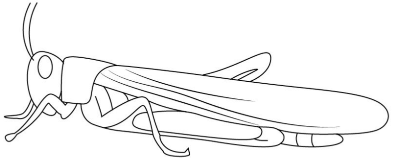
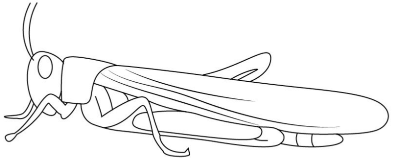


# Locust development tutorial workshop
# (How to add a new Locust Generator)

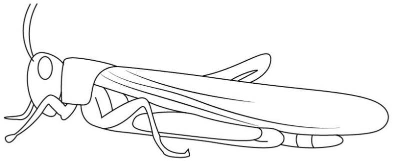
P. L. Slocum
Jan. 28, 2021

# Contents:

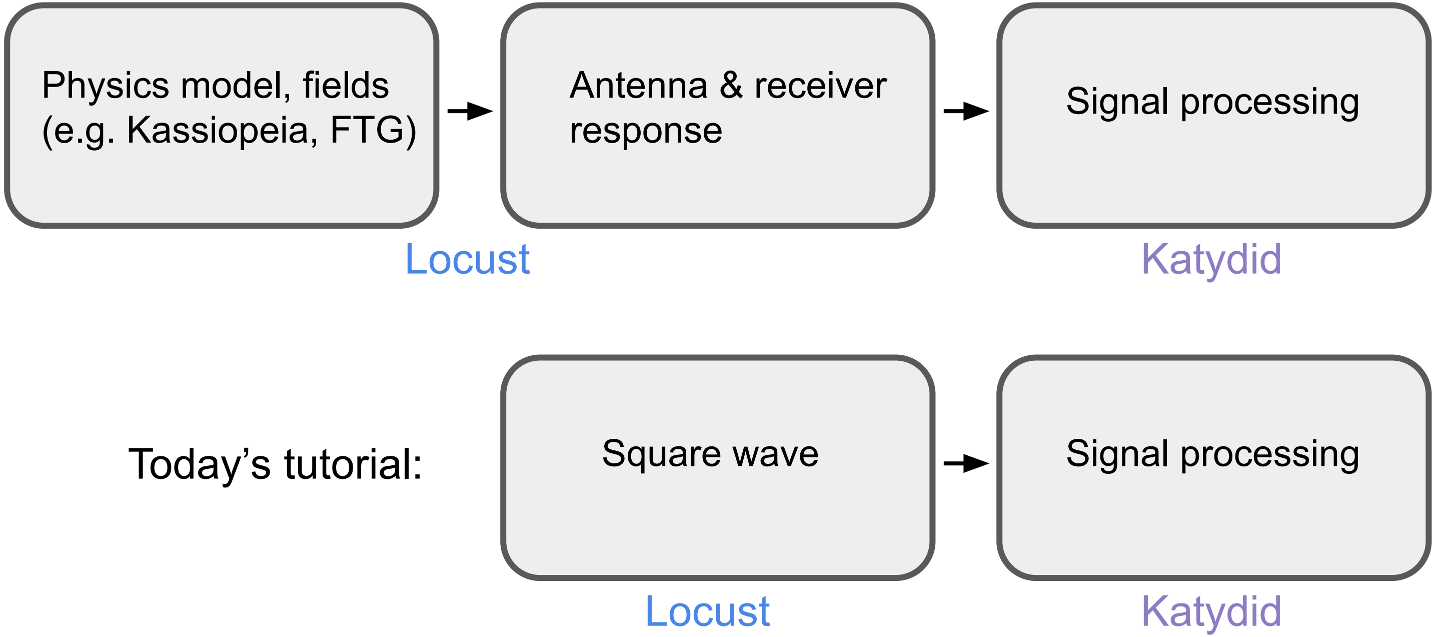


- This is a brief introduction to developing in Locust, in p8compute.
- For running previously-developed Locust with examples, please see the tutorial at https://github.com/project8/locust-tutorial/blob/master/LocustTutorial.pdf
- We will start with a description of the workflow.
  - Typical CRES-like workflow.
  - Today's tutorial workflow (a square wave signal, without CRES).
- Finally, we will write a new Generator and process its output.
- Technical questions can be posted in Slack in the new #locust channel.

# In this tutorial:



Typical workflow in Locust-Katydid:



Physics model, fields (e.g. Kassiopeia, FTG) → Antenna & receiver response → Signal processing

Locust

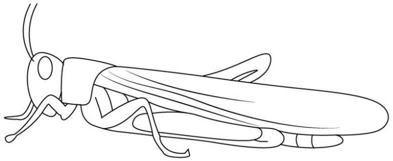
Katydid

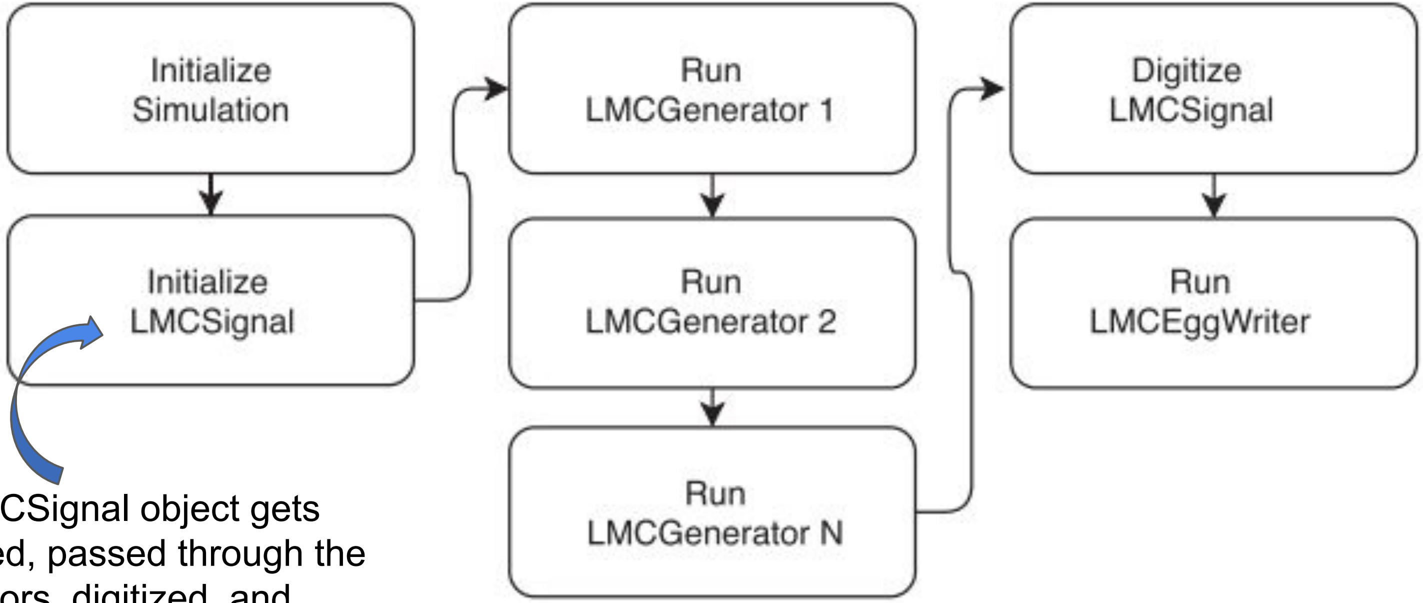
Today's tutorial: Square wave → Signal processing

Locust

Katydid

# Locust work flow diagram





Initialize Simulation

Initialize LMCSignal

Run LMCGenerator 1

Run LMCGenerator 2

Run LMCGenerator N

Digitize LMCSignal

Run LMCEggWriter

The LMCSignal object gets initialized, passed through the generators, digitized, and written to an egg file.

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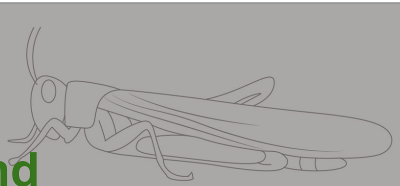
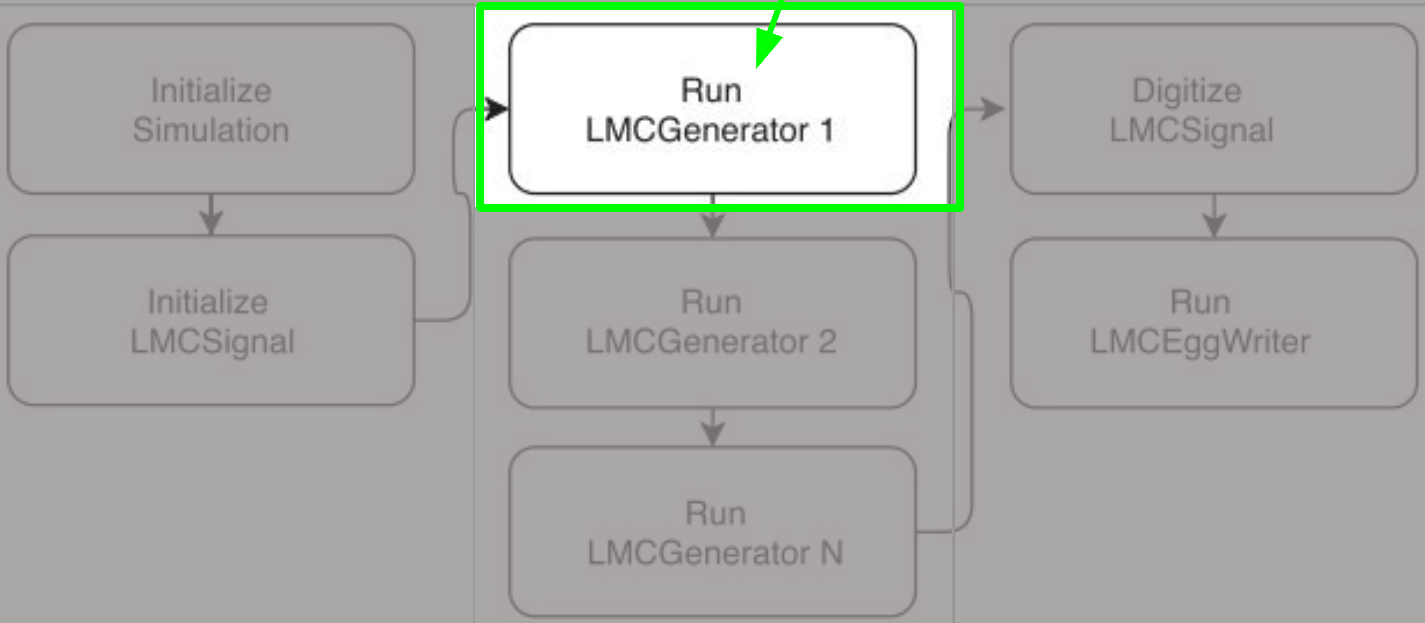
# Locust work flow diagram



Typical location for physics interface and antenna calculations.



Initialize Simulation

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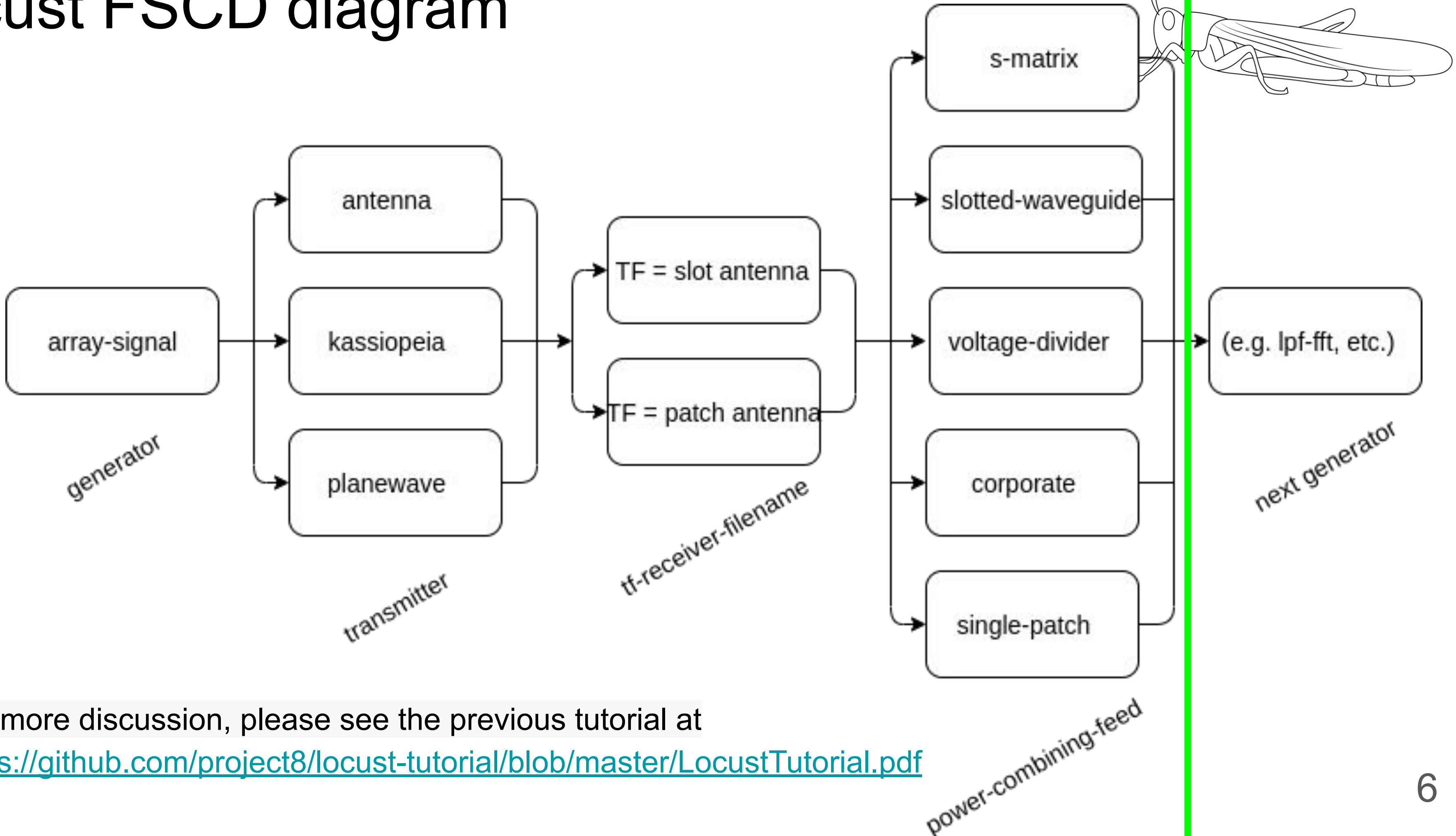
Project 8 collaboration, New J. Phys. 21 (2019) 113051

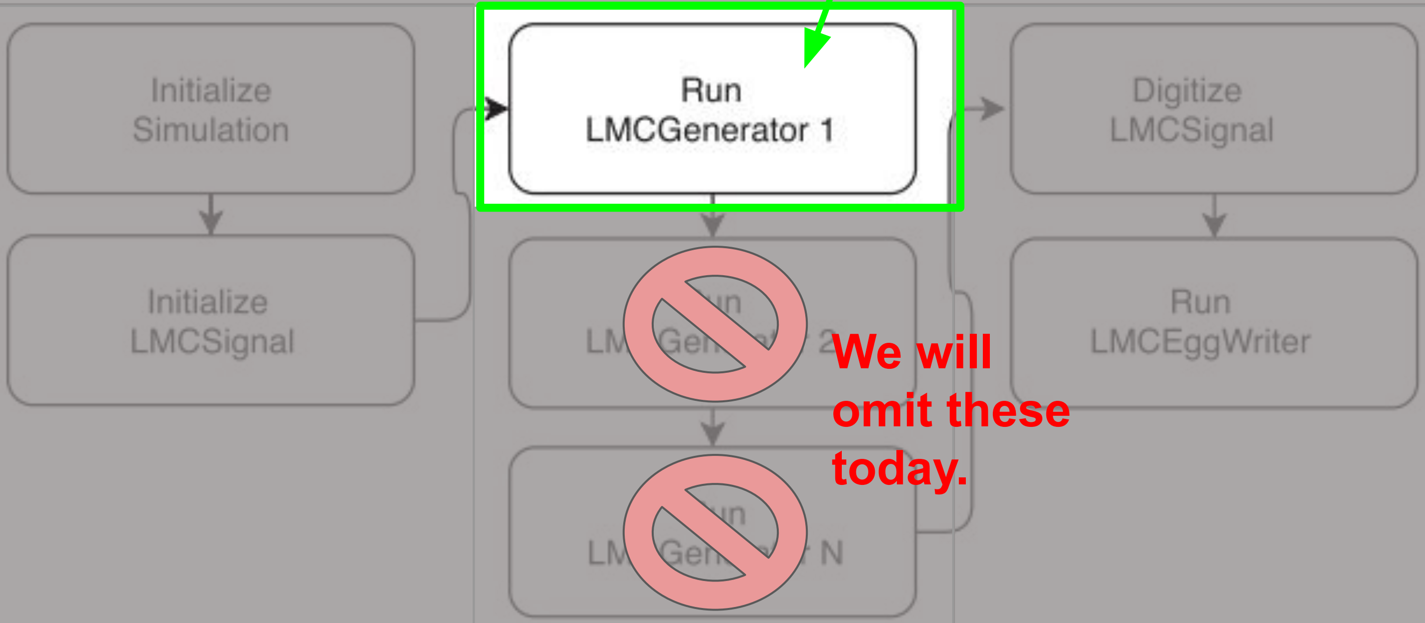
# Locust FSCD diagram



For more discussion, please see the previous tutorial at https://github.com/project8/locust-tutorial/blob/master/LocustTutorial.pdf

# Locust work flow diagram

For today we will start from a blank template, here.



We will omit these today.

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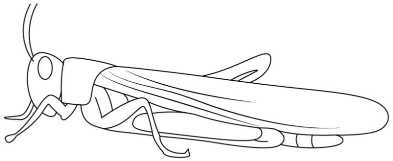
# First, some steps for setting up



Before we start the examples:

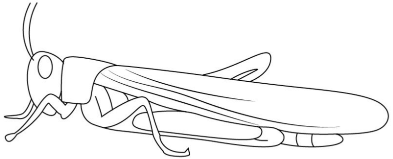
1. Install docker as in https://docs.docker.com/get-docker.
2. sudo docker pull project8/p8compute (sudo is unnecessary on Macs)
3. sudo docker pull project8/p8compute-jupyter (sudo is unnecessary on Macs)
4. Create a directory in your home directory, called ~/p8tutorial:

```
mkdir ~/p8tutorial
```

5. In the ~/p8tutorial directory, clone (or pull) the locust-tutorial repo:

```
cd ~/p8tutorial
git clone git@github.com:project8/locust-tutorial
```

# First, some steps for setting up (cont.)



7. Now clone Locust into ~/p8tutorial:

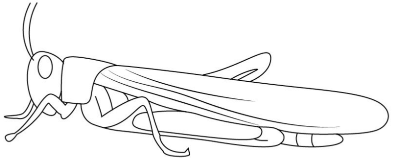
```
cd ~/p8tutorial
git clone git@github.com:project8/locust_mc
cd locust_mc
git checkout feature/tutorial
git submodule update --init --recursive
```

8. Start p8compute-jupyter and leave it open for the duration of the workshop:

   (all one line):
   ```
   docker run -p 8888:8888 -v ~/p8tutorial/locust-tutorial:/work -v ~/p8tutorial/locust_mc:/locust_mc project8/p8compute-jupyter
   ```

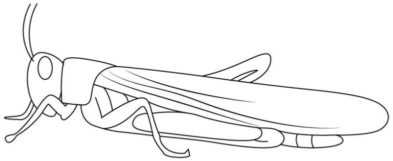
9. Open a browser tab using one of the links provided in the resulting terminal output.

# Start the p8compute container, compile Locust



- Start the container mount the Locust and work directories:
  (all one line):
  ```
  docker run -it -v ~/p8tutorial/locust_mc:/locust_mc -v ~/p8tutorial/locust-tutorial:/work project8/p8compute:latest /bin/bash
  ```
- Compile Locust
  ```
  source /usr/local/p8/compute/v0.10.2/setup.sh
  cd /locust_mc
  mkdir cbuild
  cd cbuild
  mkdir output/   (for https://github.com/project8/locust_mc/issues/177)
  cmake ../
  make install
  ```
  Or, if compiling with Kassiopeia,
  ```
  cmake -Dlocust_mc_BUILD_WITH_KASSIOPEIA=ON ../
  ```

# Create a new square wave signal Generator



Skip for today Jan. 28

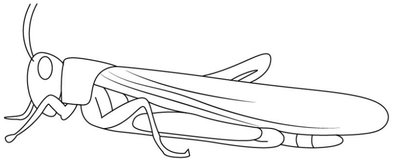
- Outside the container (if done from inside then change file permissions with chmod a+w):

```
cd ~/p8tutorial/locust_mc/Source/Generators
cp LMCTemplateGenerator.cc LMCSquareWaveSignalGenerator.cc
cp LMCTemplateGenerator.hh LMCSquareWaveSignalGenerator.hh
```

- Outside the container, in your favorite text editor, IDE, or both, open 6 files:

Source/Generators/LMCSquareWaveSignalGenerator.cc,
Source/Generators/LMCSquareWaveSignalGenerator.hh
Source/Core/LMCRunLengthCalculator.cc,
Source/Core/LMCRunLengthCalculator.hh
Source/Core/LMCVisitor.hh
Source/CMakeLists.txt

# Edit the 6 files:



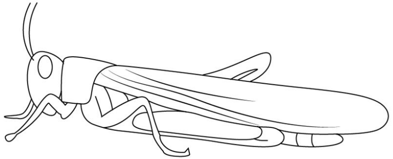
- In Source/Core/LMCRunLengthCalculator.cc uncomment these lines:

```
/*
void RunLengthCalculator::Visit( const SquareWaveSignalGenerator* )
{
 // nothing to see here, move along, please
 return;
}
*/
```

- In Source/Core/LMCRunLengthCalculator.hh uncomment this line:

```
// void Visit( const SquareWaveSignalGenerator* );
```

# Edit the 6 files, cont.



- In Source/Core/LMCVisitor.hh uncomment this line:

  ```
  // class SquareWaveSignalGenerator;
  ```

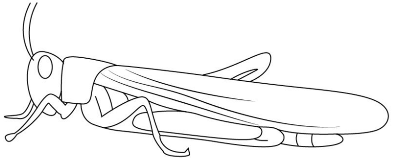
- In Source/CMakeLists.txt, under set( LOCUST_MC_HEADER_FILES) uncomment this line:

  ```
  # Generators/LMCSquareWaveSignalGenerator.hh
  ```

- In Source/CMakeLists.txt, under set( LOCUST_MC_SOURCE_FILES) uncomment this line:

  ```
  # Generators/LMCSquareWaveSignalGenerator.cc
  ```

# Now, edit the new generator:



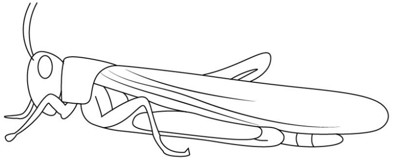
- In LMCSquareWaveSignalGenerator.hh:

  Replace [NAME] with SQUAREWAVESIGNAL (3 times).
  Replace [name] with SquareWaveSignal (6 times).
  Replace [domain] with Time (1 time, in comment).
  Replace config-name with square-wave (2 times).

- In LMCSquareWaveSignalGenerator.cc:

  Replace [name] with SquareWaveSignal (18 times).
  Replace [domain] with Time (1 time).
  Replace [config-name] with square-wave (1 time).
  Edit the name and date in the comment.

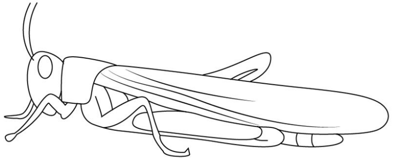
# Recompile Locust in the container



- This is a short slide:

  ```
  cd /locust_mc/cbuild
  cmake ../
  make install
  ```

# Now we need a config file



- Inside the container (or from outside container):

```
cd /locust_mc/cbuild/config
cp LocustBlankTemplate.json /work/LocustSquareWaveTemplate.json
```

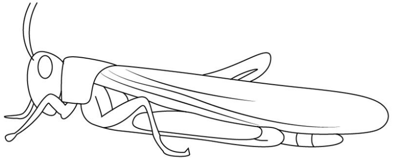
(If done from inside the container, you may need to change write permission for editing):

```
chmod a+w /work/LocustSquareWaveTemplate.json
```

- Outside the container in text editor, open the new ~/p8tutorial/locust-tutorial/LocustSquareWaveTemplate.json, add your new generator to the list of “generators”, and save it:

```
 "generators":
 [
       "square-wave",
       "digitizer"
 ],
```

# Test:  Run the new generator



- In the container, run your locally-cloned, and now expanded, Locust:

  (all one line):

  ```
  /locust_mc/cbuild/bin/LocustSim
  config=/work/LocustSquareWaveTemplate.json
  ```

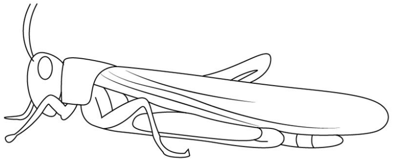
  Confirm that the output egg file is written to /locust_mc/cbuild/output/locust_mc.egg . (It will contain all zeroes.)

  ```
  ls -l /locust_mc/cbuild/output/locust_mc.egg
  ```

- Process the egg file with Katydid in the container, like this:

  ```
  Katydid -c config/katydid.json
  ```

# Now, outside container, edit the Generator to produce a square wave

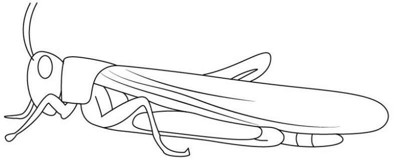


- In LMCSquareWaveSignalGenerator.cc, uncomment these lines in function DoGenerateTime( Signal* aSignal ):

```
/*
double RF_freq = 50.e6; // Hz
double amplitude = 1.e-5; // volts

        for( unsigned index = 0; index < aSignal->TimeSize(); ++index )
        {
            int nRFHalfCycles = int(index*(1./(fAcquisitionRate*1.e6)*(2.0*RF_freq)));
//          int nRFHalfCycles = int(index*(1./(fAcquisitionRate*1.e6)*(2.0*fRF_frequency)));
            double voltage = amplitude; // square wave is high
                if ( nRFHalfCycles%2==1 ) voltage = -amplitude; // square wave is low
            aSignal->SignalTimeComplex()[index][0] +=  voltage; // in-phase (I)
//          aSignal->SignalTimeComplex()[index][1] += [...]; // quadrature (Q) = 0 for real signals.
        }
*/
```

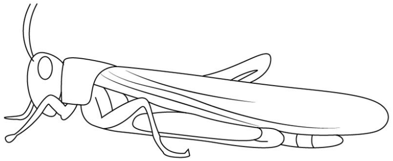
Uncomment here

# Inside container, compile, run, process:

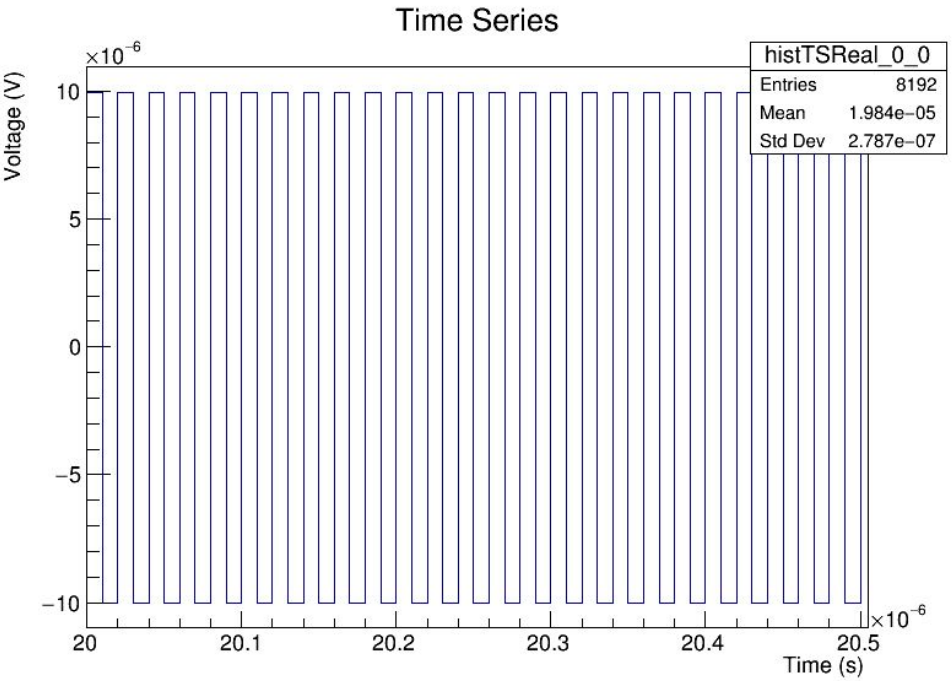


```
cd /locust_mc/cbuild

make install

bin/LocustSim config=/work/LocustSquareWaveTemplate.json

Katydid -c config/katydid.json
```

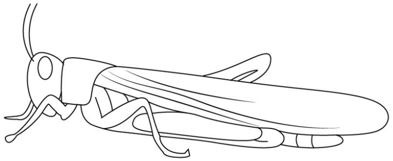
# Plot Katydid output time series with Root



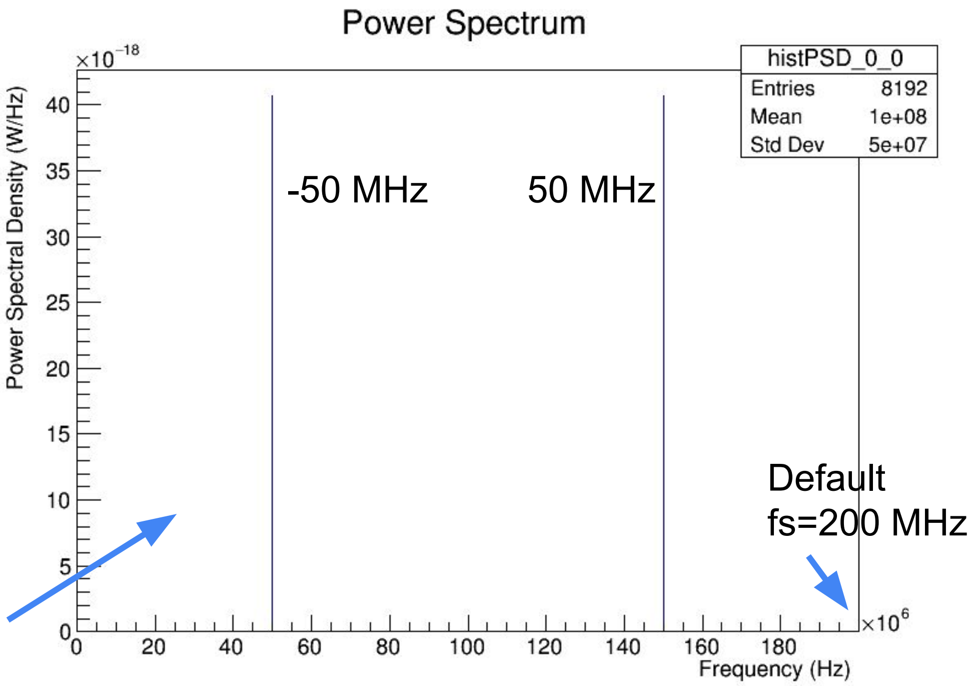
- In the jupyter browser tab, navigate with single clicks to /work/scripts/plotting/PlotTimeSeries2.ipynb
- Click the ▸▸, then click “Restart and run all cells”.
- This plot should appear in the lowest panel   -> .



# Plot Katydid frequency spectrum with Root



- In the jupyter browser tab, navigate with single clicks to /work/scripts/plotting/PlotPSD2.ipynb
- Click the ▸▸, then click “Restart and run all cells”.
- This plot should appear -> .



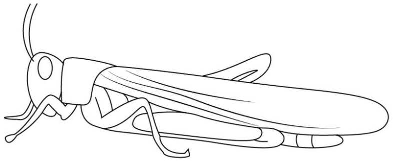
-50 MHz

50 MHz

Default fs=200 MHz

This is a symmetric fft spectrum because it comes from a real (not complex) signal. Center corresponds to DC.

# Let’s parametrize the frequency of the square wave



- This is a convenient way to modify the generator without recompiling the code.
- In LMCSquareWaveSignalGenerator.hh uncomment to add a new private variable:

```
// double fRF_frequency;
```

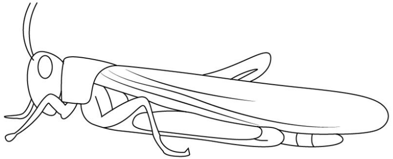
- In LMCSquareWaveSignalGenerator.cc uncomment to add a new class variable:

```
// fRF_frequency( 10.0e6 )
```

- In LMCSquareWaveSignalGenerator.cc, uncomment this into function Configure():

```
 /*
if( aParam.has( "rf-frequency" ) )
{
    fRF_frequency = aParam.get_value< double >( "rf-frequency", fRF_frequency );
}
*/
```

# Let’s parametrize the frequency of the square wave (cont):



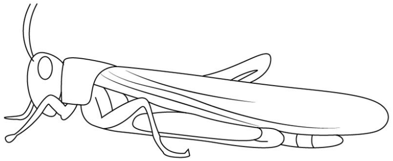
- Replace local hard-wired variable RF_freq with the new parameter fRF_frequency:

Comment this line: // `double RF_freq = 50.e6; // Hz`
Comment this line: // `int nRFHalfCycles = int(index*(1./(fAcquisitionRate*1.e6)*(2.0*RF_freq)));`
Uncomment this: `// int nRFHalfCycles = int(index*(1./(fAcquisitionRate*1.e6)*(2.0*fRF_frequency)));`

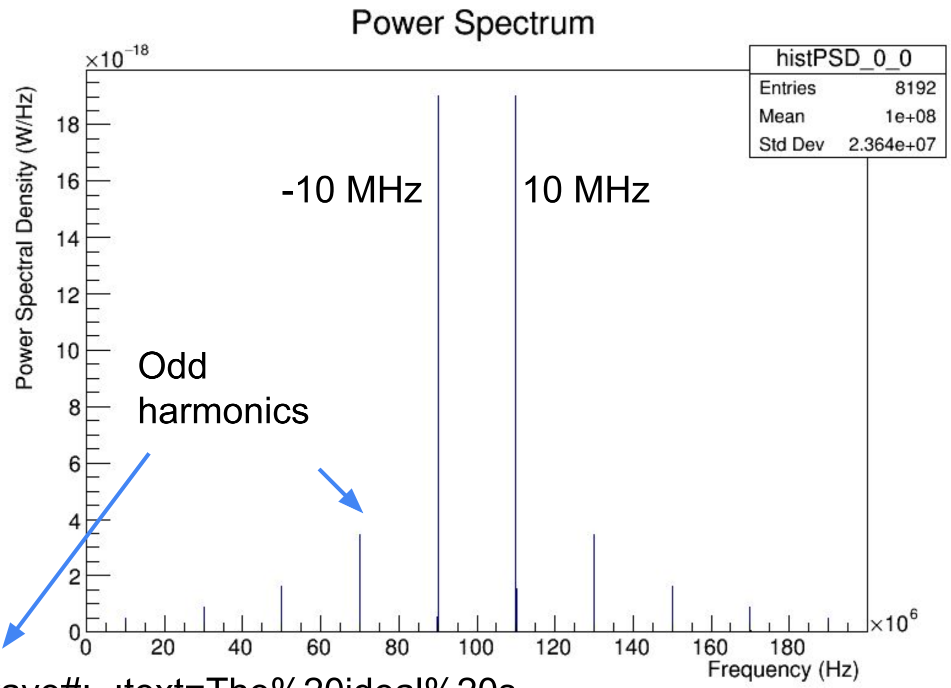
- Compile, run, process:

```
cd /locust_mc/cbuild
make install
bin/LocustSim config=/work/LocustSquareWaveTemplate.json
Katydid -c config/katydid.json
```

# Plot Katydid frequency spectrum with Root



- In the jupyter browser tab, navigate with single clicks to /work/scripts/plotting/PlotPSD2.ipynb
- Click the ▸▸, then click “Restart and run all cells”.
- This plot should appear -> .



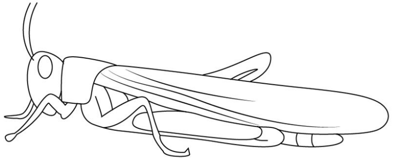
-10 MHz

10 MHz

Odd harmonics

https://en.wikipedia.org/wiki/Square_wave#:~:text=The%20ideal%20square%20wave%20contains,wave%20is%20the%20Gibbs%20phenomenon.

# Tune the square wave frequency:



- In ~/p8tutorial/locust-tutorial/, edit LocustSquareWaveTemplate.json to add this field:

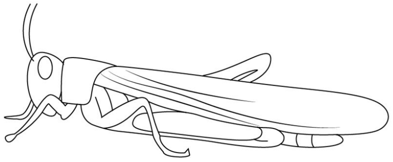
  ```
  "square-wave":
  {
      "rf-frequency": 25.0e6,
  },
  ```

  (This will change fRF_frequency from default 10 MHz to 25 MHz.)

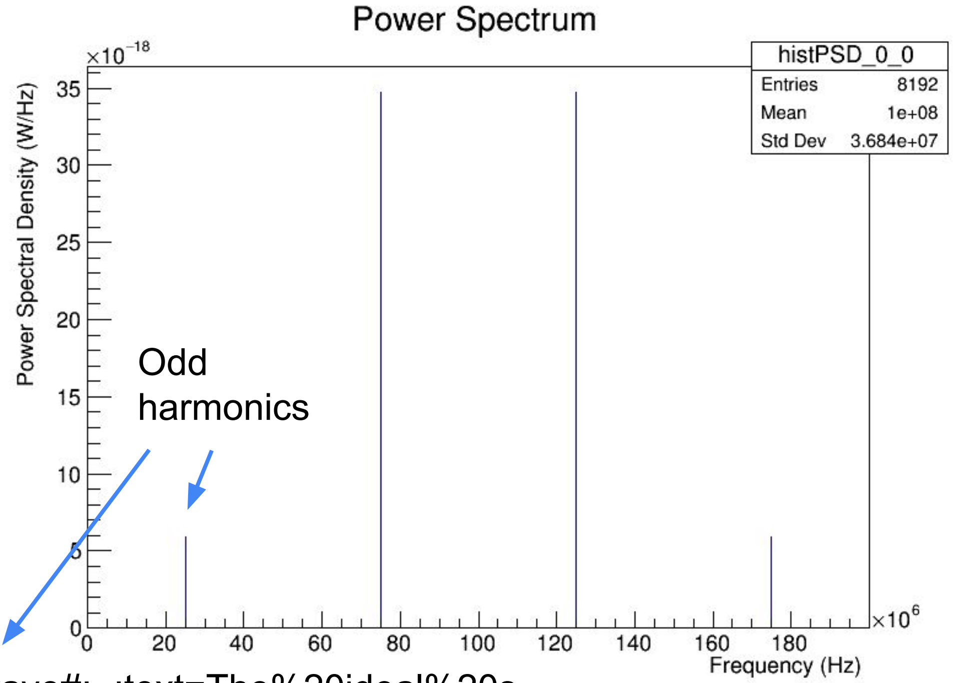
- Run, process (without needing to compile):

  ```
  bin/LocustSim config=/work/LocustSquareWaveTemplate.json
  Katydid -c config/katydid.json
  ```

# Plot Katydid frequency spectrum with Root



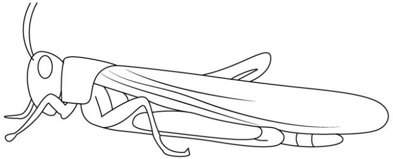
- In the jupyter browser tab, navigate with single clicks to /work/scripts/plotting/PlotPSD2.ipynb
- Click the ▸▸, then click “Restart and run all cells”.
- This plot should appear -> .



Odd harmonics

https://en.wikipedia.org/wiki/Square_wave#:~:text=The%20ideal%20square%20wave%20contains,wave%20is%20the%20Gibbs%20phenomenon.

# Conclusion and next steps



- In this tutorial we wrote a new subclass of LMCGenerator.
- For additional practice, new configurable subclasses could be added to other parent classes, e.g.:
  - LMCTransmitter.
  - LMCReceiver.
  - LMCPowerCombiner.
- Other unique physics models could also be implemented as a subclass of LMCGenerator.