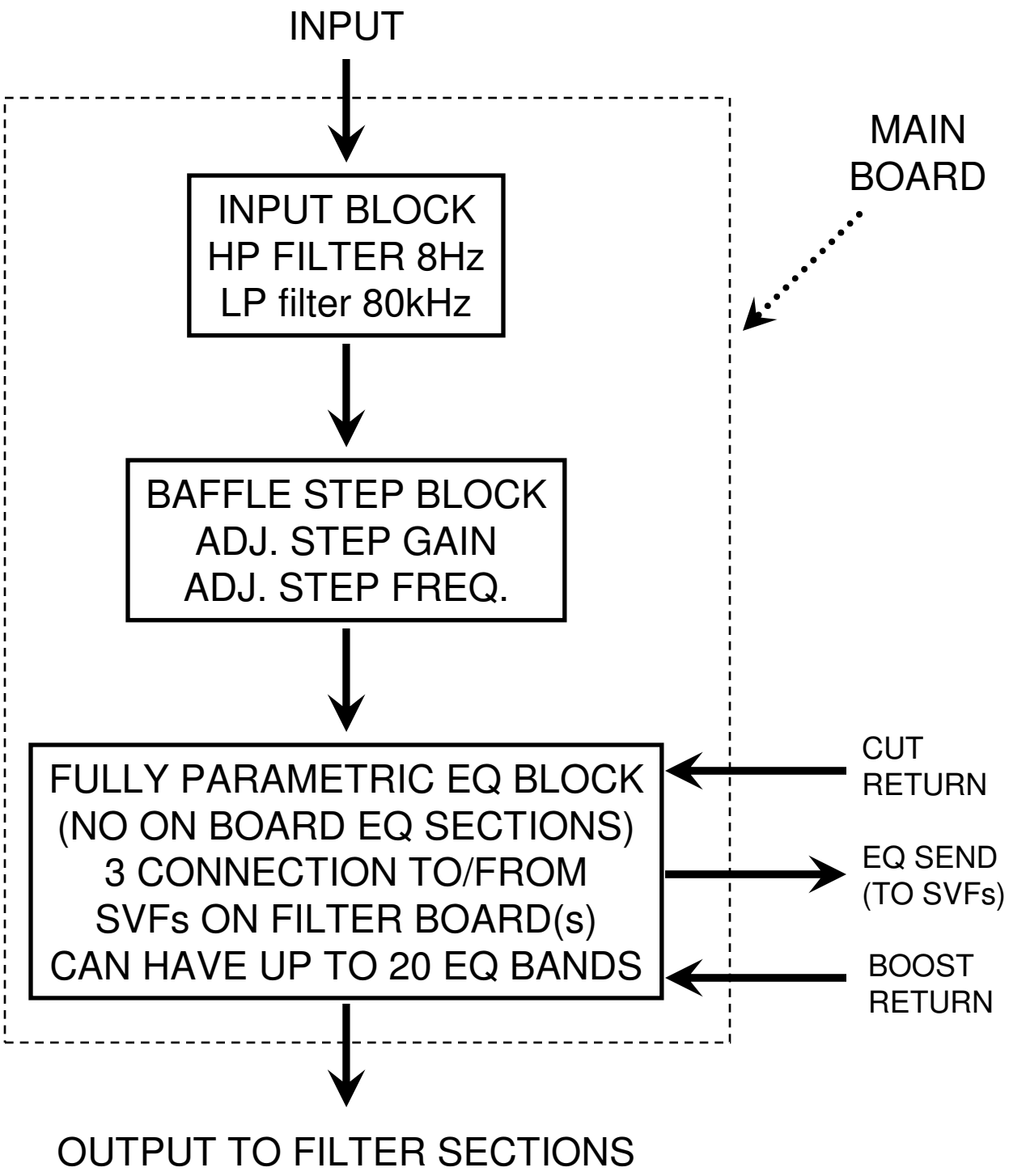
THE MODULAR CROSSOVER – AN OVERVIEW

- The crossover is a single-channel, unbalanced line-level design that permits flexible configurations, and consists of one main board plus one or more filter boards
- The main board consists of input, baffle step, and EQ circuitry
- Each filter board contains two independent filter blocks. Each block is a 2nd-order State-Variable Filter (SVF) that provides low-pass (LP), band-pass (BP) and high-pass (HP) functions.
- Each filter block may be connected either as a symmetric LP/HP second order filter OR as a fully parametric EQ band.
- Using the circuitry on the main board, the EQ adds (for boost) or subtracts (for cut) the SVF's BP output from the signal. From 0 to 20 filter blocks may be connected as EQ sections. A boost/cut range of 6dB boost to over 20dB cut can be selected via a potentiometer in each filter block. One EQ band is typically used as part of baffle step compensation
- Higher order filters can be achieved by cascading filter blocks. Likewise, 3-way, 4-way, etc. crossovers may be achieved by connecting filter blocks in to a tree topology
- The SVF topology permits all parameters on the main and filter boards to be independently adjustable via potentiometers. As a result, the system can be adapted to almost any set of drivers, and re-adjusted after the crossover has been built and installed. The adjustable parameters include:
  - Baffle Step center frequency and step size (dB)
  - Frequency of the LP/HP and EQ functions: 16 Hz – 5k Hz
  - Q of the LP/HP ($0.5<Q$) and EQ functions ($1.2<Q<20$)
- The input of each LP/HP filter block has adjustable gain. This can be used for:
  - Overall volume control
  - Output volume control for each driver when filter blocks are cascaded in to 4th or higher order topologies.
- The main board has an on-board AC to ±15VDC regulated power supply with external DC power connectors for the filter board(s)

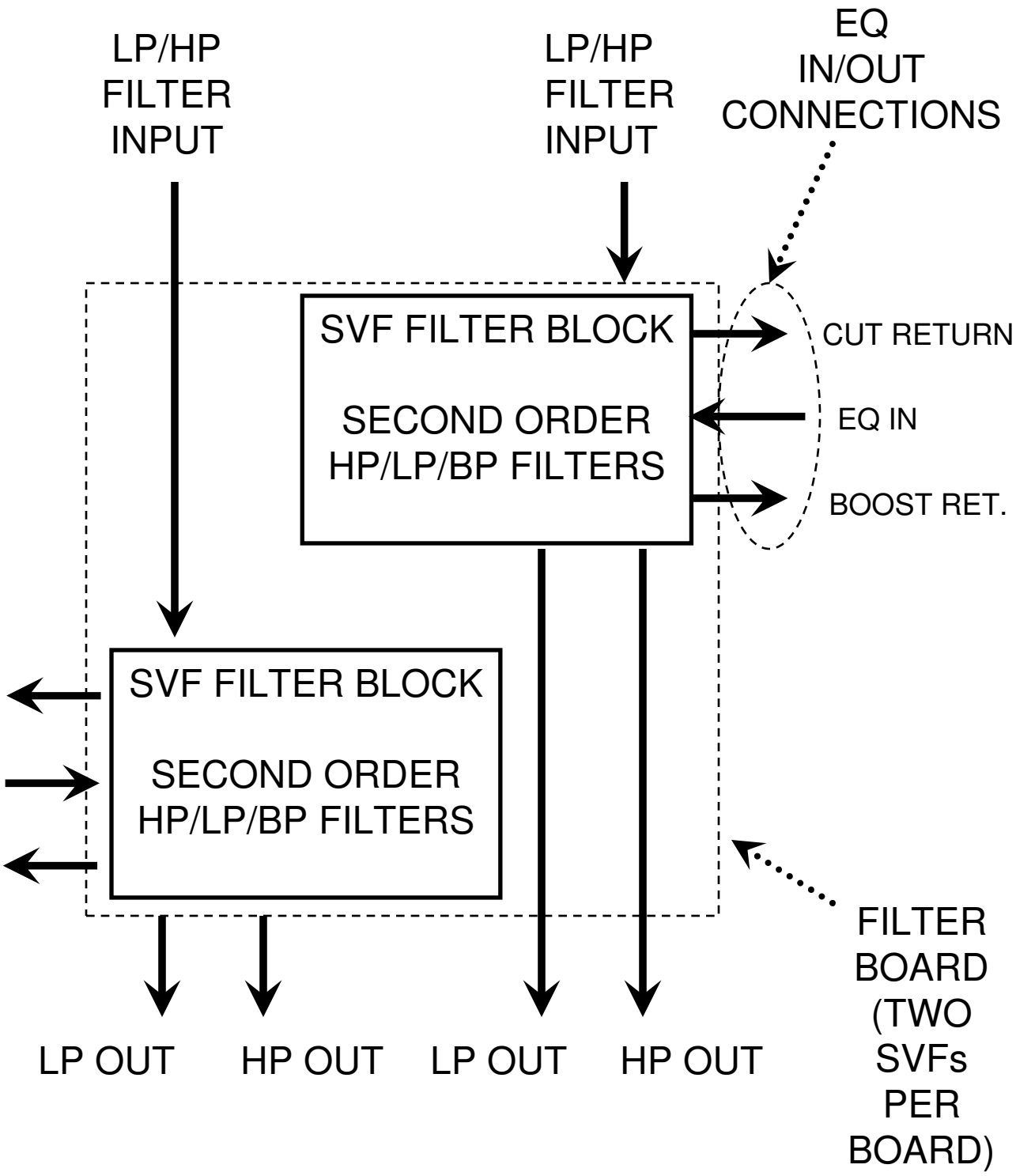
Additional Information

- Power can be supplied to the boards in several ways:
  - If the amplifier transformer's secondaries are 25VAC or less, they can also be connected to the on-board regulated PS on the main board, and the resulting DC used to power the filter board(s).
  - An inexpensive center tapped transformer with dual 16VAC - 25VAC secondaries can be used to supply the on-board regulated PS.
  - If a ± DC power supply is already available, the DC power can be supplied to the board via the DC power connectors and the components that make up the on-board regulated supply omitted.
- The flexible design permits:
  - Multi-way active loudspeakers
  - In-speaker volume control
  - In-speaker parametric EQ bands for:
    - Taming response peaks resulting from cone-breakup
    - Adjusting the speaker's "brightness" level (e.g. lower treble EQ)
    - Managing room modes in the bass range
    - providing for low end boost/cut to match response with room gain
- The crossover was conceived to be paired with in-speaker amplifiers to create an active loudspeaker. Although only even order crossovers can be created using the filter boards, first-order RC filters can easily be added to amplifier inputs to create odd order crossovers.
- By combining two or more LP/HP filter blocks and one or more EQ bands, flexible subwoofer-to-main speaker crossover systems can be constructed.
- Note that, since the EQ circuitry is located on the main board, it functions on the audio signal coming in to that board, e.g. on the crossover's input signal.
- It is important to remember that a loudspeaker in a closed box is a second order high-pass filter, and the Fc and Q of the driver-in-box can be used as part of the overall acoustic crossover.

MODULAR CROSSOVER:
MAIN BOARD BLOCK DIAGRAM



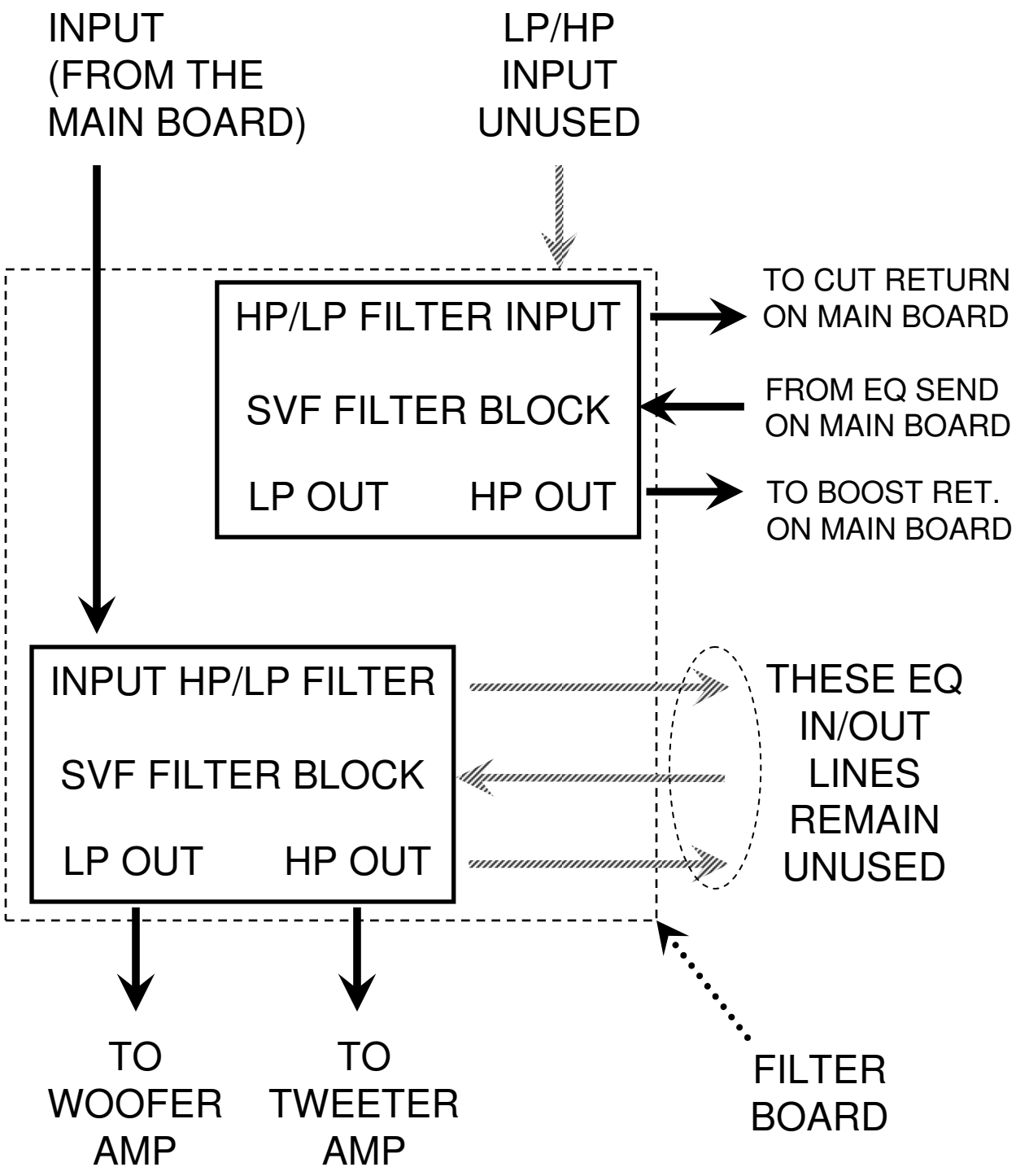
MODULAR CROSSOVER:
FILTER BOARD BLOCK DIAGRAM



EXAMPLE OF TYPICAL USE - 2-WAY SPEAKER:

2nd ORDER LP/HP CROSSOVER AND ONE EQ BAND (USED AS PART OF BAFFLE STEP COMPENSATION)

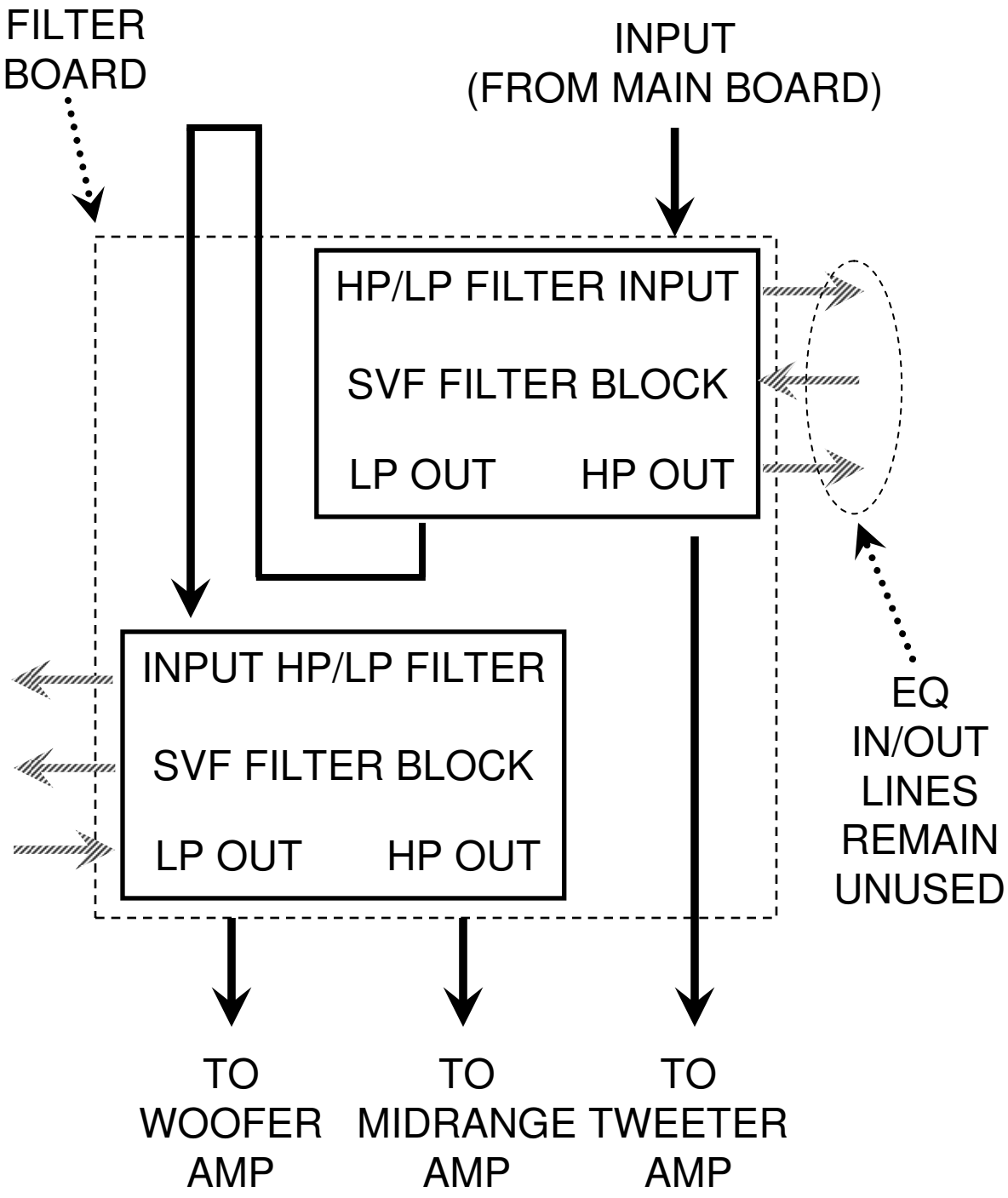
NOTE: MAIN BOARD NOT SHOWN



EXAMPLE: 3-WAY SYSTEM

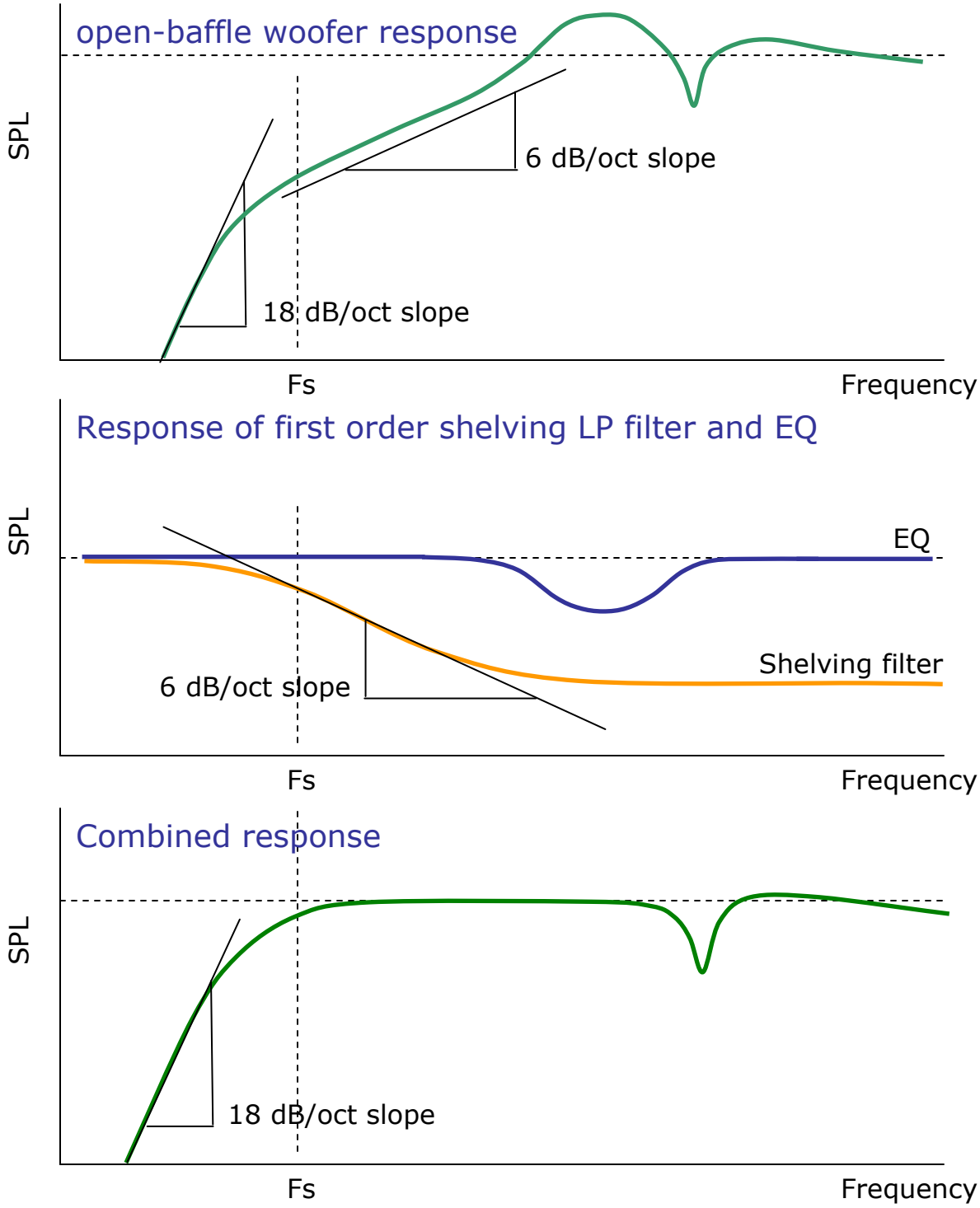
TWO SECOND ORDER CROSS-OVERS

NOTE: MAIN BOARD NOT SHOWN



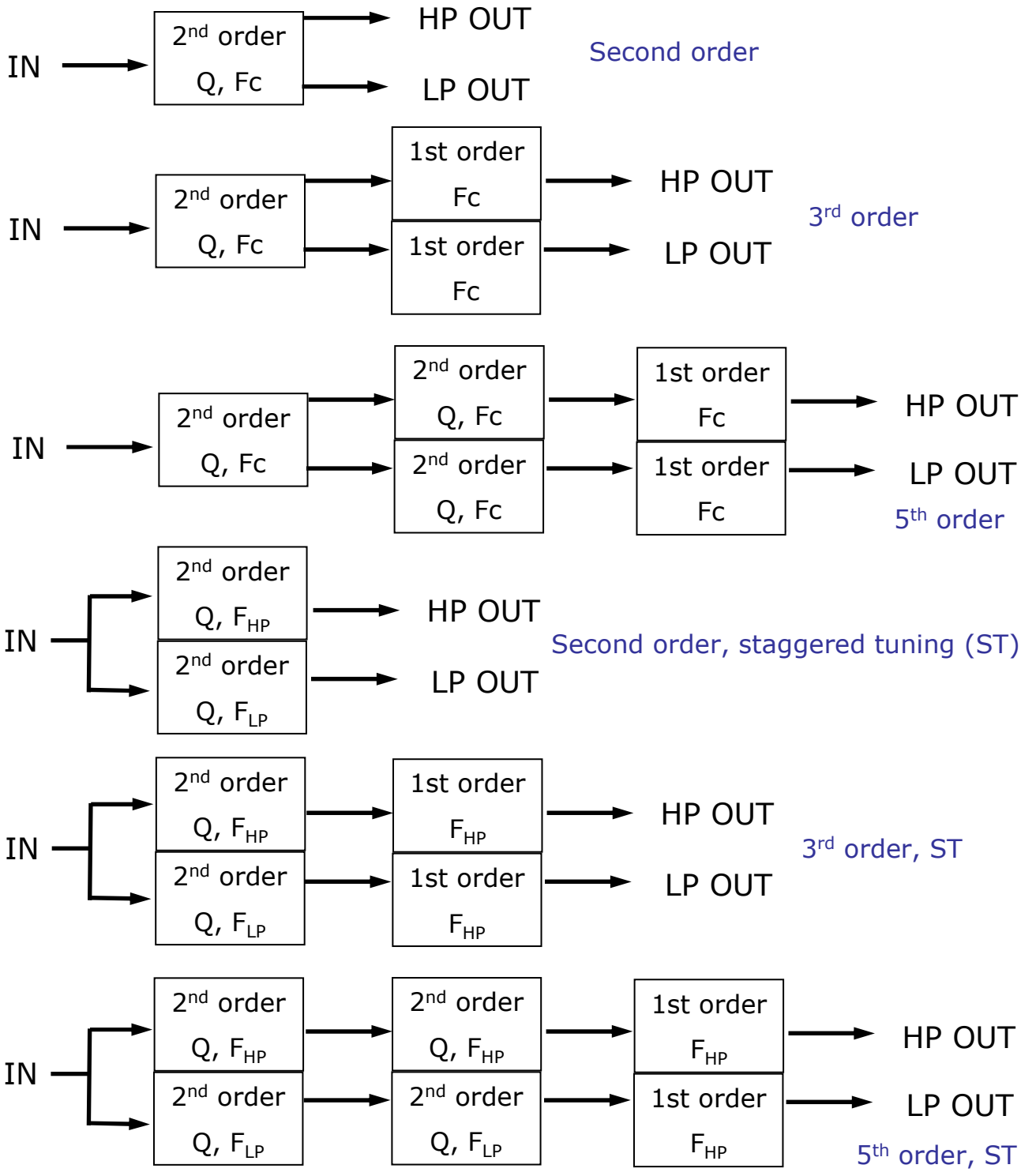
COMPENSATING FOR OPEN BAFFLE ROLL-OFF

The baffle step circuit on the main board is a first order LP shelving filter. As a result, this circuit can be combined with an EQ band to flatten the response of open-baffle loudspeakers, which roll off at 6dB per octave above driver resonance, and often have a peak and null in the response, as illustrated below.



Designing an Active Crossover using the Filter Blocks

1. Select Order, Crossover Type, and Crossover Frequency (Fc)
2. Look up values for Q, F_{LP}, and F_{HP} in table
3. Use examples below to connect filter blocks. IN = input from main board

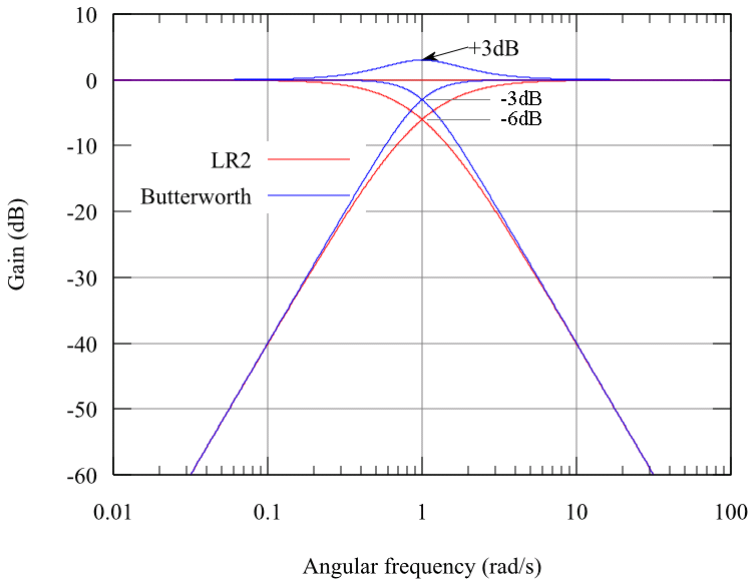


TABLES OF FILTER ORDER AND Q

Symmetric Tuning Type Crossovers

TYPE	STAGE	ORDER	Q	F_{HP}	F_{LP}
BUT-2	1	2	0.71	1.000	1.000
BUT-3	1	1		1.000	1.000
	2	2	1.00	1.000	1.000
BUT-4	1	2	0.54	1.000	1.000
	2	2	1.31	1.000	1.000
BUT-5	1	1		1.000	1.000
	2	2	0.62	1.000	1.000
	3	2	1.62	1.000	1.000
LR-2	1	2	0.50	1.000	1.000
LR-4	1	2	0.71	1.000	1.000
	2	2	0.71	1.000	1.000
LR-6	1	2	0.50	1.000	1.000
	2	2	1.00	1.000	1.000
	3	2	1.00	1.000	1.000

BUT = Butterworth; LR = Linkwitz-Riley. Note that $F_{HP} = F_{LP} = F_C$ for these types.



Comparison of the frequency response (on axis) for BUT-2 and LR-2 crossovers

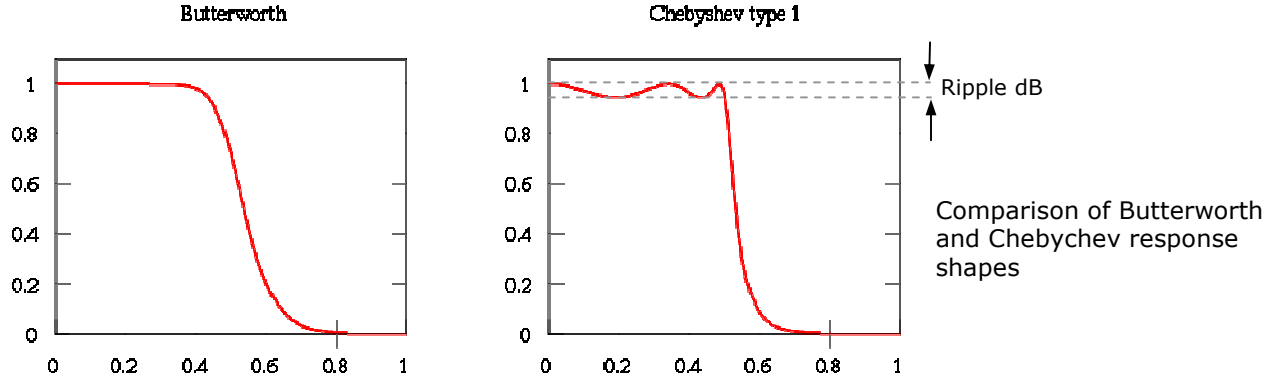
FOR MORE INFO SEE: http://www.musicanddesign.com/Power.html

Chebyshev (Staggered Tuning) Crossovers

TYPE	STAGE	ORDER	Q	F_{HP}	F_{LP}
CHEB1(0.5)-2	1	2	0.863	0.812	1.231
CHEB1(0.5)-3	1	1		1.263	0.791
	2	2	1.71	0.935	1.069
CHEB1(0.5)-4	1	2	0.70	1.675	0.597
	2	2	2.95	0.970	1.031
CHEB1(0.5)-5	1	1		1.661	0.601
	2	2	1.18	1.448	0.690
	3	2	4.55	0.982	1.018
CHEB1(1.0)-2	1	2	0.95	0.952	1.050
CHEB1(1.0)-3	1	1		1.423	0.703
	2	2	2.02	1.000	0.997
CHEB1(1.0)-4	1	2	0.78	1.892	0.528
	2	2	3.56	1.007	0.993
CHEB1(1.0)-5	1	1		1.859	0.538
	2	2	1.39	1.526	0.665
	3	2	5.56	1.001	0.994

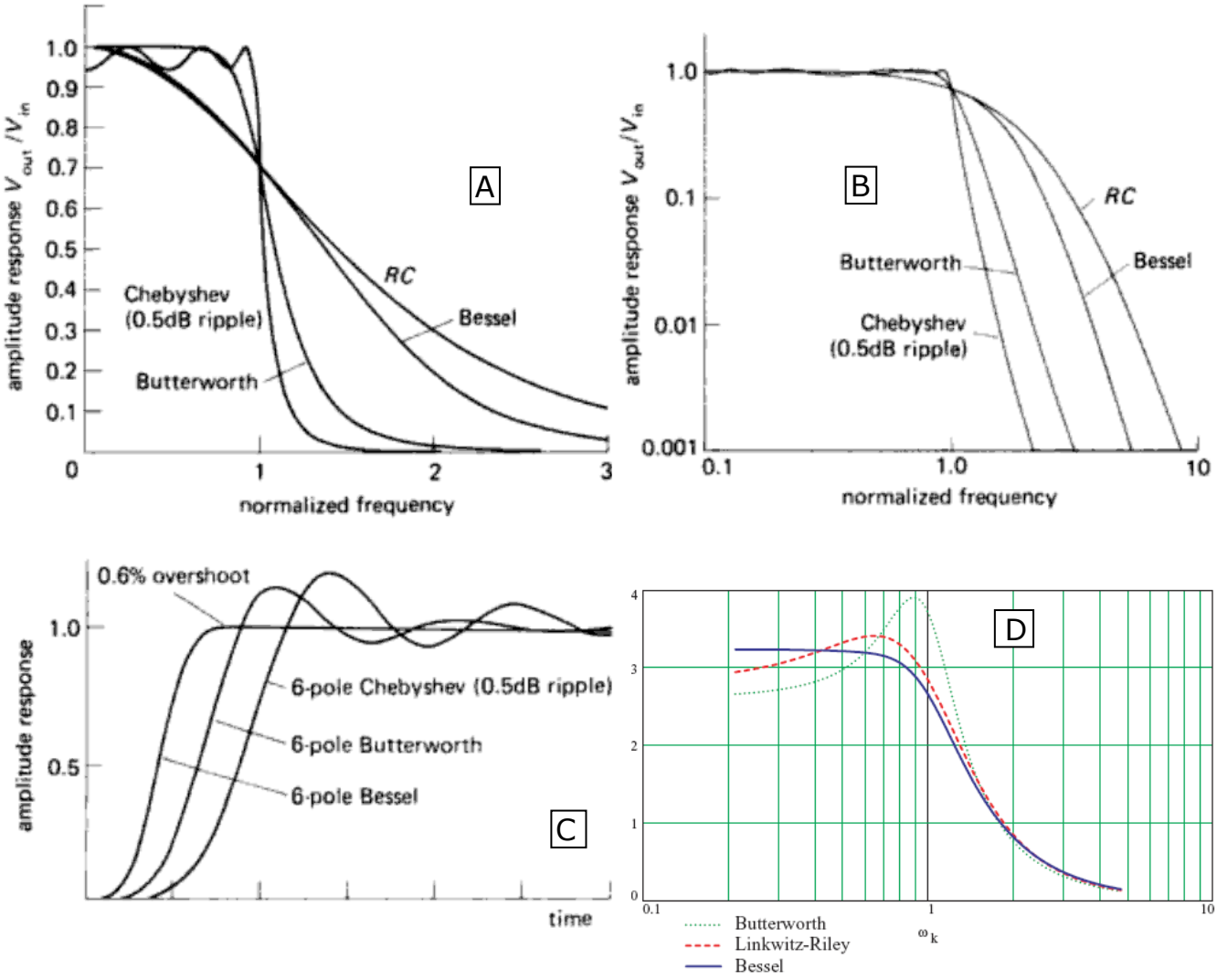
CHEB1(0.5) = Chebychev Type 1, 0.5dB Ripple
CHEB1(1.0) = Chebychev Type 1, 1.0dB Ripple

The crossover frequency is normalized to Fc=1.0. The high-pass (HP) and low-pass (LP) corner frequencies must be set to the multiples shown (F_{HP}, F_{LP}), e.g. for a 1000 Hz crossover point, the CHEB1(1.0)-3 LP crossover is a second order section with Fc=997 Hz and Q=2.02 connected in series to a first order stage with Fc=703Hz.



Comparison of Butterworth and Chebychev response shapes

Comparing the performance of different type of filters



LEGEND:
A: Frequency response comparison, with linear y-axis
B: Frequency response comparison, with log y-axis (note 0.1 = -20dB)
C: Step response comparison of 6-pole (6^{th} order) filters
D: Group Delay comparison for BUT, LR and Bessel 4^{th} order filters

In general, Bessel type has good transient response but slow attenuation for a given filter order and slow increase of attenuation rate with filter order. Chebyshev has steep attenuation at the edge of the passband, but has ripples in both the frequency and time domains. The Butterworth type has flat passband frequency response and transient properties that are in-between Bessel and Chebyshev. The properties of Linkwitz-Riley crossovers are similar to Butterworth and are in between Bessel and Chebychev.