Module IN3031 / INM378 Digital Signal Processing and Audio Programming

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based on slides by Tillman Weyde

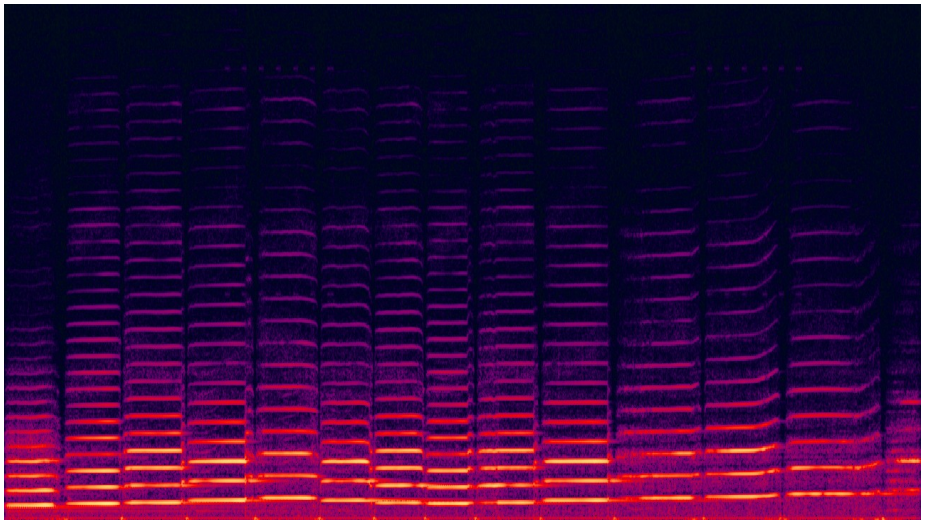
Music in Games
Filter Banks

Music in Games

Interactive Music

- Games have **no fixed progression** of events
  - **Music** needs to be **adaptable**. Approaches:
    - Write **different pieces** of music: only possible to a limited extent
    - **Loop parts** of the music: common approach
  - **Adaptation**
    - Horizontal - re-sequencing
      (**different sequences** of looped sound material)
    - Vertical - re-orchestration
      (**different combinations** of layered sounds)

Musical Structure



- Loops and layers should (normally) create a coherent musical structure in
  - Time (metre and rhythm, horizontal)
  - Frequency (harmony, vertical)

Beat, Metre, and Metrical Hierarchies

- Introduction
- Beat and Metre
- Metrical Stress Patterns and Time Signatures
- Even, odd, and compound metres
- MIDI Time Signature
- Computing a Metrical Hierarchy

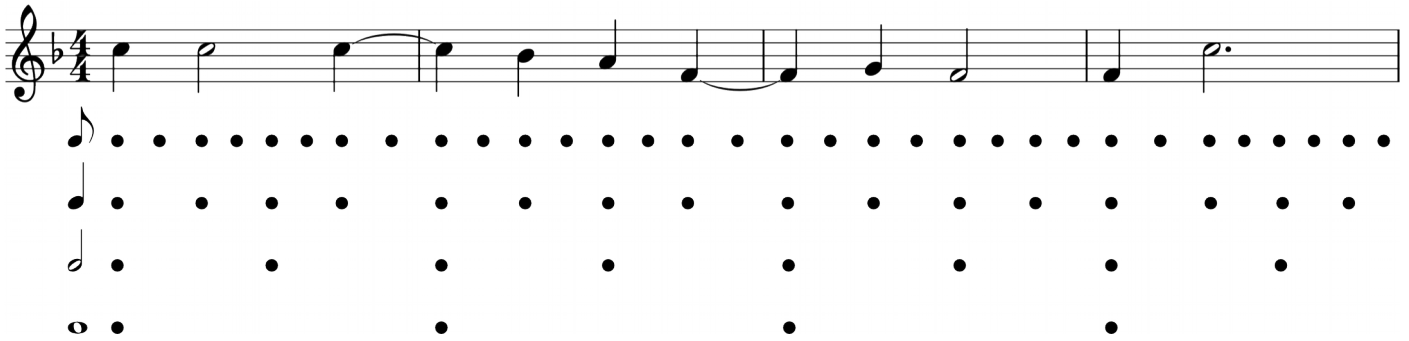
Introduction

Introduction

- How do **dancers synchronise** with the music?
- How do **musicians synchronise** when they play together?

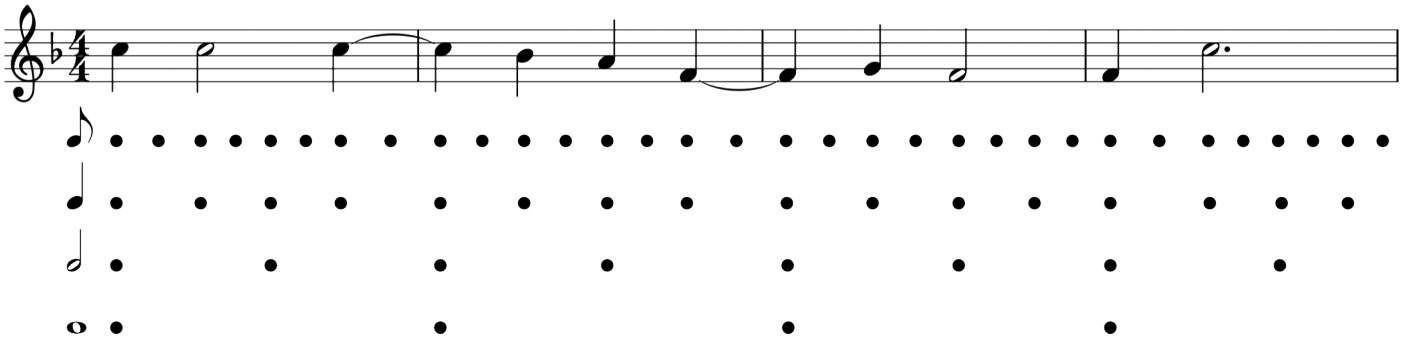
- This by done by using **patterns in time**
- Musical **beat** and **metre** organise these patterns

Music and Time



- Musical **time** is **structured:**
  - the **beat** (or pulse) creates a (mostly) regular **grid**
  - Metre creates **regular beats** and **groups** with internal **structure**

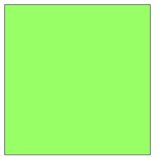
Beat



- Most music has a perceived ***beat*** or *pulse*
  - a succession of **stressed point** in time (**beats**)
  - beats have **approximately equal** time between them (**isochronous** sequence)
- The **frequency** of **beats** is called the **tempo**
  - tempo is defined in **BPM** (**beats per minute**)
  - tempos are typically in the **range 50-200**BPM

Beat Perception

- The **beat** is **inferred** in the **perception** of **music**
  - a perfectly **regular** sequence of notes evokes a **beat unequivocally**
  - a very **irregular** sequence evokes **no beat perception**
  - composers and musicians **use** this **differently** (e.g. classical vs. jazz)
- Beat **perception** is **related** to **movement** (dance music, work songs, ...)



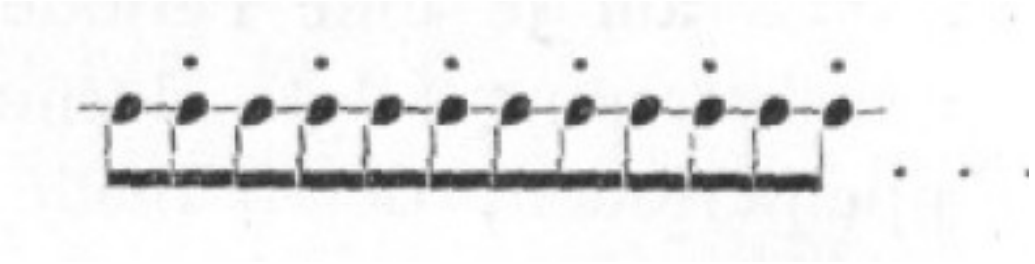
Beats and Musical Organisation

- **Notes** can **occur aligned** to the beat, but at a higher or lower rate
- The temporal organisation music is based on **stressed** and **unstressed notes**

Common Patterns

- **Beats** are **grouped** in patterns

- One stressed (**downbeat**) one light (**upbeat**), (stress is indicated by dots over the note)



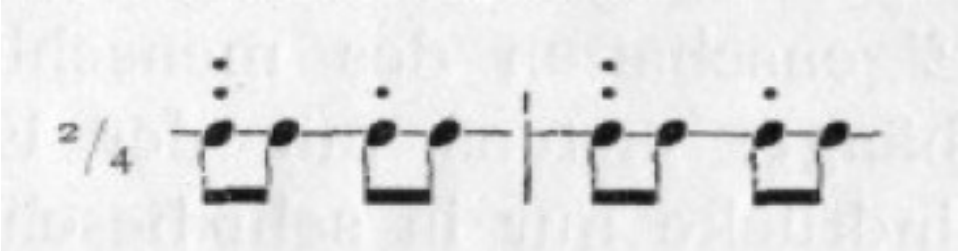
- This is **even** perceived when a **completely uniform** isochronous sequence is played

Metre

- The distribution of **strong and weak times** in time is called the **metre** of the music
- The **repeated pattern** represents usually **one *bar*** (brit.) or *measure* (am.), delimited by vertical ***barlines***
- In music notation, the metre is usually indicated by the ***time signature***
- time signature is written as a fraction x/y
  - x is the number of **beats per measure**
  - y indicates that a beat has **1/y duration**

Common Time Signatures

2/4



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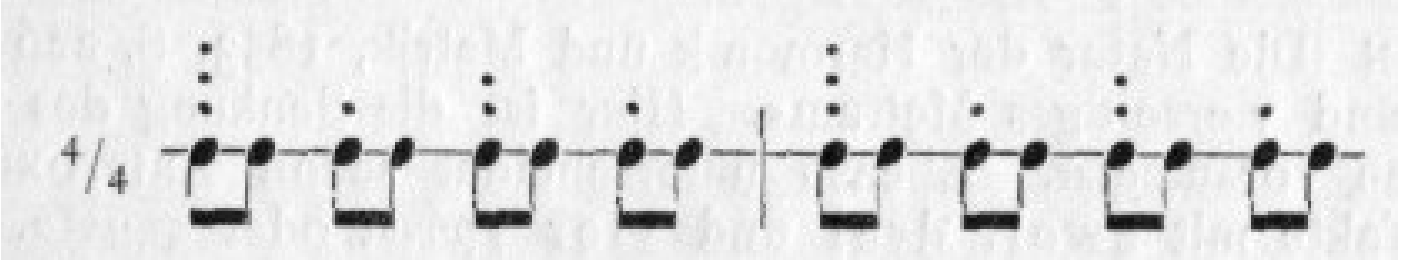

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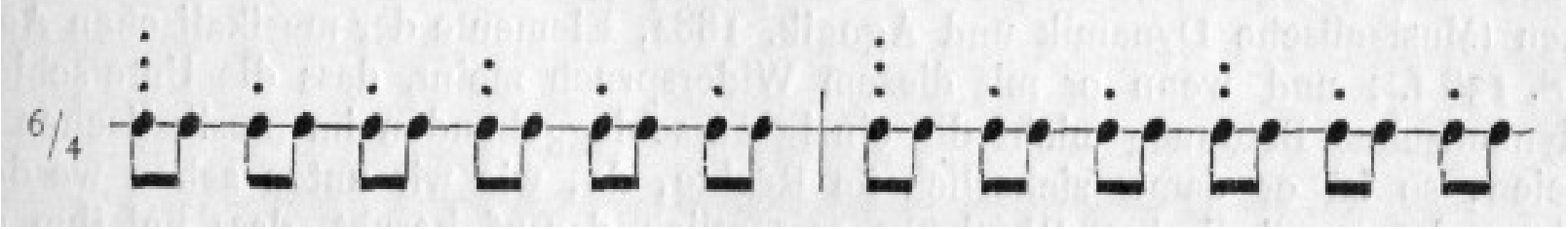
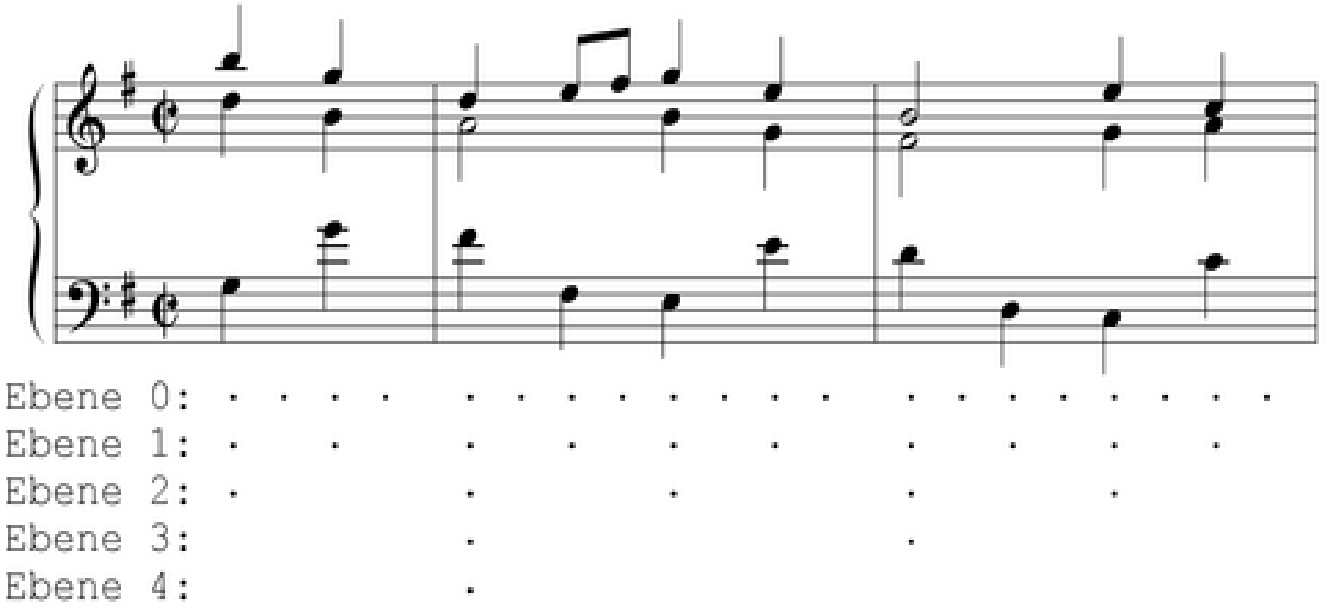


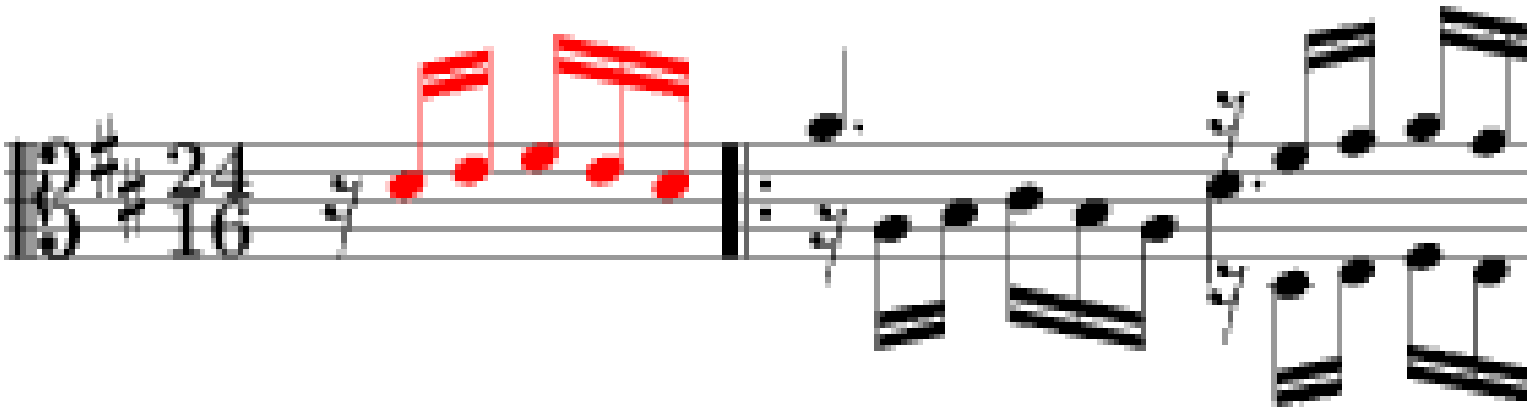
Metrical Levels

- **Levels** of **stress** in a time signature

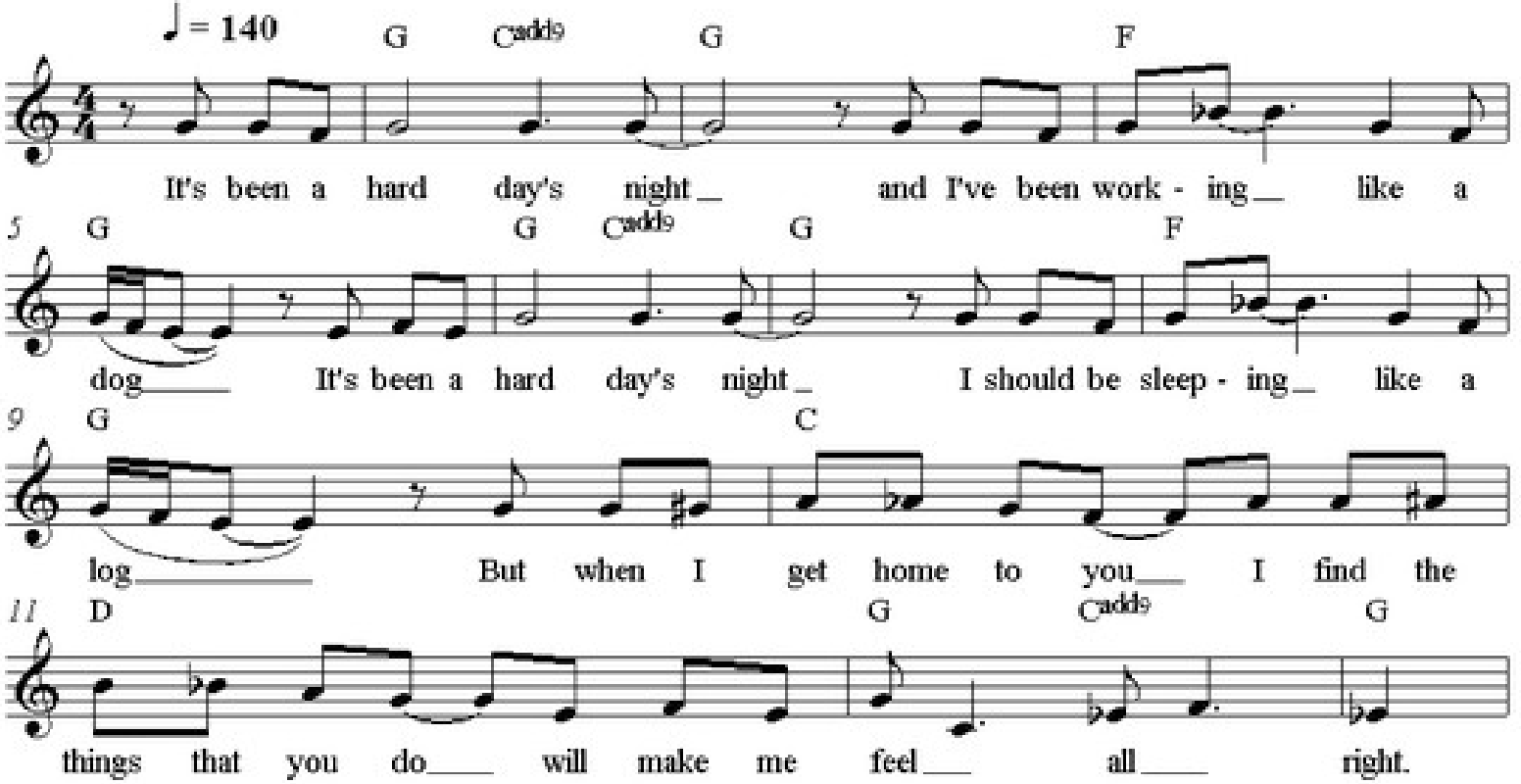


Anacrusis/Upbeat

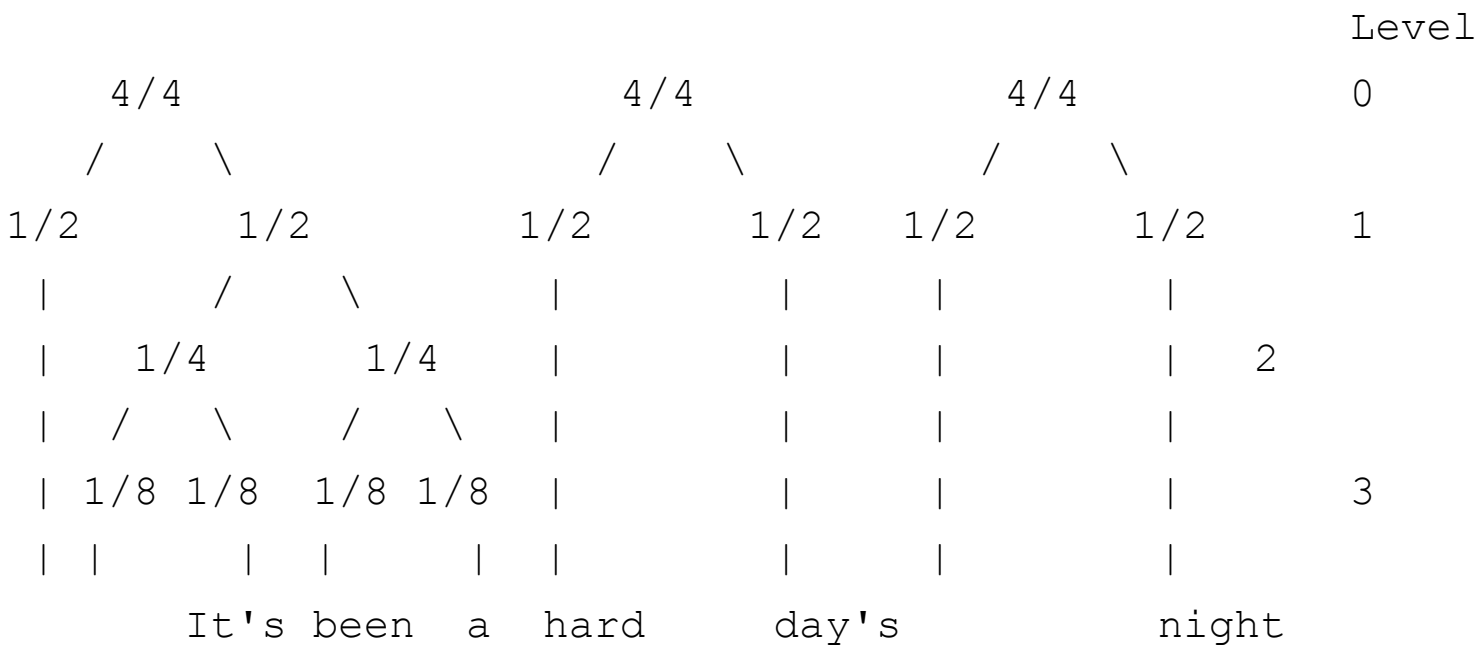
- The first **measure** may be **incomplete**



Well known example



Metrical Organisation



Compound meters

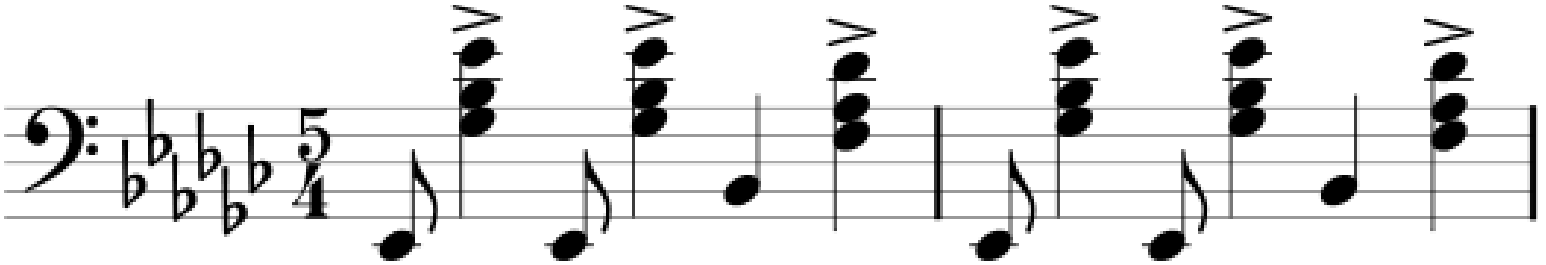
- A measure can have **irregular subdivisions**

e.g. 3+2+2 / 8

- Examples:

  Bulgarian dances

  Jazz ('Take Five', Latin Rhythms)



Musical Instrument Digital Interface (MIDI)

- A hardware, messaging and file format **standard**, introduced in **1982**
- Binary format, most **messages** are **8-bit**
- Modelled after **western music theory**
- Now ubiquitous in digital and (some) analogue instruments
- Other messaging formats are available: CV, Open Sound Control, MIDI HD (in development), some ad-hoc solutions

MIDI Time Signature

MIDI Standard Files (0) Meta Message

FF 58 04 nn dd cc bb **Time Signature**

Time signature of the form:
nn/2^dd
eg: 6/8 would be specified using nn=6, dd=3
The parameter cc is the number of MIDI Clocks per metronome tick. Normally, there are 24 MIDI Clocks per quarter note. However, some software allows this to be set by the user. The parameter bb defines this in terms of the number of 1/32 notes which make up the usual 24 MIDI Clocks (the 'standard' quarter note).

nn	Time signature, numerator
dd	Time signature, denominator expressed as a power of 2. eg a denominator of 4 is expressed as dd=2
cc	MIDI Clocks per metronome tick
bb	Number of 1/32 notes per 24 MIDI clocks (8 is standard)

A MIDI Example

(24 ticks per quarter note)

0 NoteOn 80 127

24 TimeSig 4 2 24 8

24 NoteOn 80 0 <-- (a.k.a NoteOff)

24 NoteOn 80 127

36 NoteOn 60 127

48 NoteOn 60 0

48 NoteOn 60 127

66 NoteOn 60 0

72 NoteOn 80 127

96 NoteOn 80 0

Loops and Metre

- The **metrical structure** is normally **maintained** during loop playback.
- Common **loop sizes** are 4, 8 or 16 bars (although sometimes musical structures have different values, e.g. 'Eleanor Rigby' by the Beatles has a 5 bar structure)

Loops and Harmony

- **Harmony** describes the sounding of **several** (pitched) **notes together**
- In harmonic contexts, some notes sound **consonant**, others sound **dissonant**/inappropriate.
- Layered music loops need **common harmonic** structure (not true for plain sound loops)
- Each layer in the same **harmonic** pattern ensures they are musically 'compatible'

MIDI vs Audio

- **MIDI** representation
  - used **mostly in music production**
  - used to be applied in Games directly
- MIDI is **symbolic representation**
  - Advantages:
    - independent tempo and pitch
    - easy to modify for musicians
    - low data volume
  - Disadvantages
    - sound quality (depends on used sound library)

MIDI vs Audio in Loops

- Audio
  - can have superior quality (e.g. recorded human performance)
  - costly and lossy change of pitch/tempo
  - changing individual notes hardly possible

  → careful planning needed, good for final production
- MIDI
  - very flexible (easy to change tempo, pitch, notes)

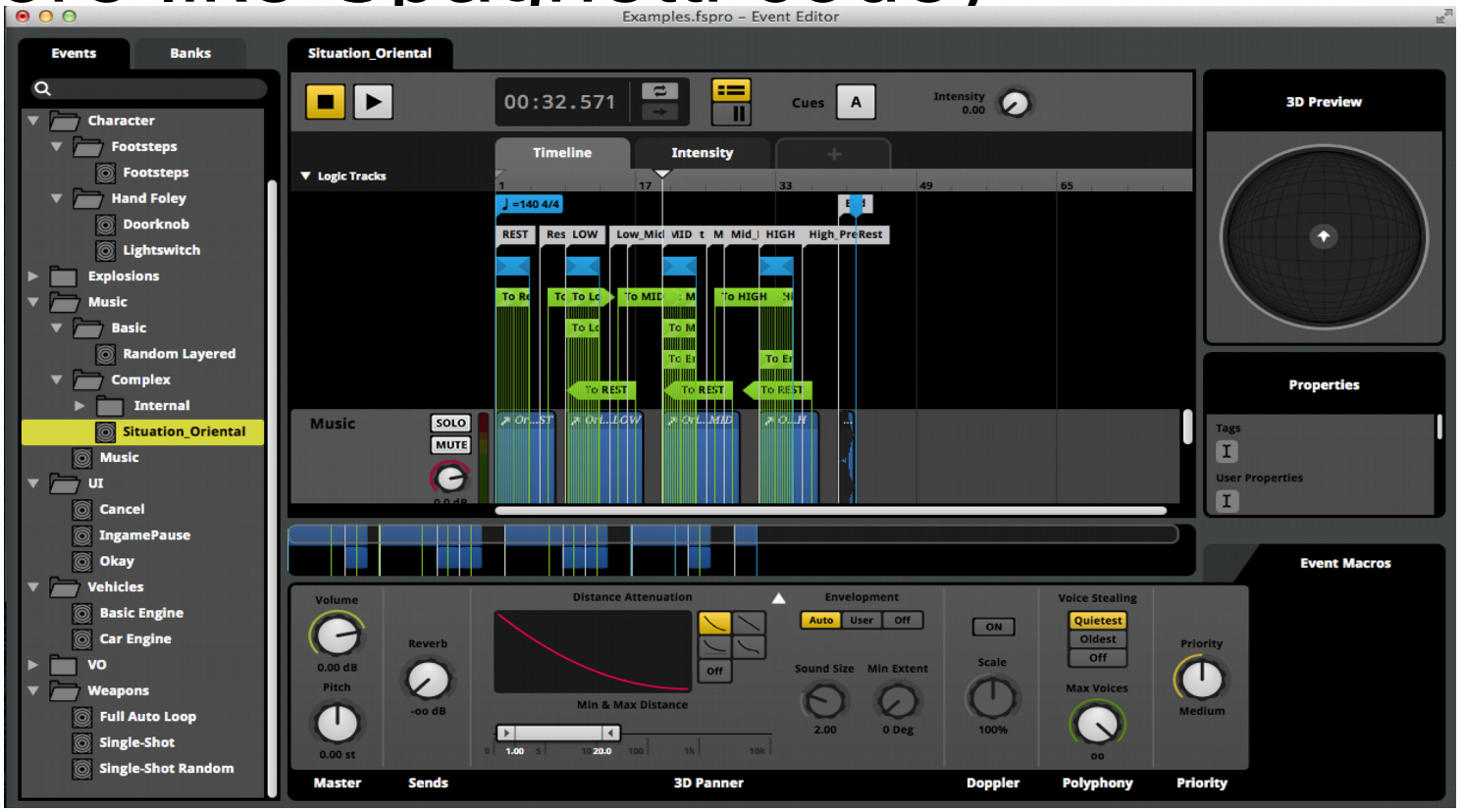
  → can experiment, good for developing a soundtrack

FMOD for Game Music

- Supports
  - **Loops**
  - **Synchronisation** based on beats and bars
  - **Conditional transitions** and **repetitions**
- Used to be **separate FMOD** Music system, **now integrated** with Studio Event system

Interactive Music in FMOD

- The new FMOD Studio interface (more like Spaghetti code)

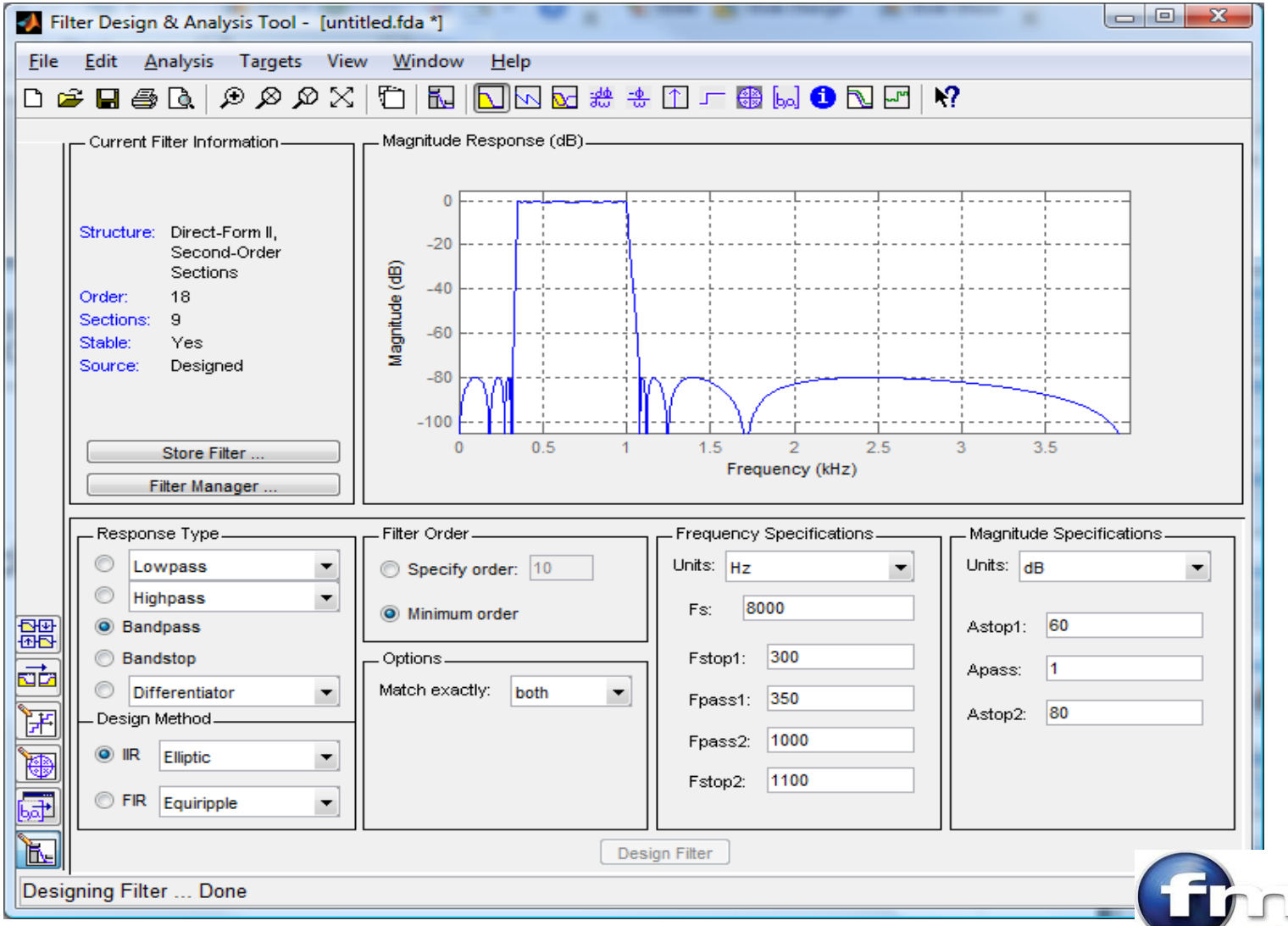


Filter Banks

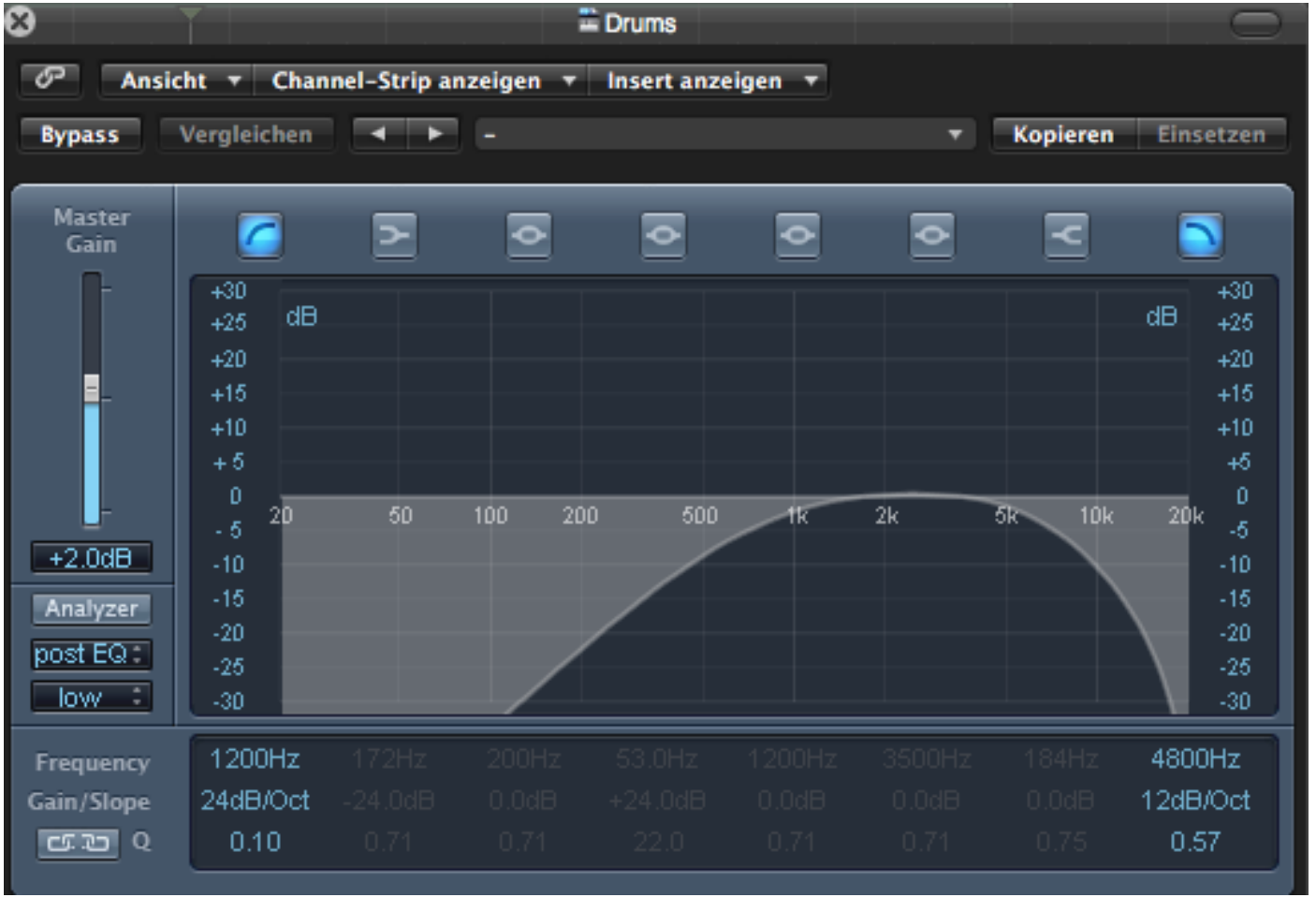
Real Time Digital Filters

- Common filters are **linear time-invariant** (LTI) systems, i.e. they do not change **their behaviour** depending on time or amplitude
  - FIR **finite impulse response** filters implement convolution
  - IIR **infinite impulse response** filters add recursion
- Filters for Real Time processing are **causal**
  - They use only past values

Band Pass Filter



Band Pass in Music Production

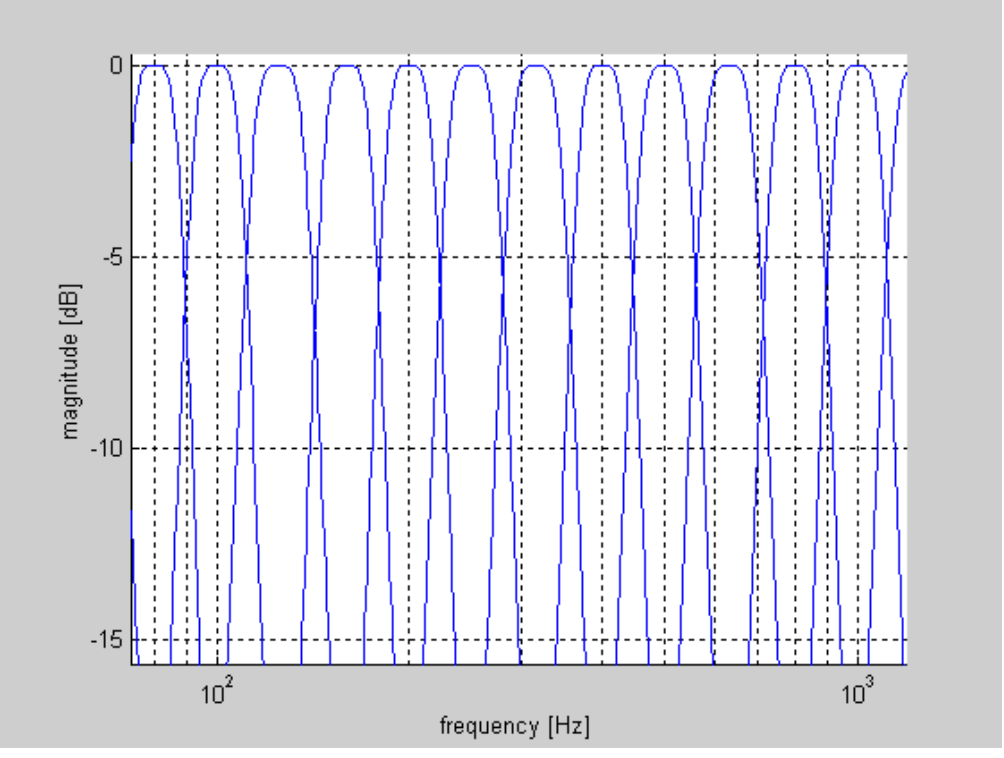


Filter banks

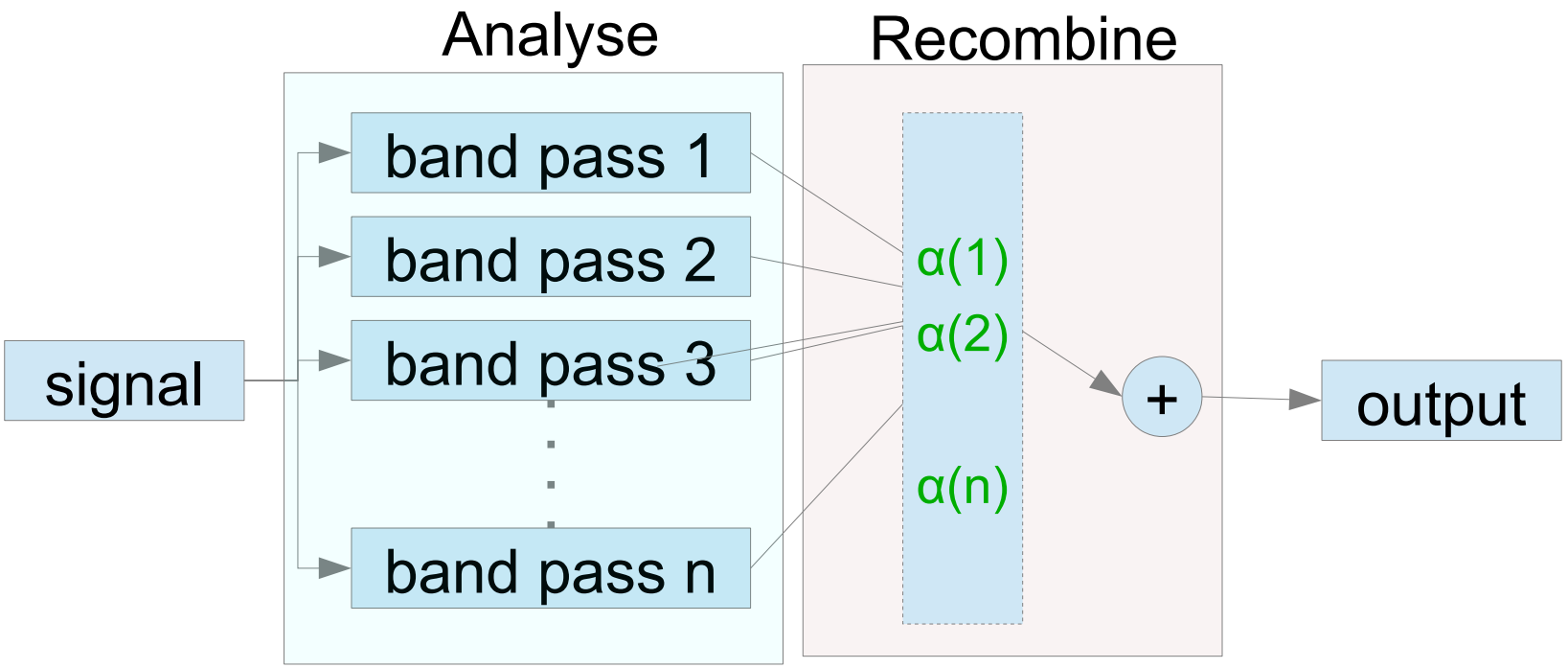
- **Multiple** band pass **filters**
  - **Logarithmically spread** over the spectrum
  - **Overlapping** up to half the pass band
- Analyse distinct **frequency bands**
  - **Critical bands** in hearing
  - **Real time** alternative to Fourier analysis
- **Resynthesis** used in Vocoders

Filter Bank Pass-Bands

- Multiple **band pass** filters
  - Cover the spectrum
  - Magnitude responses add up to 1 (approx)

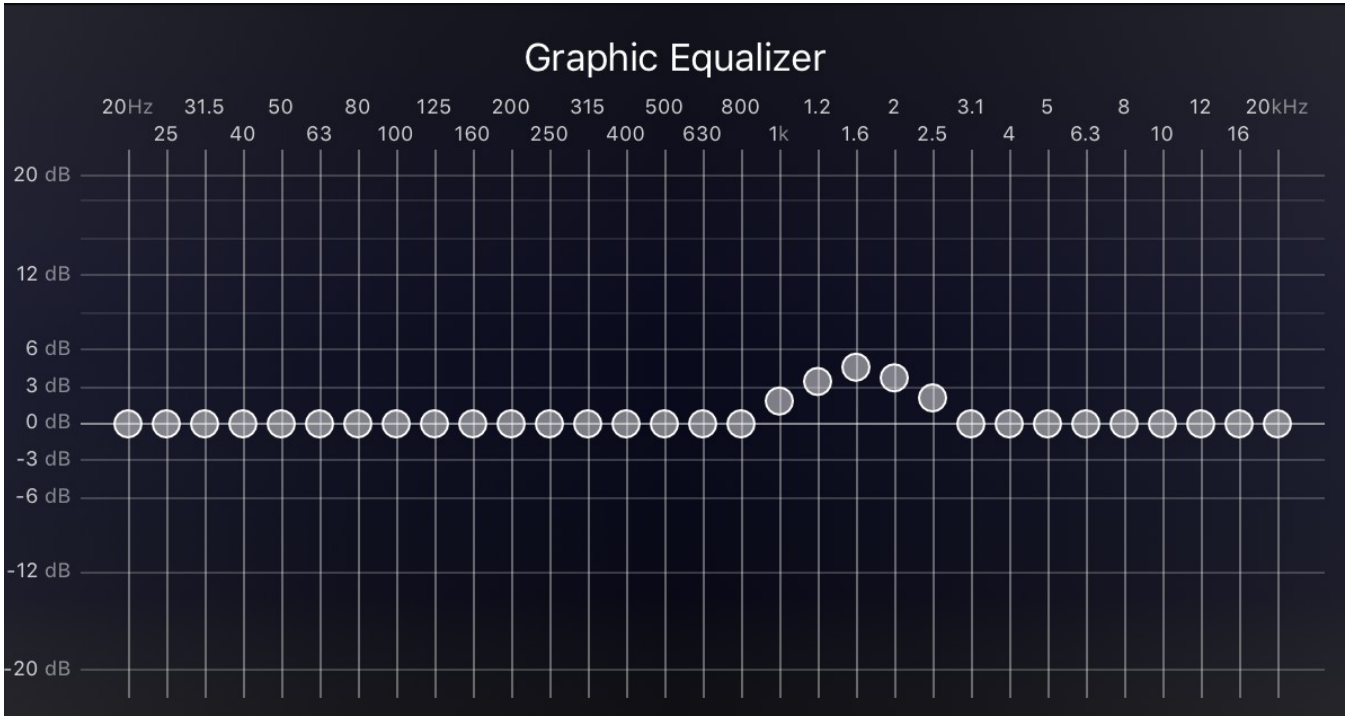


Equalisation with Filterbank



Filter Bank EQ

- Typically bands spaced in octaves or thirds



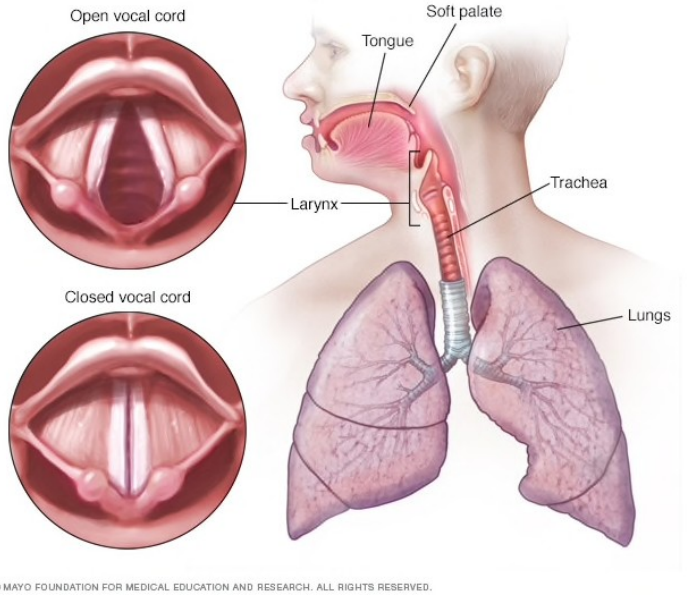
Filter Bank Vocoder

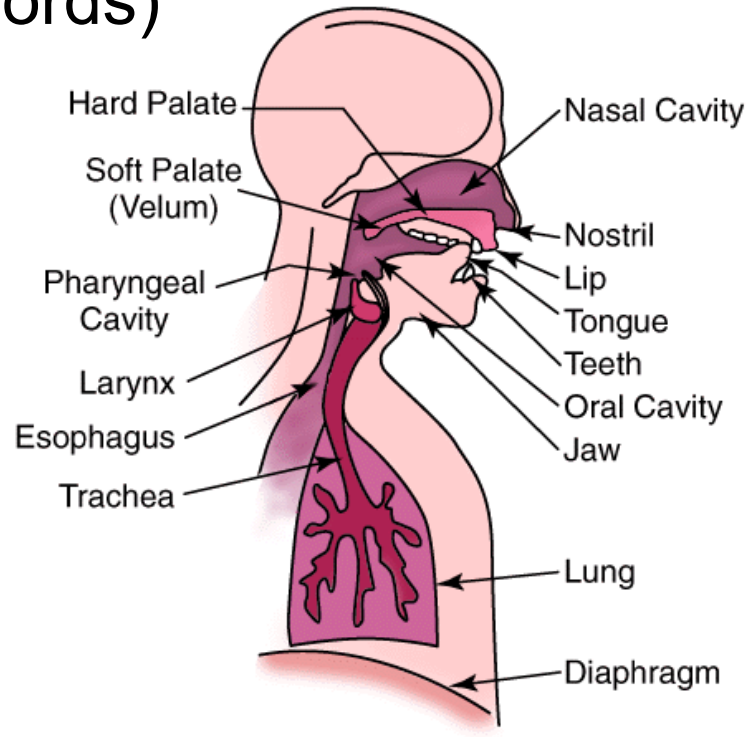
Vocoder: voice coder

- Idea
  - **Extract the spectrum** from speech
  - **Reduce spectrum**
  - Transfer the spectrum to **another signal** (carrier)
- Originally **developed for communication**

Filter Bank Vocoder

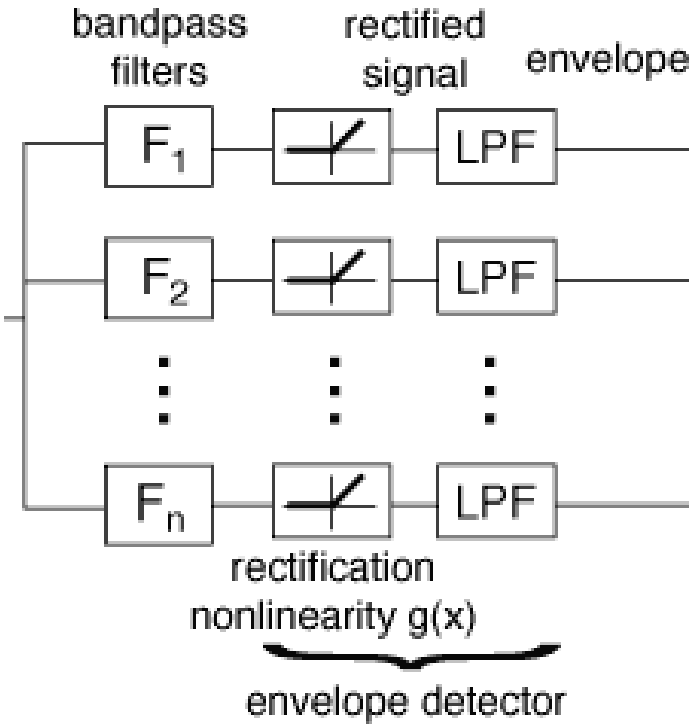
- Why is this a good idea?
  - human voice can be modelled as
    - sound **source** (vocal chords)
    - and a **filter** (vocal tract)





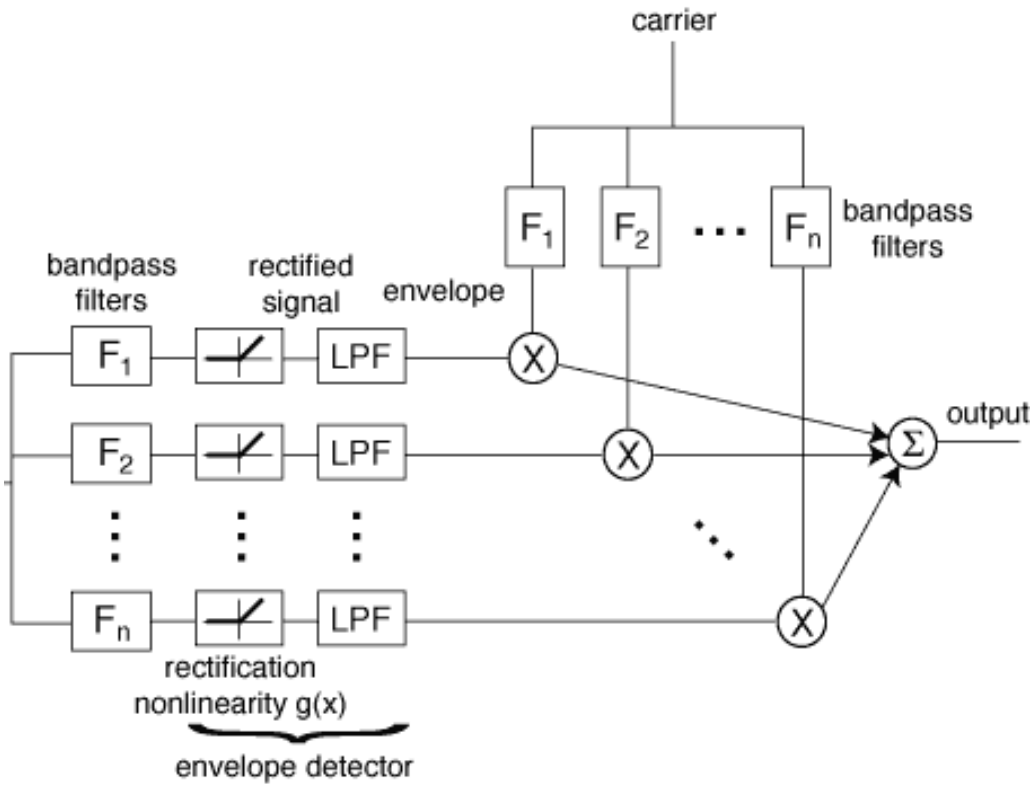
Filter Bank Analysis

- Real-time continuous spectral analysis
- Operation
  - **Split** the signal into **frequency bands**
  - **Track** the amplitude envelope (rectify and low-pass filter)



Filter Bank Synthesis

- Operation
  - Use a **carrier signal** (broadband)
  - Split into **frequency bands**
  - **Amplify** per band **with voice envelope**



Vocoder Use

- Films

  Computer and **robot voices**
- Music examples

  Electronic: e.g. Kraftwerk

  Pop: e.g. Earth Wind and Fire, Electric Light Orchestra
- A '**talkbox**' is a **acoustical version** of the vocoder

Cochlear Implants

- **Similar** architecture to **vocoders**
- Need to generate neural compatible stimuli at the end