ChucK => A Concurrent, On-the-fly Audio Programming Language

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What is ChucK?

- General-purpose audio programming language
  - Strongly typed and strongly timed
  - Object oriented
  - Platform independent
  - Designed from the ground up
    - Not based on a single existing language
- A New Programming Model
- Solves a number of problems

Audio Programming

- Considerations
  - development
    - Flexibility & Programmability
    - Elegant mapping of audio concepts to language
    - Levels of abstraction
    - Timing (and Concurrency?)

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  - run-time
    - Real-time
    - Usability / control
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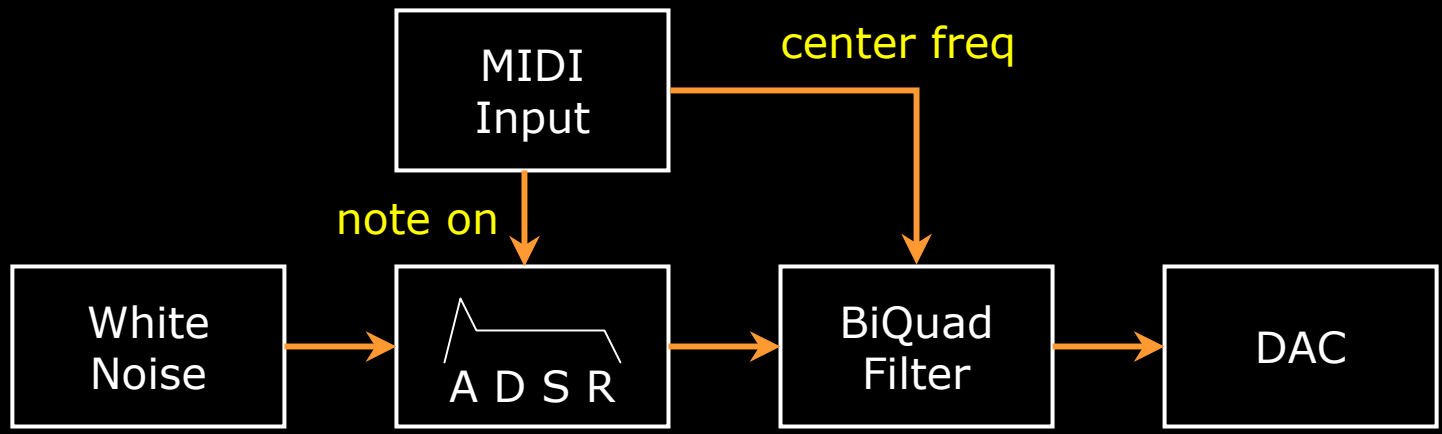
- Problem:

  difficult to incorporate into a single language

Question: Can we design one language that supports:

- Representation of audio concepts
  - reason about flow from code
- both high AND low levels of abstraction
  - Data and time
  - reason about time directly from code
- Concurrency
  - can be useful (but hard!)
    - Timing
    - Synchronization
    - Performance

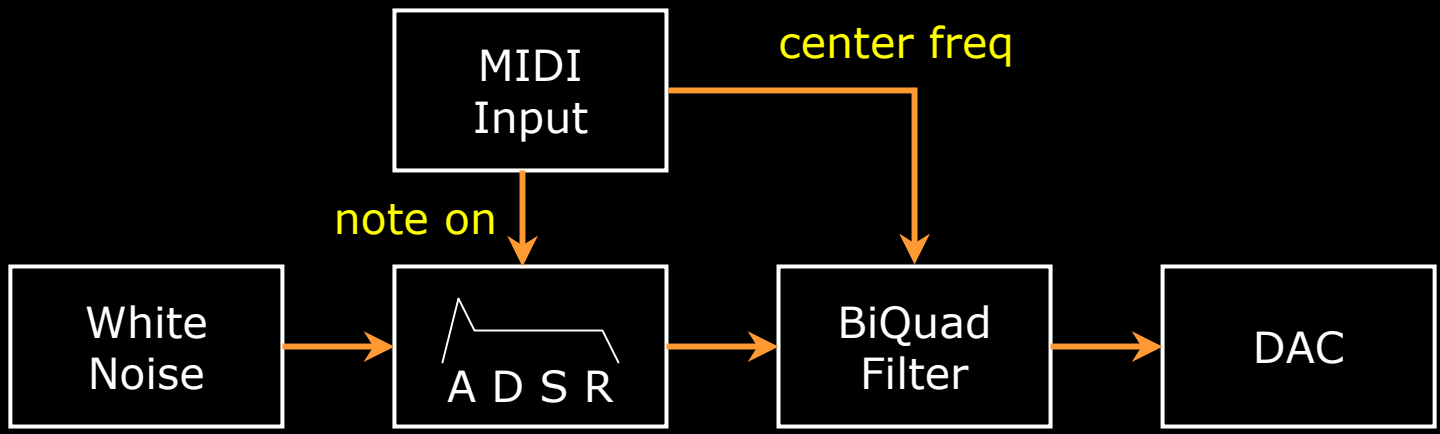
Problem 1: Representation




```
dacOut.tick(biQuad.tick(adsr.tick() * noise.tick()));
```

```
if( timeCount % 44 == 0 )
{
    if( midi.nextMessage() == __SK_NoteOn_ )
    {
        (midi.getByteThree() ? adsr.noteOn() : adsr.noteOff());
        biQuad.setFreq( MD2Freq(midi.getByteTwo()) );
    }
}
```

Solution 1: Representation




```
noise3 => ADSR => biquad1 => dac;
midi => ( ADSR, biquad1 );
```

Solution 1: Representation

=> Syntax

- Simple chuck: `x => y;`
- Chain chuck: `w => x => y => z;`
- Nested chuck: `w => ( x => y ) => z;`
- Cross chuck:
```
w => (x, y);
(w, v) => (x, y, z);
```

- Un-chuck: `x =< y =< z;`
- Re-chuck: `x =<> y;`

=> Semantics

- Action-oriented
- Overloaded on types
  - Defined for primitives
  - unit generators
  - System mechanisms
- Chuck operator helps represent flow

Problem 2: Level of Control

- What is the appropriate level of control for...
  - Data? (bits, bytes, objects, ...)
  - Time & Control rate? (sample, ms, ...)
- Solution: provide many levels of control!
  - Work at multiple levels of abstraction for both data and time

Problem 2: Level of Control

```
noise => env => biQuad => dac;

while( true )
{
    500 + (300 * sin(now*FC)) => biQuad.freq;
    100:ms => now;
}
```

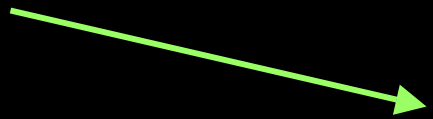
Demo 1

ChucK Timing Constructs

- **dur** is a native type
  - Units:
    - samp, ms, second, minute, hour, day, week
  - Arithmetic:
    - 3:**second** + 100:**ms** => **dur** quarter;
- **time** is a native type
  - **now** keyword holds current chuck time
  - Arithmetic:
    - 5:**second** + **now** => **time** later;

Time Example

```
4:second + now => time later;
while( now < later )
{
    now => stdout;
    1:second => now;
}
```



```
> chuck foo.ck
0
1
2
3
```

Advancing Time

- Time stands still until you "advance" it
- Two semantics for advancing time
  - Chuck to now

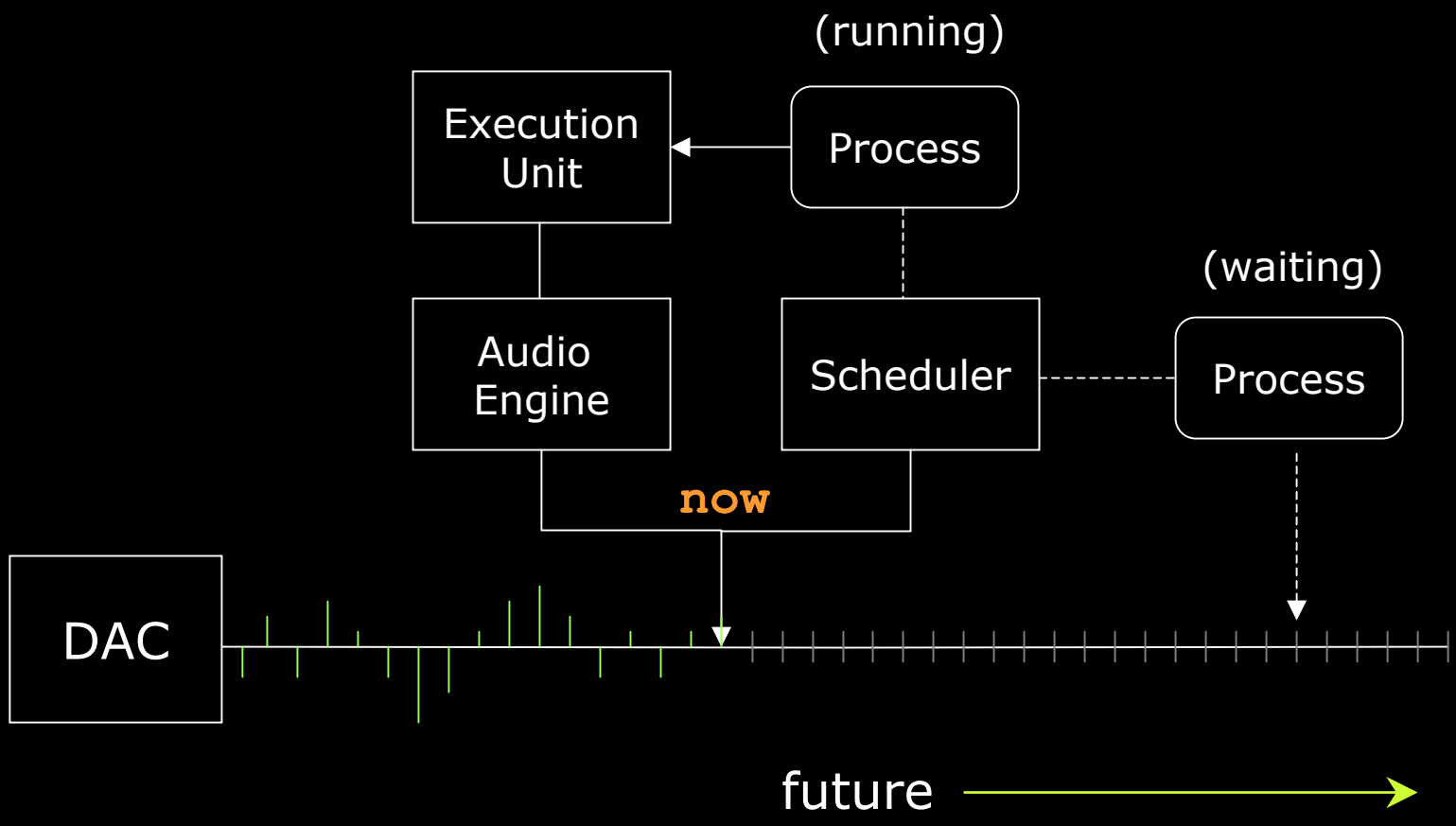
    ```
    1::second => now;
    ```

  - Wait on event

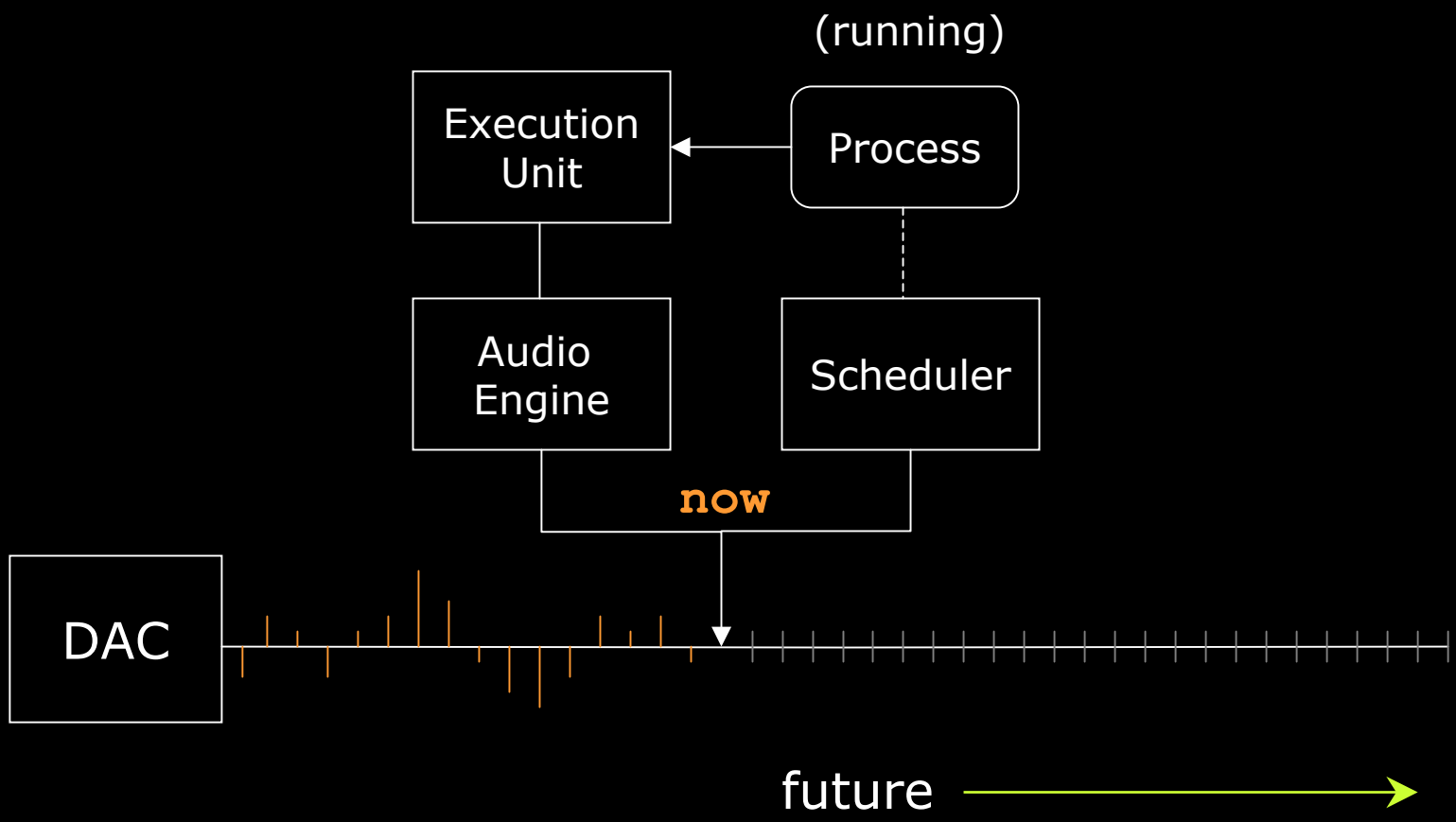
    ```
    midi_event => midi_handler;
    ```

- You are responsible for keeping up with time
- Timing embedded in program flow

How It Works


(running)
Execution Unit
Process
(waiting)
Audio Engine
Scheduler
Process
now
DAC
future

How It Works


(running)
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Dynamic Control Rate

```
"snare" => sndbuf sbuf => dac;

50 => int r;
0 => float a;

while( true )
{
    0 => sbuf;
    70 + (30 * sin(a)) => r;
    .1 +=> a;
    r::ms => now;
}
```

Demo 2

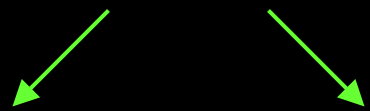
Consequences of Timing Mechanism

- Consistent, deterministic notion of time
- Strong correspondence of program flow and timing
- Control rate
  - Arbitrary
  - Dynamic
  - Sample-Synchronous

Timing model makes chuck more powerful by allowing deterministic concurrency...

Problem 3: Concurrent audio programming

```
noise => env => biQuad => dac;
```



```
0.0 => float v;
while( true )
{
    sin(v*FC) => biQuad.freq;
    1.0 +=> v;
    100:ms => now;
}
```

```
while( true )
{
    if( midiin.noteOn() )
        midiin.vel => env;

    13:ms => now;
}
```

Concurrency is hard!

- Synchronization and timing
- Overhead
- Programming model
  - expressing concurrency in code

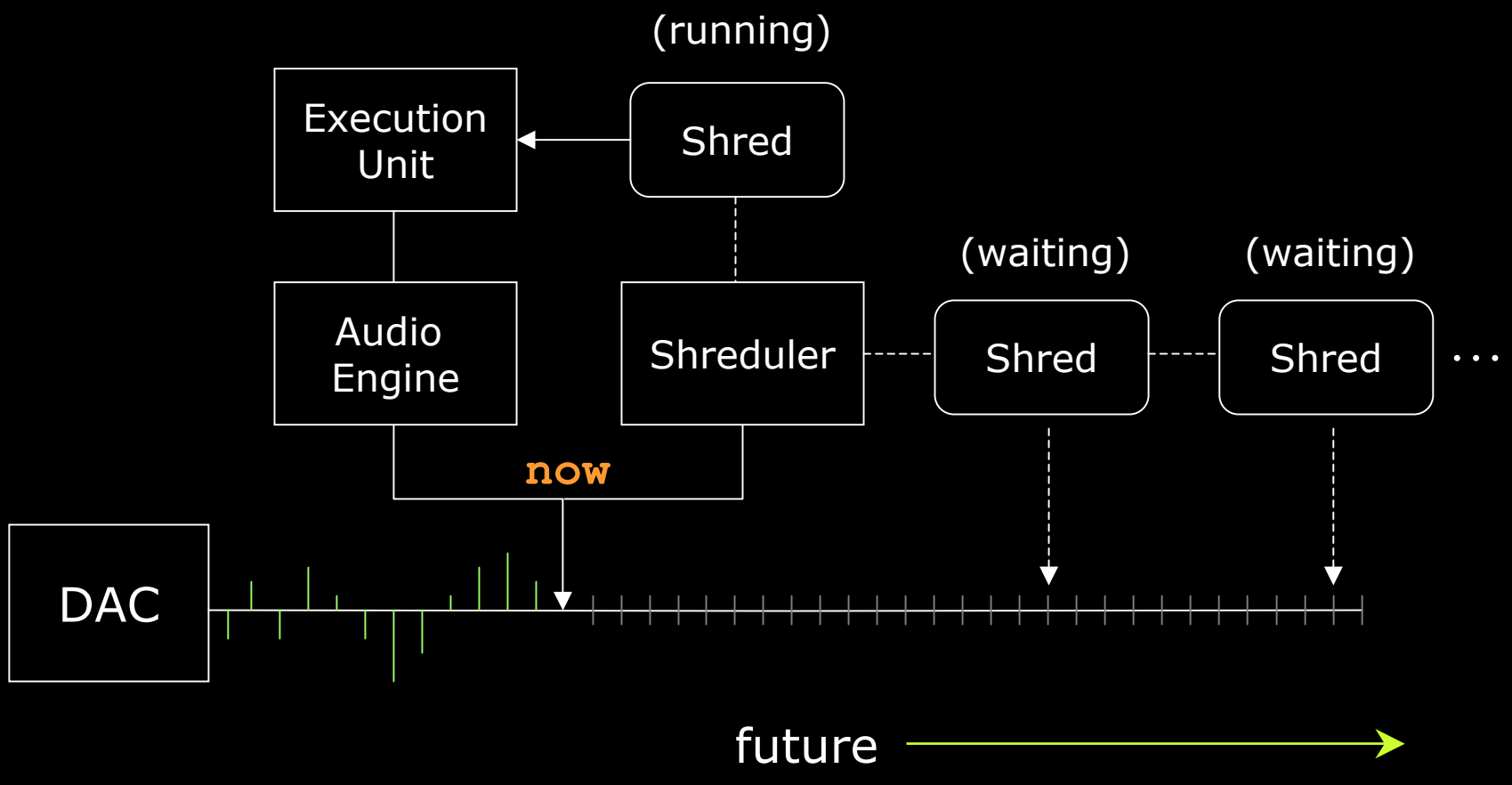
Programming with Shreds

- Threads
  - Preemptive / non-deterministic
  - Use a fork()
  - No timing guarantees
- Shreds
  - Deterministic shred of computation
  - Use a spork()
  - Sample-synchronous precision

Properties of Shreds

- Resemble non-preemptive threads
- User-level constructs (no kernel interaction)
  - High-performance
    - Context switch
    - Synchronization / shreduling
- Automatically synchronized by time!
- Managed by the ChucK shreduler
- Deterministic execution

How it Works


(running)
Execution Unit
Shred
Audio Engine
Shreduler
(waiting)
Shred
(waiting)
Shred
...
now
DAC
future

CONTROL RATES AND SHREDS

- DETERMINED BY PROGRAMMER PER SHRED
- CHUCK CONTROL RATES ARE:
  - ARBITRARY
  - DYNAMIC
  - SIMULTANEOUS

DEMO 3

3-shred example:

```
500::ms => now;
"bass" => sndbuf sb => dac;

while( 1 )
{
    0 => sb;
    500::ms => now;
}
```

```
750::ms => now;
"snare" => sndbuf sb => dac;

while( 1 )
{
    0 => sb;
    500::ms => now;
}
```

```
625::ms => now;
"hatcl" => sndbuf sb => dac;

while( 1 )
{
    0 => sb;
    250::ms => now;
}
```

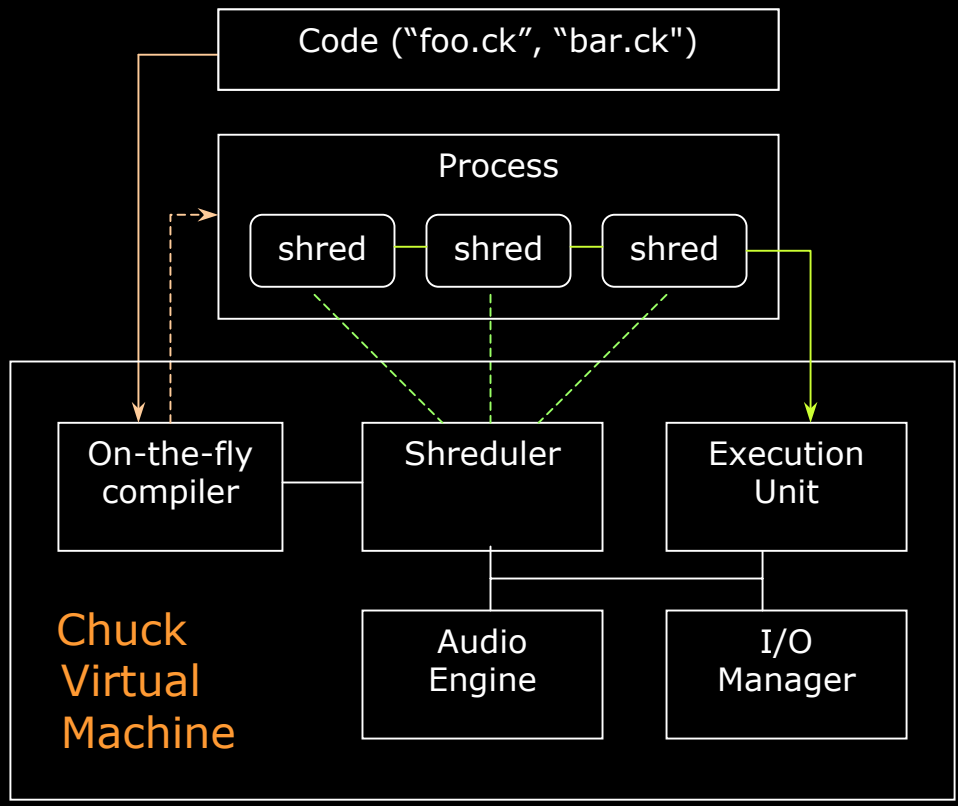
Consequences of Concurrency with timing

- Possible to write truly parallel, sample-synchronous audio code
- Can work at low and high level
  - Fine granularity == power and control
  - Arbitrary granularity == flexibility and efficiency
- Program on-the-fly...

On-the-fly Programming

- Goal: add/modify/remove parts of the program as it is running
- Experimentation & performance possibilities
- Use the shred mechanism
  - Add and remove shreds from the virtual machine
  - Use networking, GUI, or command line

ChucK Virtual Machine



Acknowledgements

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ChucK is free from the authors:

http://chuck.cs.princeton.edu/

http://soundlab.cs.princeton.edu/

Questions?

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