SOUND SYNTHESIS IN LOGIC PART 1: SUBTRACTIVE

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WHAT IS A SYNTHESISER?

- What does it do?
- What does it not do?
- Attempt at a definition?
- **Key point: synthesisers build up complex sounds from component processes.** It is important to understand how these components work so that you can eventually create more complex sounds (either ‘from scratch’, or customising existing sound presets)

SOUND SYNTHESIS

- Generating musical or non-musical timbres (aka 'sound textures') from

  (1) fundamental building blocks such as pure tones (sine waves/single–frequency components - similar to the sound produced by a tuning fork)

  (2) complex sound waves electronically shaped by filters (tone controls) or distortion

- *Timbre* = tone colour or sonic 'signature'
- *Synthesisers* (aka synthesizers) - pieces of equipment which generate sound through a variety of processes (additive, subtractive, mathematical models and/or processes)

SYNTHESIS TECHNIQUES

- As implied by the foregoing, there are many different types of technique by which you can synthesise sound
- Some are good at producing **'realistic' instrument sounds**, others are useful for more **abstract or 'electronic-sounding' timbres**
- **(1) Additive synthesis:** creates sounds based on **adding simpler component sounds**-- 'pure tones' (sine waves, which are vibrations which produce only one frequency component)--to construct a complex sound with many frequency components =>**not used in most software synthesisers due to its complexity**

SYNTHESIS TECHNIQUES

- (2) **Subtractive synthesis** - a **rich sound** (with many frequency components) is **shaped by a filter**--early **analogue synthesisers were of this type** (although we now use digital methods to achieve the same type of sonic results)

- (3) **Modulation synthesis** - one **sound generator imposes its vibration on another one** (in a similar manner to vibrato in an acoustic instrument) at a high frequency, causing the resulting vibration to become more complex (original sound wave is 'bent out of shape'), **resulting in a richer sound**

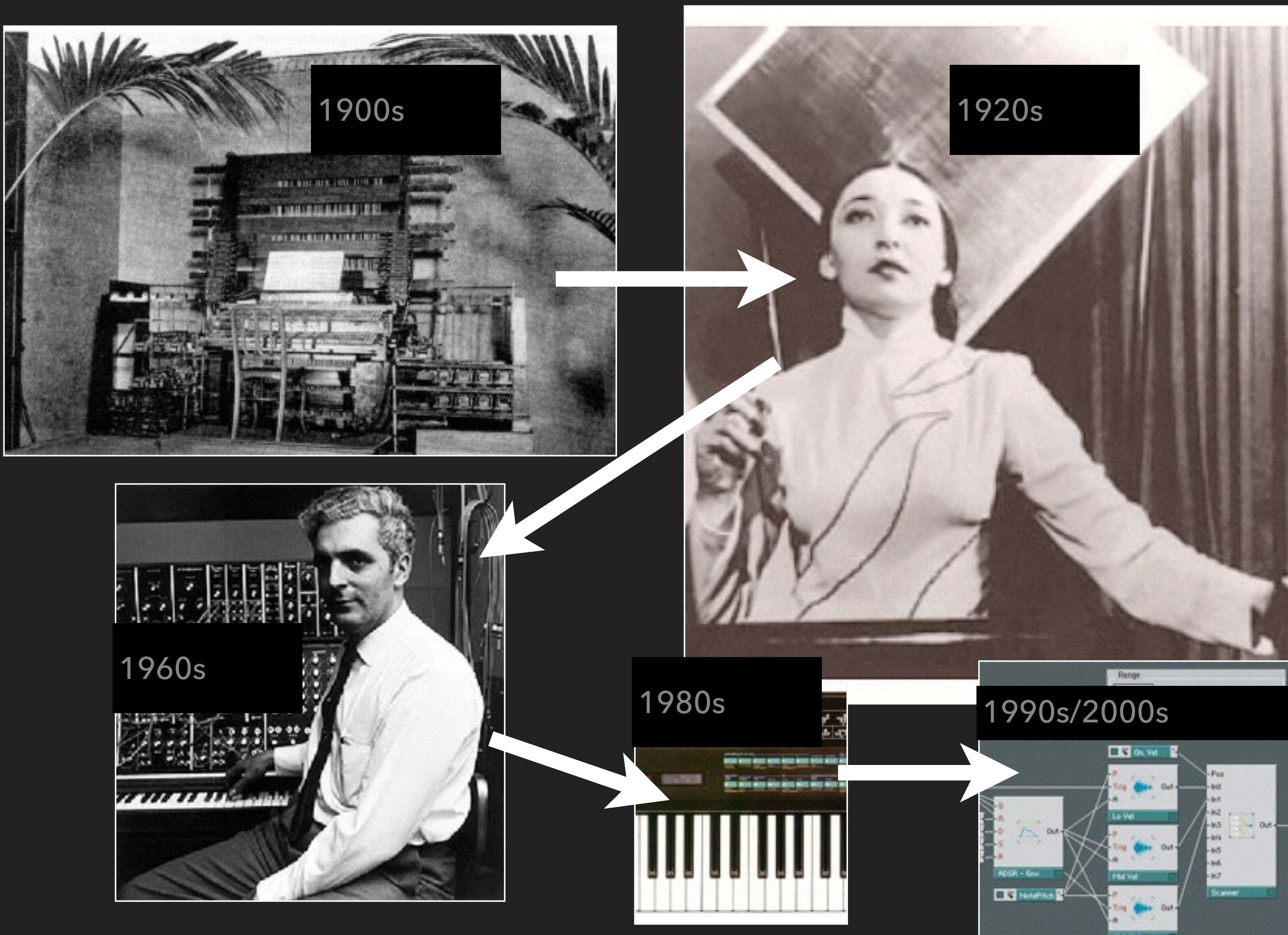
SYNTHESIS TECHNIQUES

- (4) **Physical modelling synthesis** - a musical sound is generated based on a **simplified mathematical model of the physical system in a known musical instrument** (or an extrapolation of one)
- (5) **Wavetable synthesis** - a **musical sound is generated through 'scrolling' (reading) through a 'table' of different soundwave shapes** (think of them as like film/video frames), resulting in a sound whose timbre evolves as the wave shapes change
- *[Confusingly, any digital sound generator which reads off a set of digital numbers to produce a given wave shape can be said to be using a wavetable, but **wavetable synthesis is properly reserved for this dynamic version**]*

OTHER SOFTWARE INSTRUMENT TECHNIQUE

- (Not synthesis) **Sampling** can be used to create realistic emulations of acoustic instruments - **digital recordings** are taken of individual notes which are combined into a compilation which evokes a useful range of musical materials to generate a new musical performance (different notes can be generated from a single recording based on playing it back faster or slower)

RECAP: A PICTORIAL HISTORY



SYNTHESIS IN LOGIC

- Logic has a number of synthesisers built into its software environment
- A **software synthesiser** is one which generate sound by means of a programme running on generic computer hardware, such as a personal computer
- This is in contrast to a **hardware synthesiser** (keyboard or sound module), which produces its sound using dedicated pieces of electronics (advantage - stability; disadvantage - lack of flexibility/expense)
- Software synthesisers are often called **plugins** because they are often separate from the music programme you are using, but are connected via the software equivalent of an audio lead and plug

LOGIC'S MAIN SOFTWARE INSTRUMENTS/SYNTHESISERS

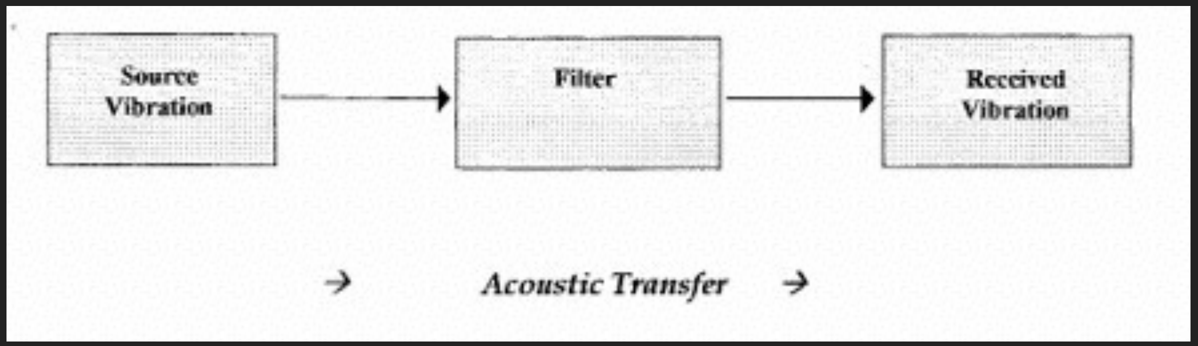
- **Subtractive:** ES1, ESP, ESM, ESP
- **Hybrid:** ES2 (subtractive plus wavetable synthesis)
- **Modulation:** EFM1
- **Physical Modelling:** Sculpture, single-instrument physical mods (EVP88, EVD6, EVB3)
- **Drum machine:** Ultrabeat (sampler plus synthesiser-based instrument components)

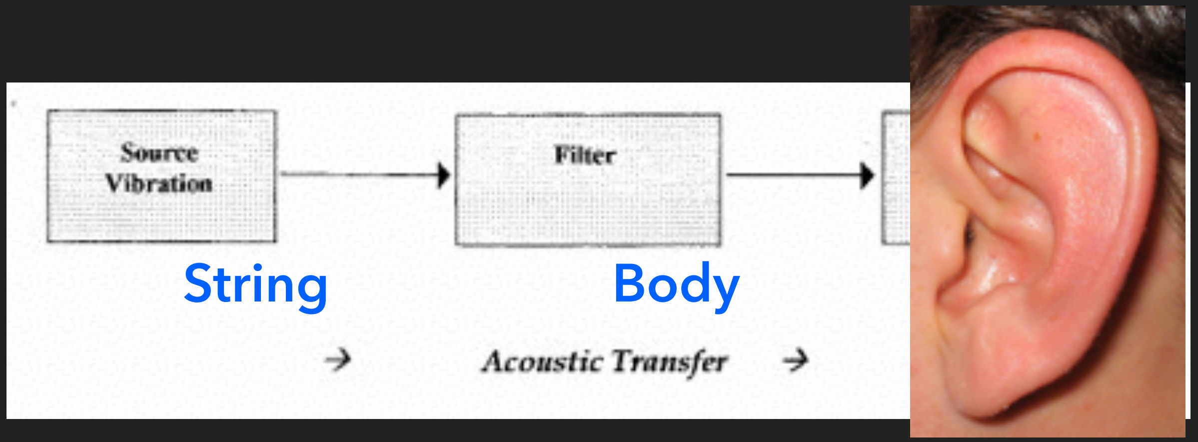
FOCUS ON SUBTRACTIVE SYNTHESISERS

- ***Subtractive synthesis:*** *popularised by Moog in the 1960s and 1970s*
- **ES1:** Logic’s most complex ‘pure’ subtractive synthesiser (can be monophonic or polyphonic)
- **ESM:** Monophonic subtractive synthesiser (useful for bass/lead sounds)
- **ESE:** ‘Ensemble’ synth––simple polyphonic subtractive synthesiser
- **ESP:** Polyphonic subtractive synthesiser (more complex than ESE, generally simpler than ES1, but somewhat distinct design choices)
- Retrosynth: New in Logic X: analogue, wavetable and FM

A MODEL FOR SOUND: SUBTRACTIVE SYNTHESIS

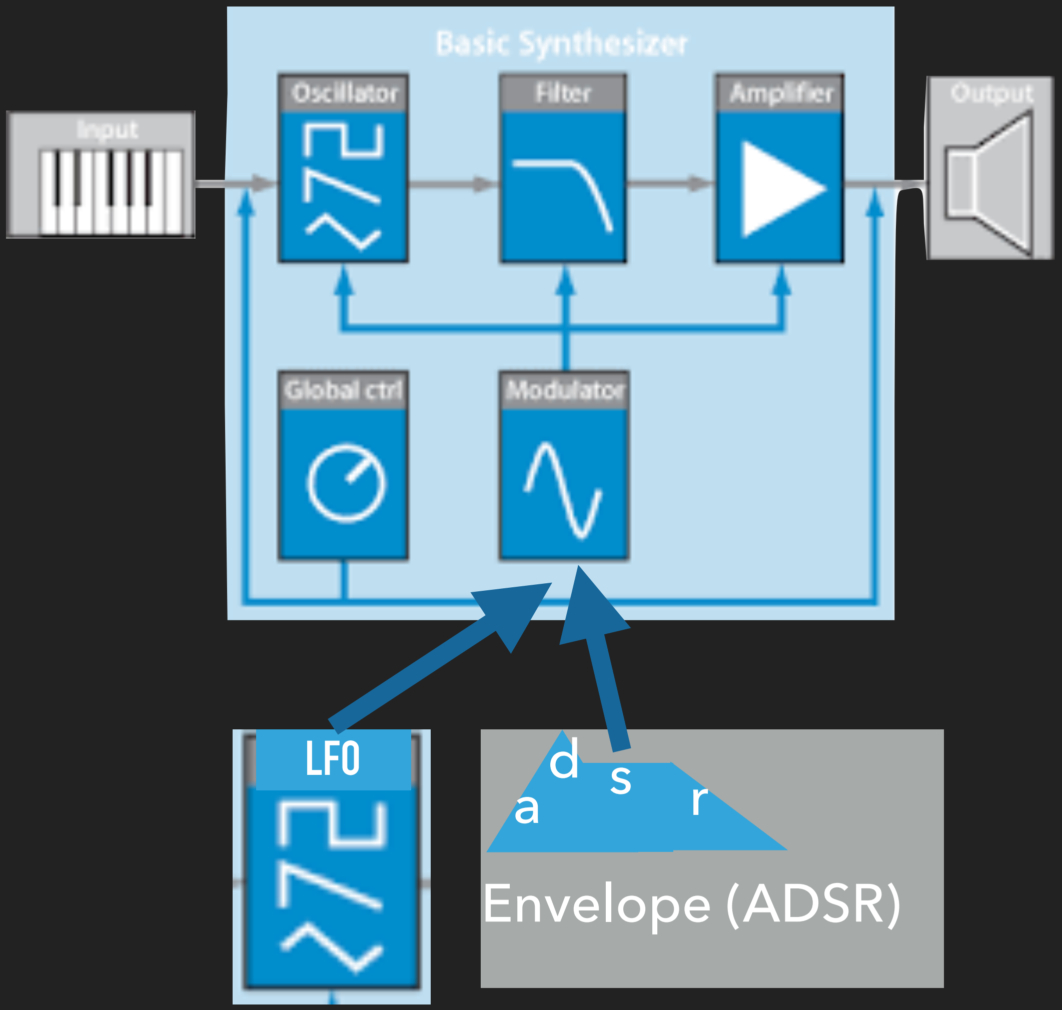
- Many of Logic's synthesisers are based on the **subtractive** model - they **take a rich sound and shape it in frequency content and amplitude**
- The 'pattern of frequencies' (and their relative strengths) in a sound source is what gives sounds their characteristic 'signature' (or timbre)
- This type of model can also be found in acoustic instruments
- Sound source (oscillator)
- Filter (electronic/digital tone control)





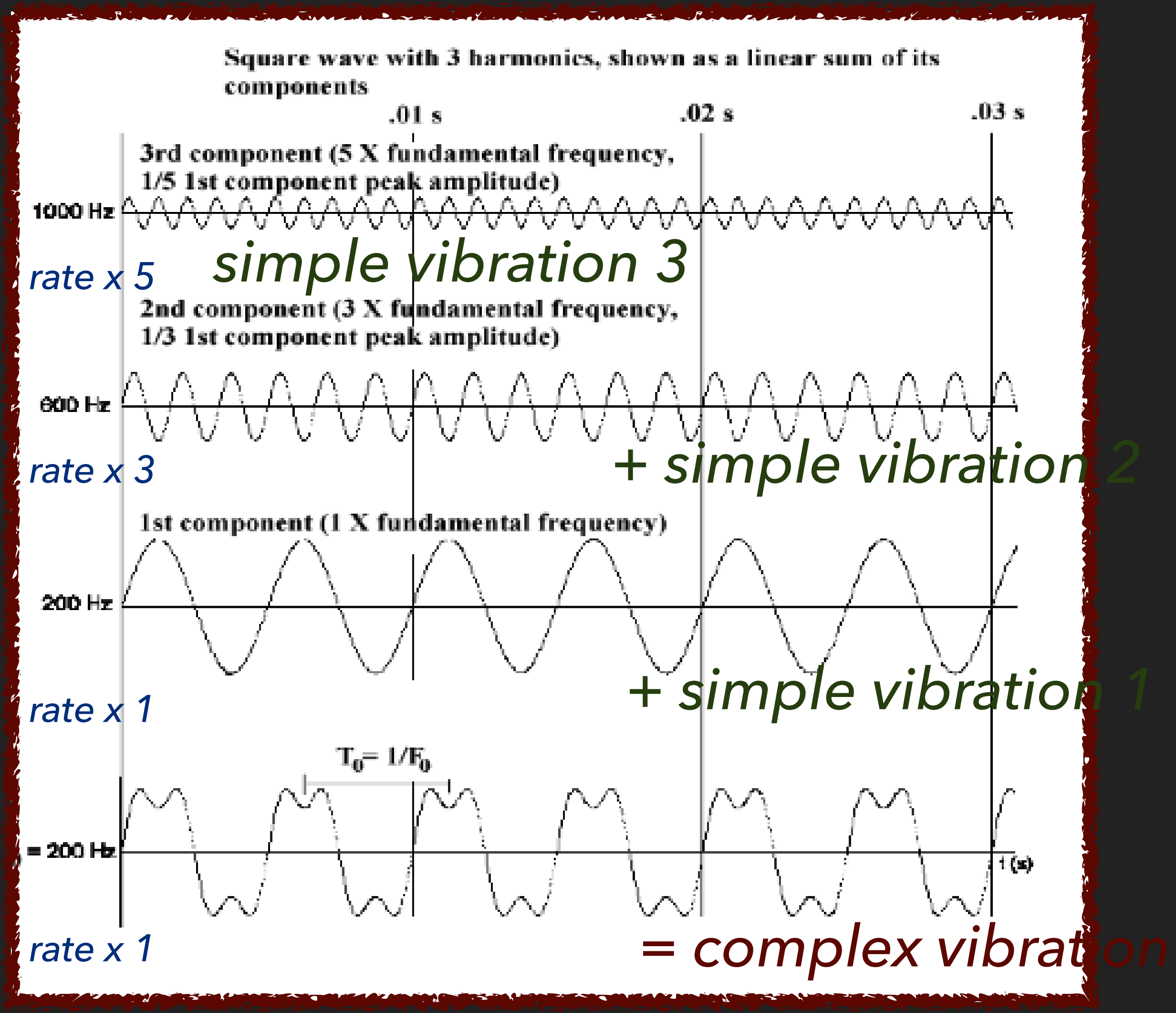
SIMPLE SYNTHESISER

- Oscillator - sound-wave generator
- Amplifier
- Envelope (ADSR) - control signal - contour generator
- LFO - low frequency oscillator - control signal
- Filter: remove frequences above or below a cutoff frequency



SOURCE: OSCILLATOR WAVE SHAPE AND TIMBRE

- We have already learned that subtractive synthesis is based on the shaping of rich sound sources using filters, changing their frequency content (and the relative strengths of these frequencies)…But what does this mean exactly?
- It's based on the concept that **a complex vibration** (such as a sound wave, or a digital description of one) **can be analysed as the sum of simple vibrations, each at single frequencies (rates)**
- This pattern of frequencies (or **spectrum**) allows us to identify different sounds/ instruments/**timbres…** we actually hear sounds in this way, as **part of our inner ear acts as a frequency analyser**



BASIC SOUND WAVES FOR SUBTRACTIVE SYNTHESIS

- So, the spectrum of a sound (and, hence, its timbre) is based on our perception of the pattern of these single-frequency components (called **harmonics**, or, in more scientific terms, **partials**)

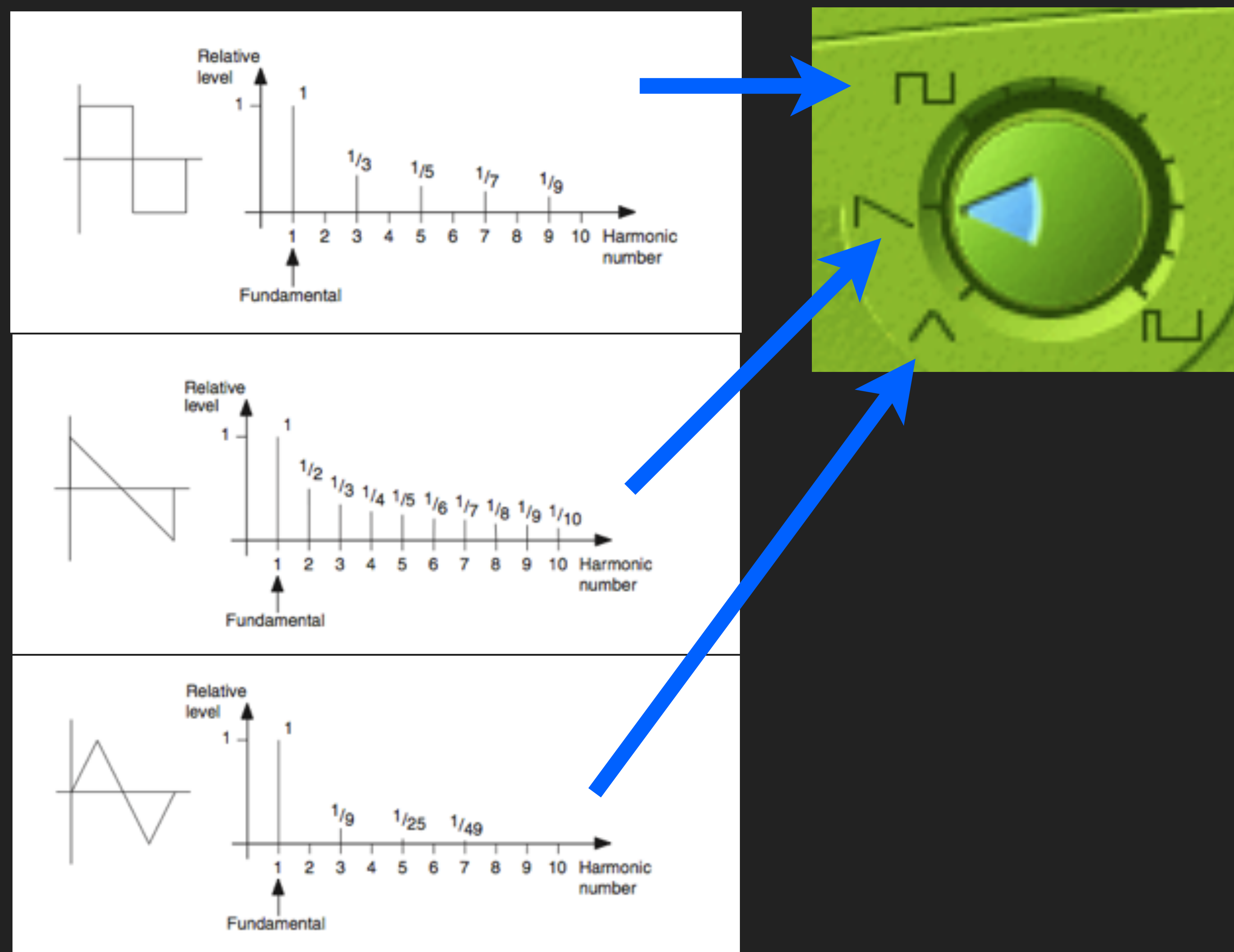
- Subtractive synthesisers start off with certain sound waves which have characteristic frequency content (with significant numbers of harmonics to 'shape' with the filter)

- **Although we can think of the waves in terms of their frequency content** (and that is how we hear them), **most basic subtractive synthesisers use the shorthand of a graphic of their wave shape**

- **The most commonly-used shapes** are simple geometrical figures: **squares/ rectangles, triangles, sawtooth** ('1/2 triangles', stepping up or down)

LIST OF COMMON SOUND WAVES USED BY SUBTRACTIVE SYNTHESISERS

- Square
- Sawtooth
- Triangle



Diagrams from Russ (2009, pp.210–11)

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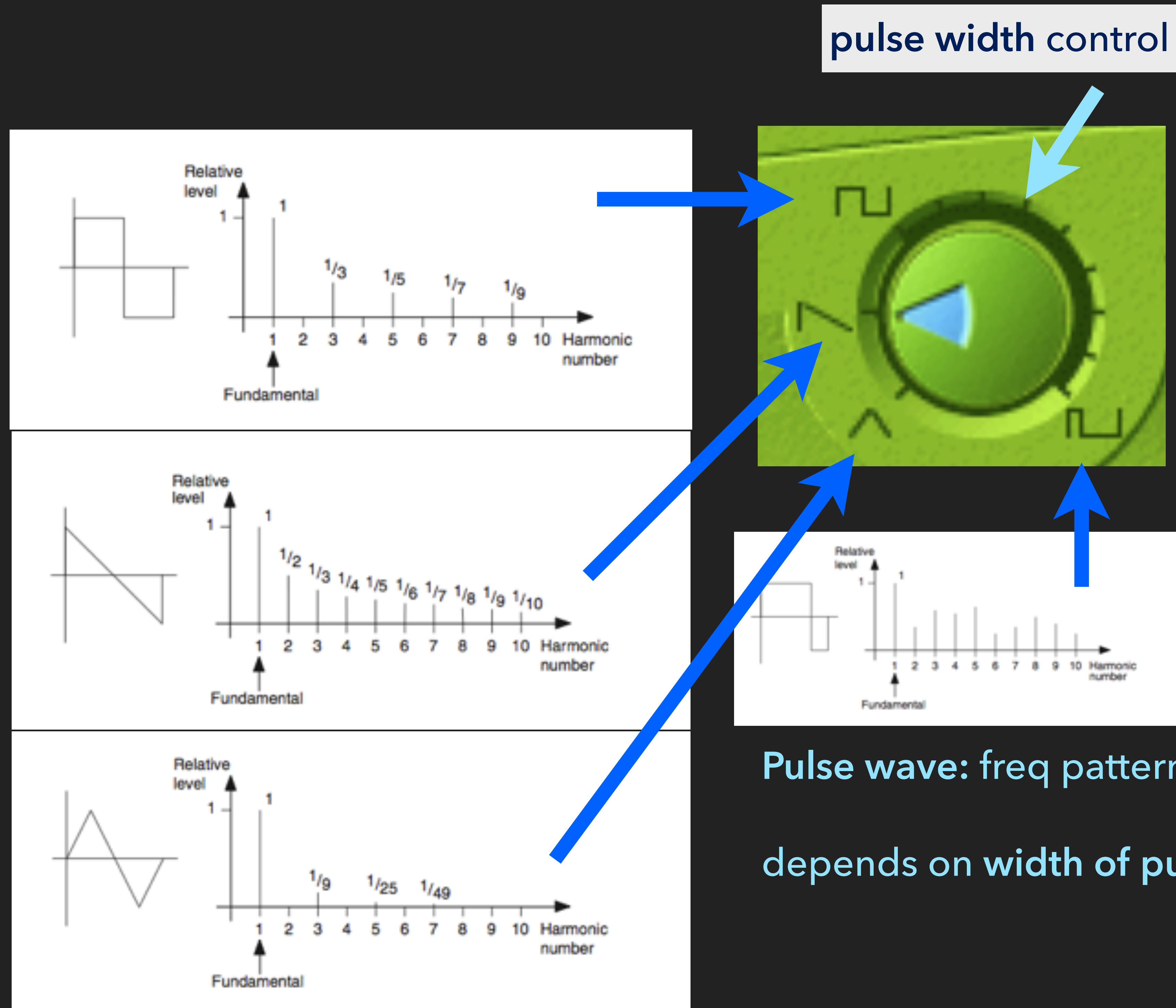
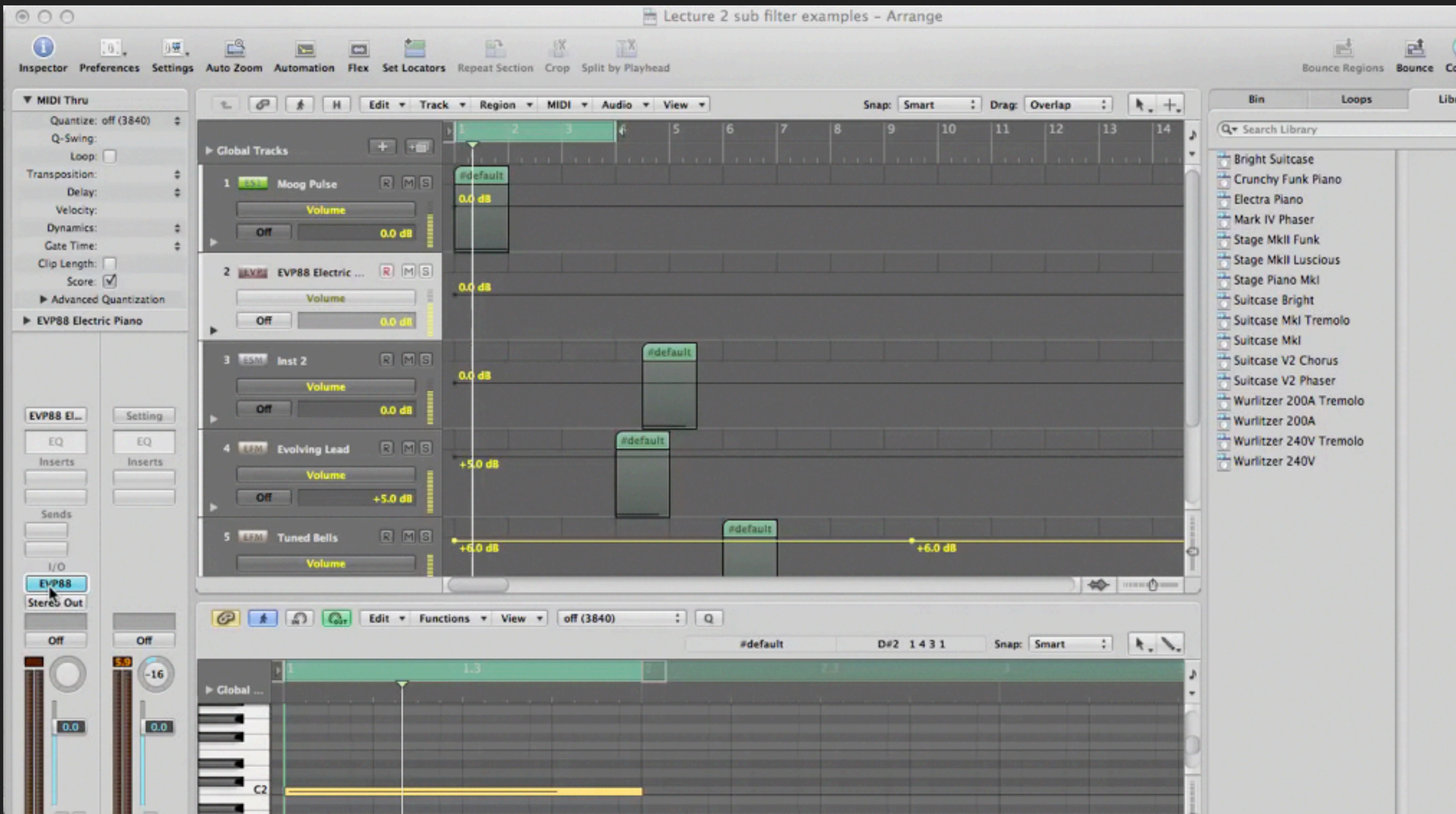


Pulse wave: freq pattern depends on **width of pulse**

Diagrams from Russ (2009, pp.210–11)

SELECTING A SUBTRACTIVE SYNTHESISER



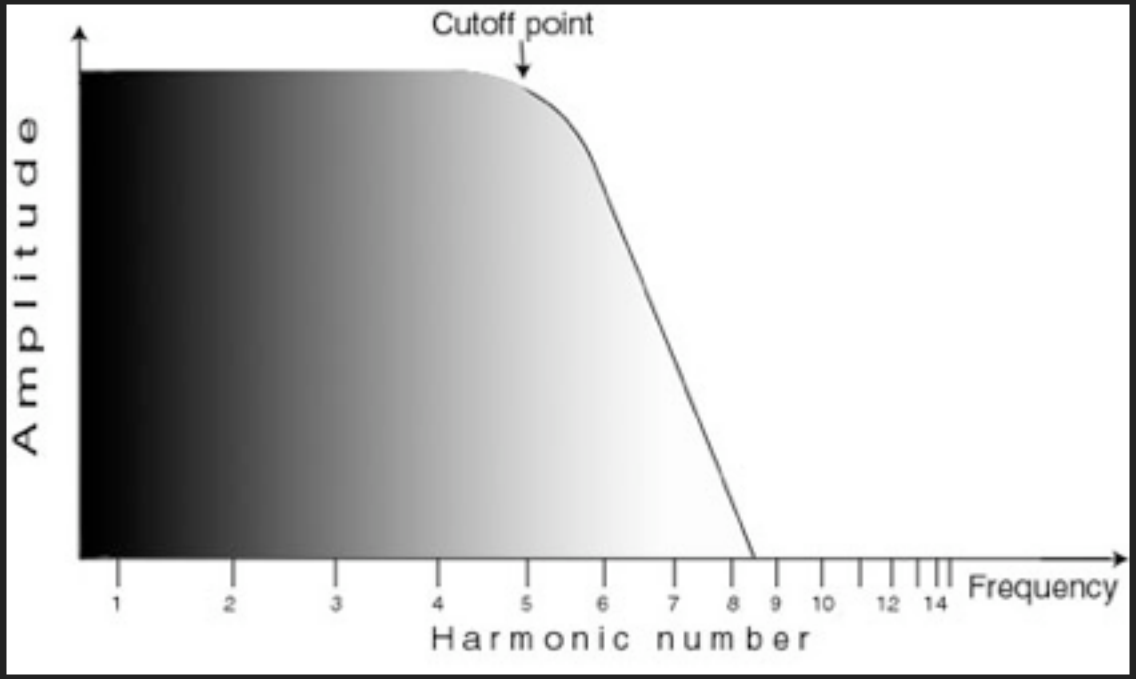
LOGIC'S ES1: OSCILLATOR WAVES

FILTERS

- All of the sounds we have heard so far have been created using only the selection of different types of wave shapes
- To add more complexity to our sounds (i.e. to shape the spectrum) in subtractive synthesis, we use filters
- Common types in subtractive synthesis:
- **Low-pass filter** - takes away high frequencies above a certain **cutoff frequency**, allows low ones to 'pass'
- **High-pass filter** - takes away low frequencies below a certain **cutoff frequency**, allows high ones to 'pass'
- **Band-pass filter** - filters above and below a certain **centre frequency**, allows frequencies around the centre frequency to pass

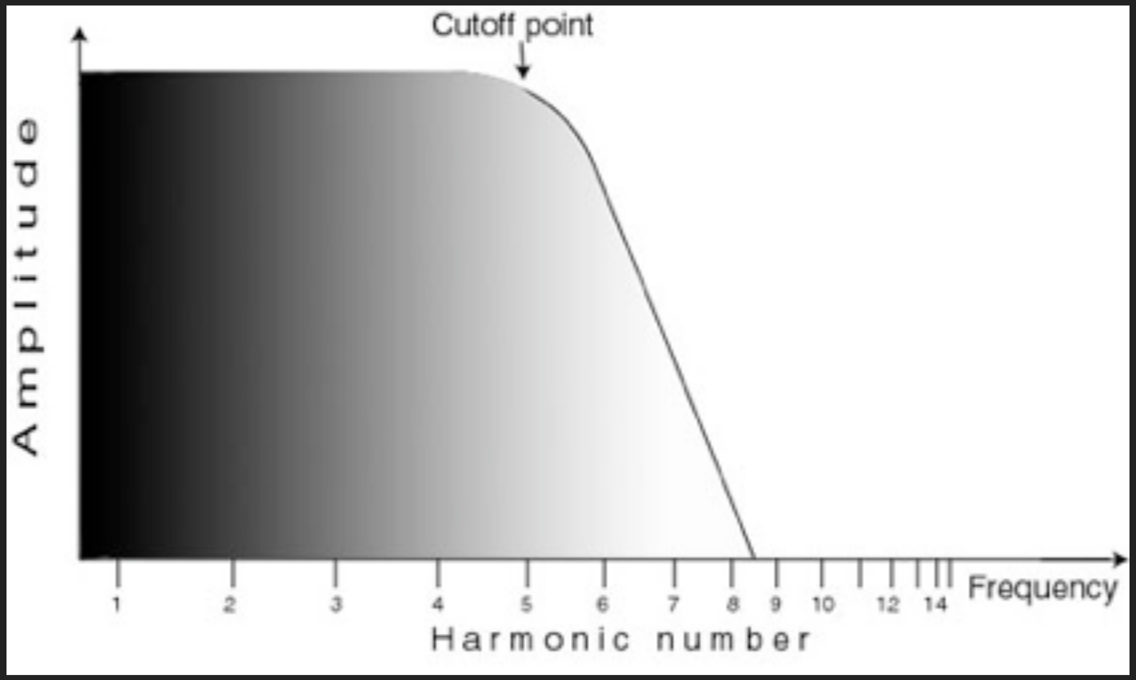
LOW—PASS FILTERS

- **Low-pass filters are the most commonly-used** filters in subtractive synthesisers
- As we saw earlier, you can think of them as being based on the body of a musical instrument, which will tend to amplify the output of a vibrating string, reed etc., but will amplify different frequencies by different amounts
- To make a simple but effective synthesised sound, one of the most important things to do is to **differentiate between bright/harsh** and **muted/dull timbres** by applying low-pass filtering

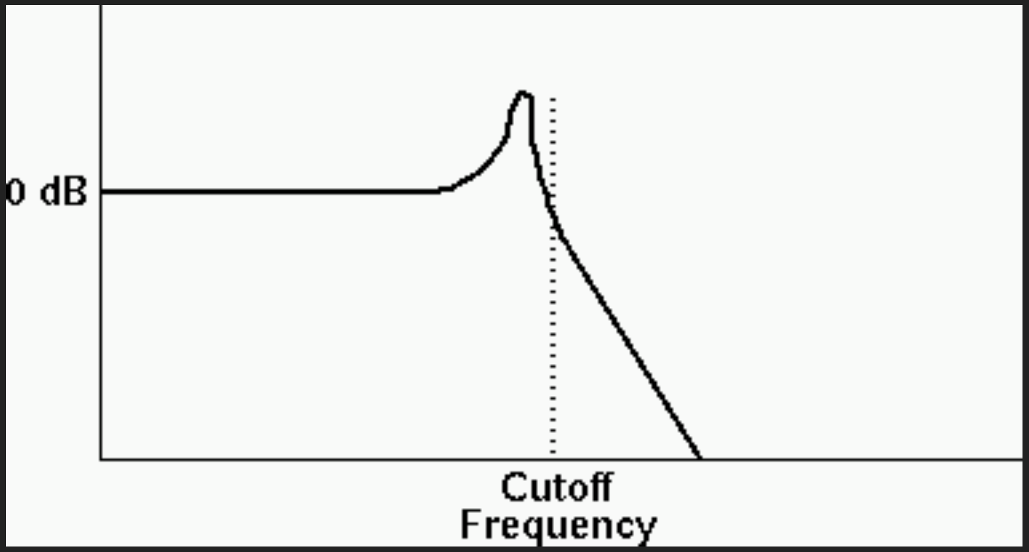


LOW-PASS FILTER CONTROLS

- Cutoff frequency - filter above this frequency
- Resonance (or Q) - feeds signal output back into the filter again - boosts amplitude around cutoff frequency - ‘ringing’ sound



Low-pass filter



Low-pass filter with resonance

FILTER SWEEPS (ON THE ES1)

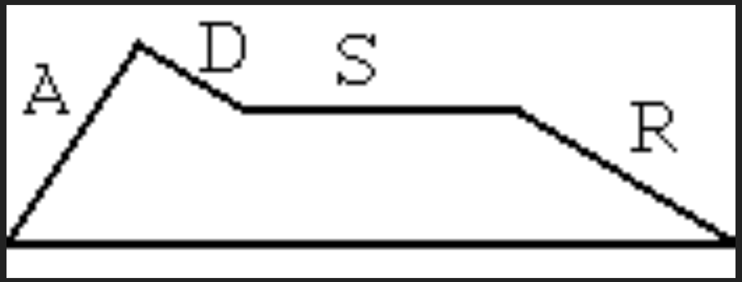
SUMMARY: OSCILLATOR AND FILTER

- We now have the main components of our subtractive synthesiser sound
- The source (oscillator) has a wave shape which possesses many different frequency components
- The filter selectively removes some of these, changing the 'balance'/'weight' of the sound's frequency spectrum so that we hear changes from 'bright' to 'dark/dull'
- But so far, we've only controlled these by hand

MODULATION SOURCES

- Moog's key invention from 1964 was a **system of remote control for synthesiser hardware** which enabled **control signals to automate processes such as filter sweeps** (which we have just seen) and basic changes in level (for describing the changes in overall loudness over time which are common characteristics of musical instruments)
- Such control signals are commonly termed **modulation sources**
- Modulation sources can be anything which automate synthesis controls/parameters
- *Not to be confused with modulation synthesis (in this context, 'modulation' is relatively slow automation of synthesis controls/parameters*

MOD SOURCE 1: ENVELOPE - ADSR

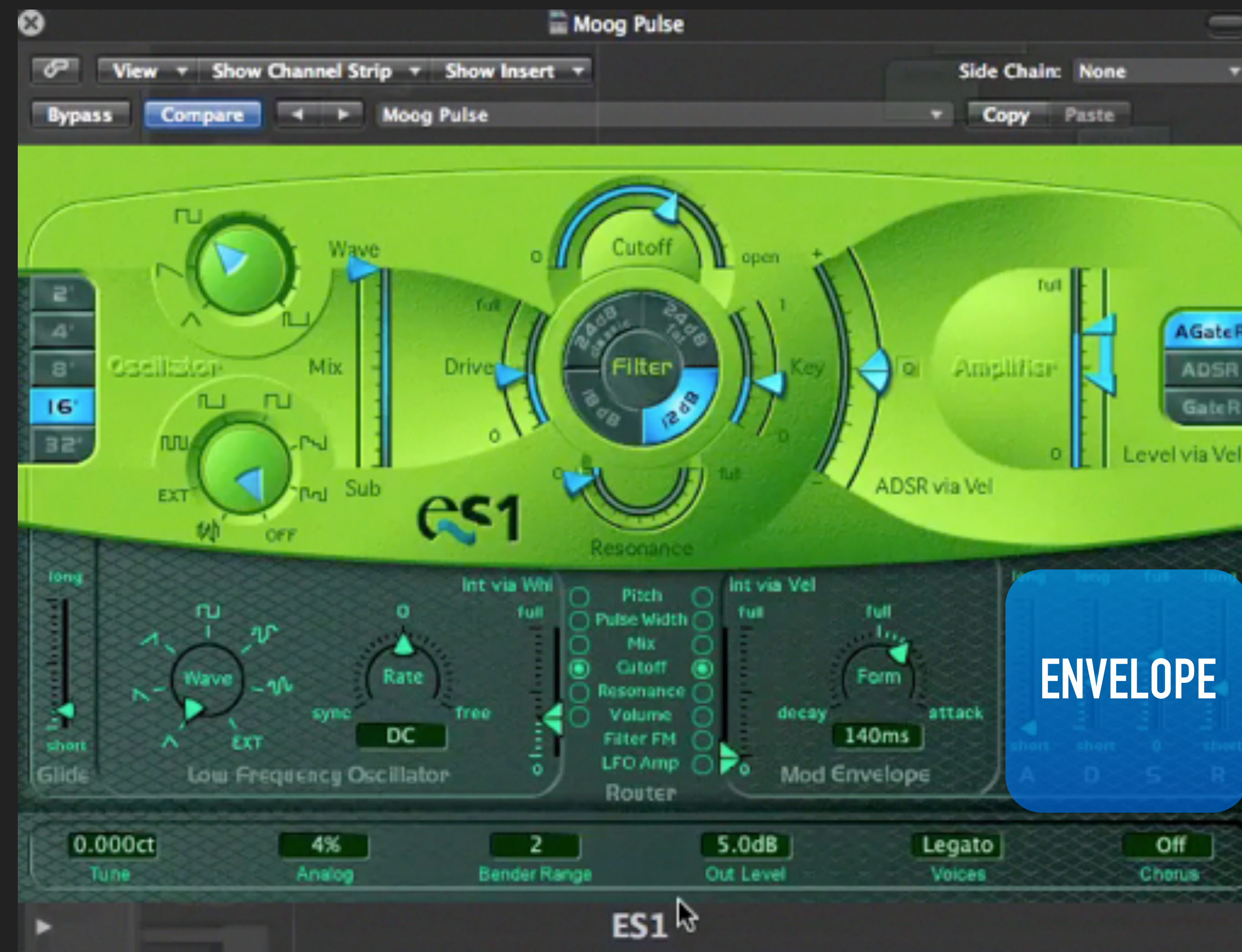


- This modulation source is a **contour generator**
- Can be used for a range of different purposes (sent to a range of different destinations)
- Possible destinations - amplitude (volume), frequency (pitch), filter (sound texture), amongst others
- We will concentrate on the most intuitive case: amplitude (volume) or change in overall sound level

MOD SOURCE 1: ENVELOPE - ADSR

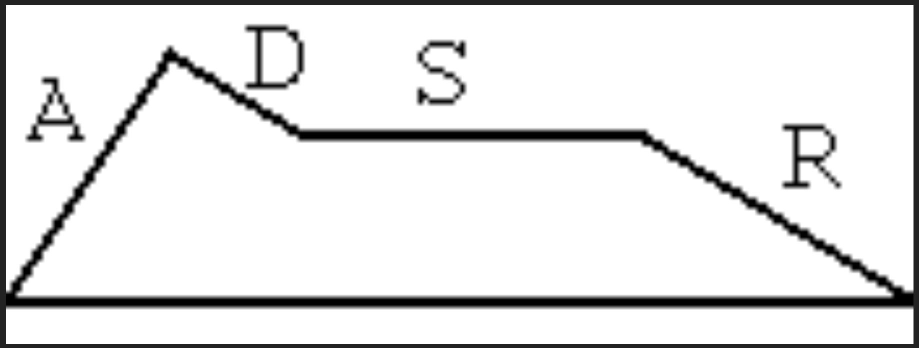
This **automated change in sound level** allows us to **approximate different types of articulations** for a note: slow swells or more sudden percussive strikes

NOTE: this is still just one component of a standard subtractive synthesiser sound…typically, this effect would be combined with applying the envelope to filter sweeps



ENVELOPE - ADSR

- Attack Time (low=fast)
- Decay Time (low=fast)
- Sustain **Level** (low/high)
- Release Time (low=fast)



Other types of envelope generators are possible - either more simple or complex.

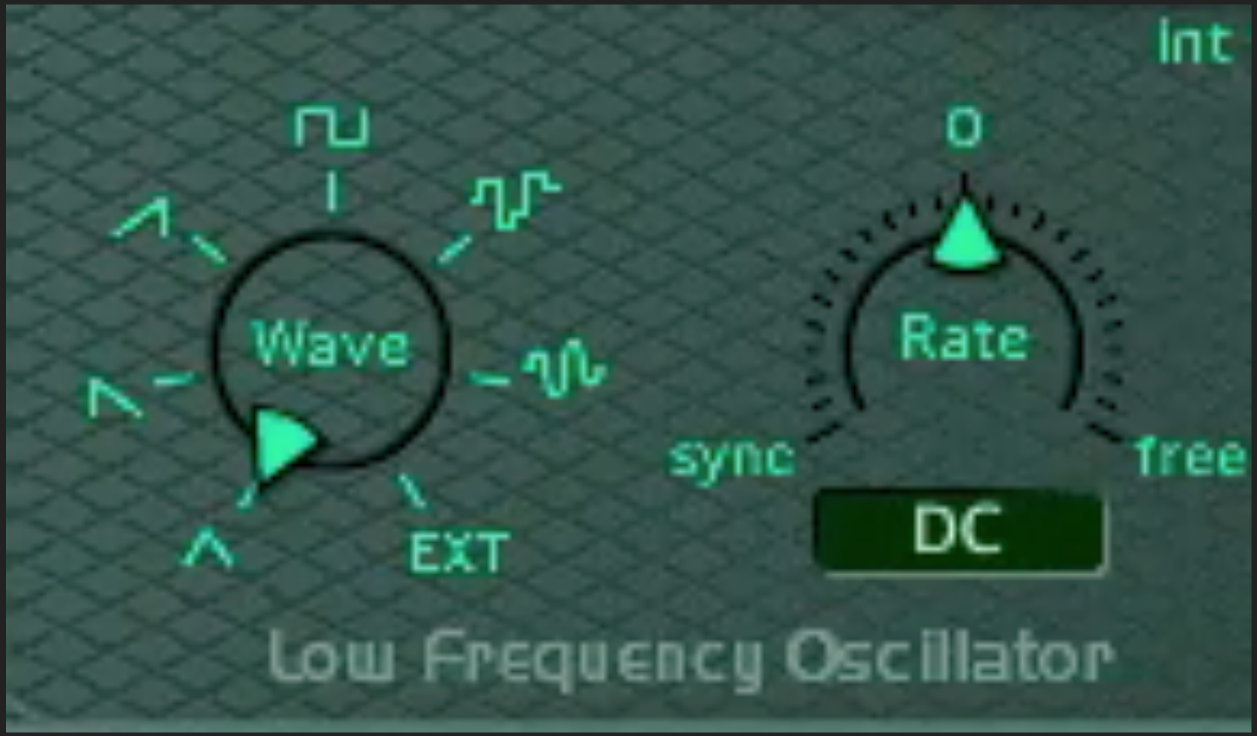
MOD SOURCE 1: ENVELOPE - ADSR

MOD SOURCE 2: LOW—FREQUENCY OSCILLATOR (LFO)

- **What's a Low-Frequency Oscillator (LFO)?**
- An oscillator is something which oscillates (vibrates with a regular pattern)
- So an LFO is, effectively, just like a 'normal' audio-producing oscillator, except it's a **'slow oscillator'**
- A normal oscillator produces waves which can directly describe sound waves due to its rate: we hear pitch for vibrations from 20 Hz (cycles per second) upwards
- An LFO typically operates below this rate: it therefore does not contribute to a sound's pitch, but rather acts as a **slower control signal**
- Like the envelope, we can apply it to different synthesis parameters, including filter cutoff and overall amplitude
- This makes the LFO one of the most important parts of a relatively complex subtractive synthesiser's sound

LOW–FREQUENCY OSCILLATOR (LFO)

- LFOs generally have similar wave shapes to 'standard' audio oscillators
- Square, Sawtooth/Ramp (up/down), Triangle
- Logic's ES1 also adds random vibrations (stepped or smooth)
- In addition to the wave control, there is an important **rate** control: how fast this LFO operates
- In Logic's ES1 this can happen at a **free** rate specified in Hz (cycles per second) or beat-synced to a certain value



LOW–FREQUENCY OSCILLATOR (LFO)

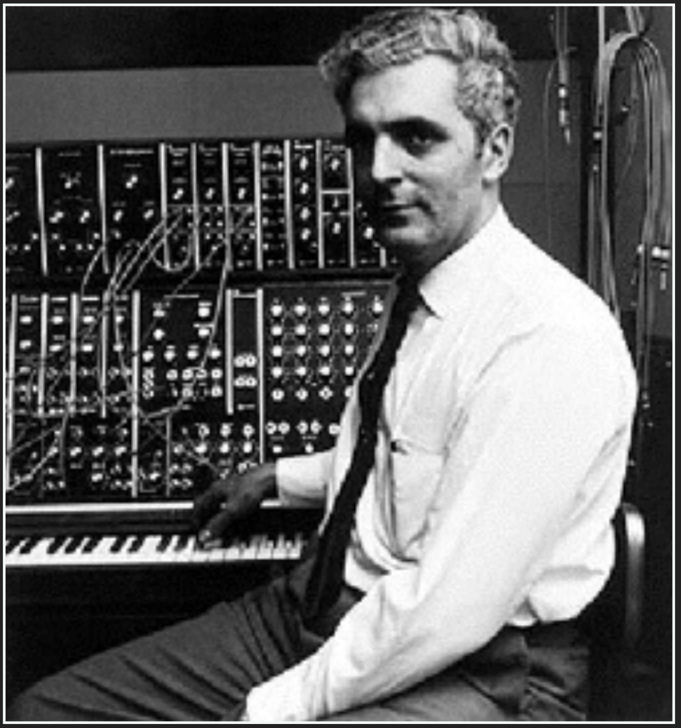
- We have to send our LFO control signal somewhere…
- **To the right, we have a range of routing possibilities** for this modulation (control) signal: pitch (for vibrato), pulse width (one method of changing spectrum), oscillator mix, filter cutoff, filter resonance and overall volume
- Beside this, we have a slider control for the amount of modulation to be applied to the destination
- This is actually two combined sliders
- The **top triangle is for LFO mod when a modulation wheel** (wheel to control modulation) on a MIDI keyboard is used

The bottom triangle is for overall (general) base setting

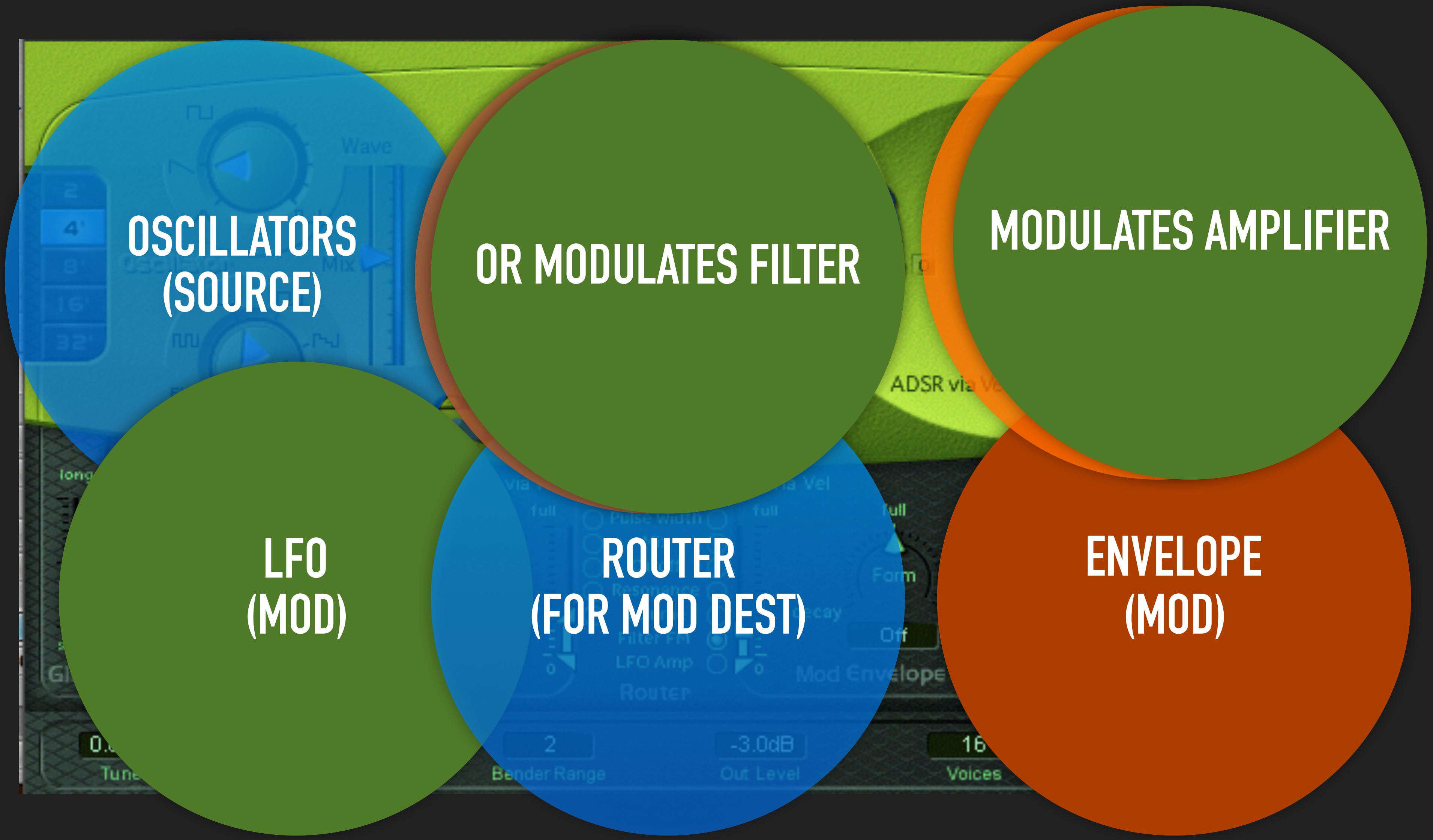
LFO IN ACTION

...SEMI-MODULAR SYNTHESIS

- The multiple routings we have available to LFO/simple envelope modulation are a little like the old Moog modular synths (not quite as complicated/ powerful, though)
- That said, the ES1 is a surprisingly complex synthesiser and you can get some really subtle (in the context of subtractive synthesis) results, with time and effort



SUMMARY—KEY ES1 CONTROLS



FURTHER INFORMATION/RESOURCES

- Russ, M. 2009. *Sound Synthesis and Sampling*. 3rd ed. Oxford: Focal (ebook, available via link from library website *when logged into portal.ulster.ac.uk*)

  ALSO Logic-specific materials:

- ASK Video. 2009. Logic Pro Video Tutorials. (Tutorial DVDs in library Non-book Media section on ground floor).
- Logic Pro manual/in-application help: *Logic Studio Instruments* (ES1 chapter)
- Other software tutorial books on Logic in library (see reading list)