.0	1.0	1.19550	1.07340	1.03600	1.24166	1.10547	1.09046	1.04425
f_2				0.83647	0.93162	0.965251	1.0	1.0	1.0	1.0
f_3							0.80537	0.90459	0.91704	0.95763
Q_1	2.0	5.0	10.0	2.87	7.09	14.15	4.094	8.68040	10.04	20.01
Q_2				2.87	7.09	14.15	2.00000	4.31847	5.0000	10.000
Q_3							4.094	8.68040	10.04	20.01
Gain				6.30dB	6.06dB	6.03dB	12.45dB	12.13dB	12.11dB	12.06dB

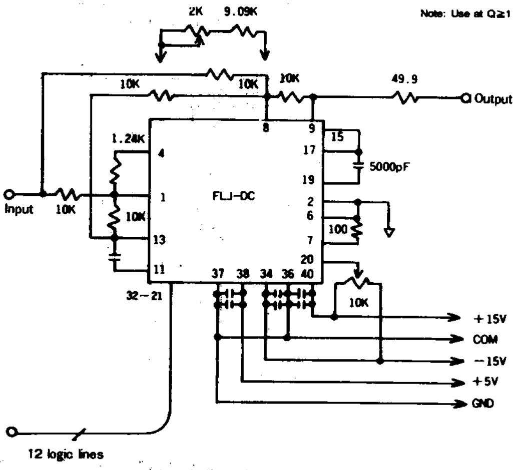
1POLE-PAIR(2 POLE)BAND ELIMINATION FILTER (Fig.12)

Non-Inverting (LP + HP, fc:10Hz ~ 15.99KHz)



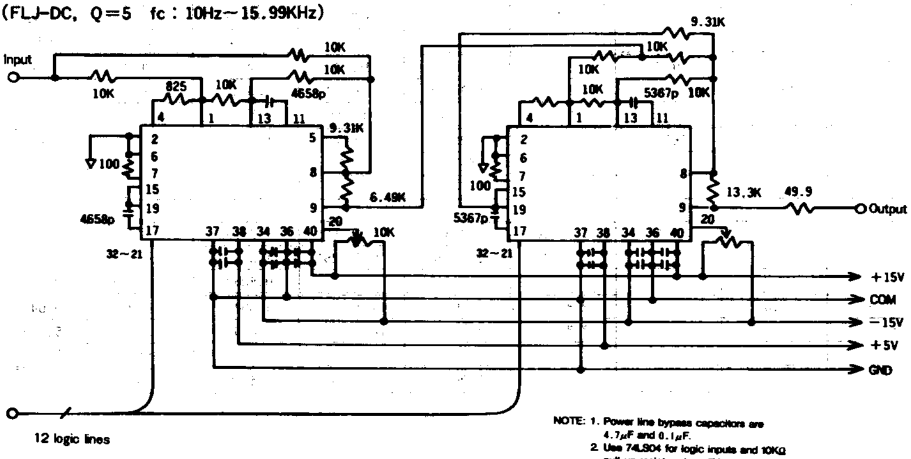
1POLE-PAIR(2 POLE)BAND ELIMINATION FILTER (Fig.13)

Inverting(I-BP, fc:10Hz ~ 15.99KHz) Q = 5



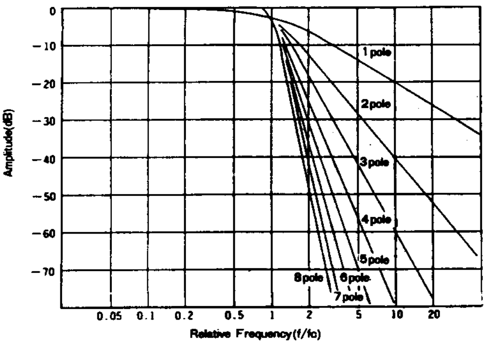
2POLE-PAIR(4 POLE)BAND ELIMINATION FILTER (Fig.14)

(FLJ-DC, Q=5 fc : 10Hz ~ 15.99KHz)

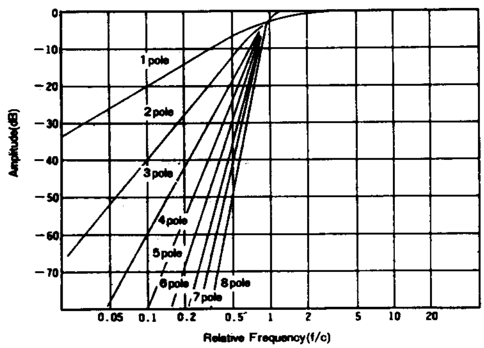


NOTE: 1. Power line bypass capacitors are 4.7μF and 0.1μF.
2. Use 74LS04 for logic inputs and 10KΩ pull-up resistors to +5V.

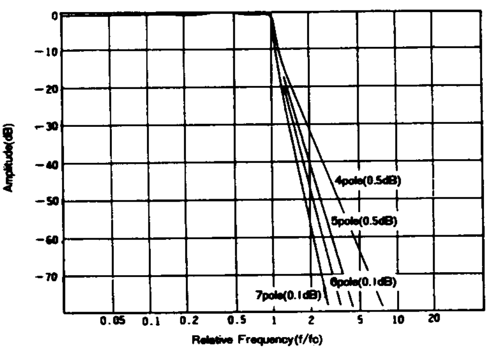
LOWPASS, BUTTERWORTH (Fig. 15)



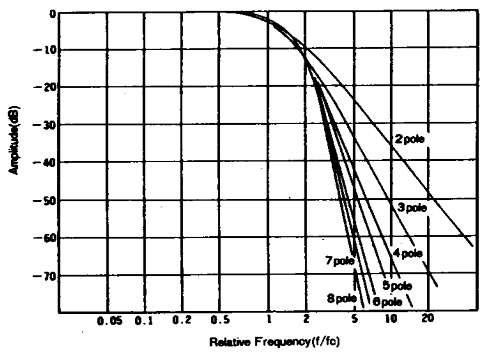
HIGHPASS, BUTTERWORTH (Fig. 16)



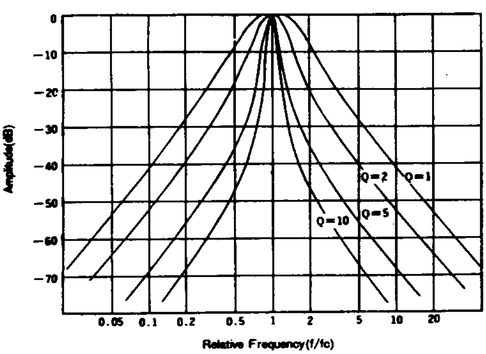
LOWPASS, CHEBYSHEV (Fig. 17)



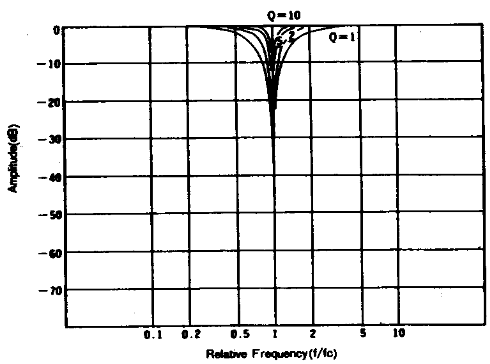
LOWPASS, BESSEL (Fig. 18)



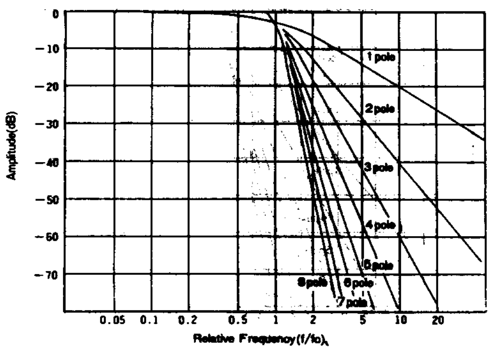
BANDPASS, 2 POLE-PAIR (4 POLE) (Fig. 19)



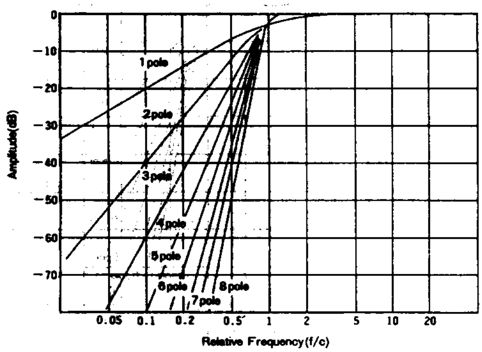
BAND ELIMINATION, 1 POLE-PAIR (2 POLE) (Fig. 20)



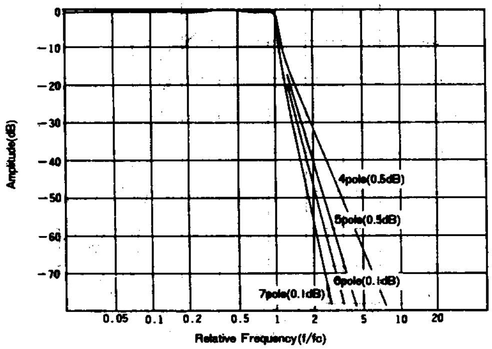
LOWPASS, BUTTERWORTH (Fig. 15)



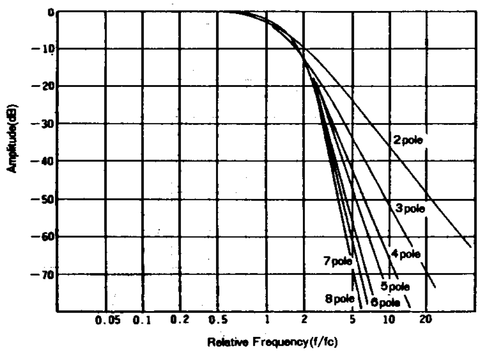
HIGHPASS, BUTTERWORTH (Fig. 16)



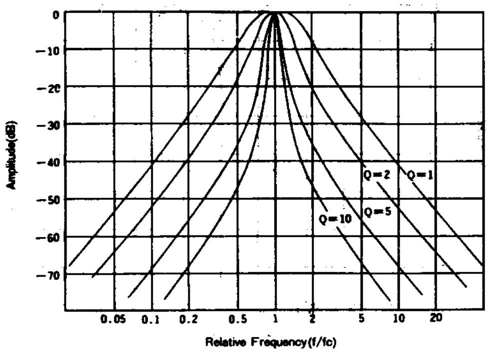
LOWPASS, CHEBYSHEV (Fig. 17)



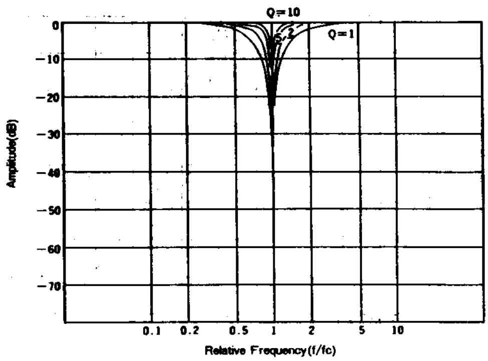
LOWPASS, BESSEL (Fig. 18)



BANDPASS, 2 POLE-PAIR (4 POLE) (Fig. 19)



BAND ELIMINATION, 1 POLE-PAIR (2 POLE) (Fig. 20)



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