Homodyne receiver

April 14, 2017

1 Homodyne receiver

This block of code simulates the reception and demodulation of an optical signal (which is the input signal of the system) outputing a binary signal. A simplified schematic representation of this block is shown in figure 1.

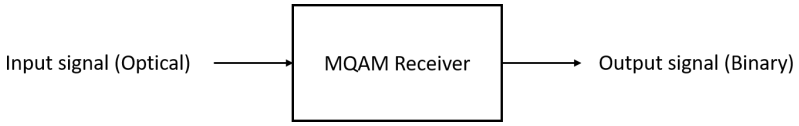

Figure 1: Basic configuration of the MQAM receiver

Functional description

This block accepts one optical input signal and outputs one binary signal that corresponds to the M-QAM demodulation of the input signal. It is a complex block (as it can be seen from figure 2) of code made up of several simpler blocks whose description can be found in the *lib* repository.

In can also be seen from figure 2 that there's an extra internal (generated inside the homodyne receiver block) input signal generated by the *Clock*. This block is used to provide the sampling frequency to the *Sampler*.

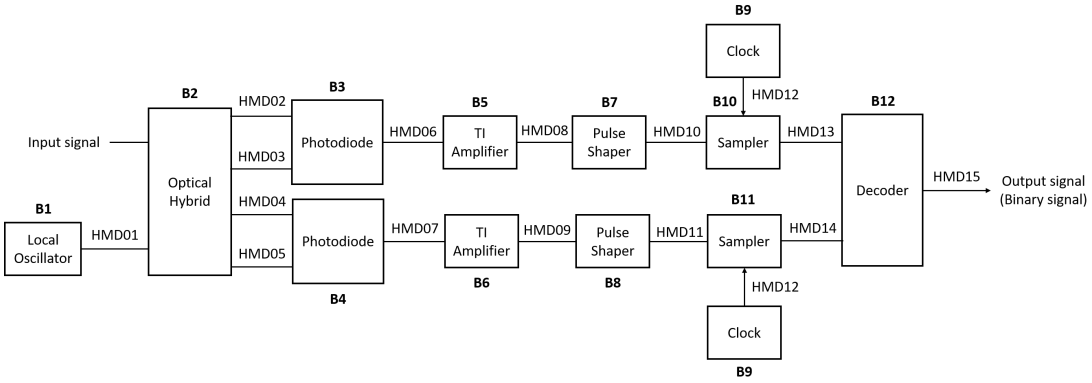

Figure 2: Schematic representation of the block homodyne receiver.

Input parameters

This block has some input parameters that can be manipulated by the user in order oto change the basic configuration of the receiver. Each parameter has associated a function that allows for its change. In the following table (table 1) the input parameters and corresponding functions are summarized.

Input parameters	**Function**	Type	**Accepted values**
IQ amplitudes	setIqAmplitudes	Vector of coordinate points in the I-Q plane	**Example** for a 4-qam mapping: { { 1.0, 1.0 }, { -1.0, 1.0 }, { -1.0, -1.0 }, { 1.0, -1.0 } }
Local oscillator power (in dBm)	setLocalOscillatorOpticalPower_dBm	double(t_real)	Any double greater than zero
Local oscillator phase	setLocalOscillatorPhase	double(t_real)	Any double greater than zero
Responsivity of the photodiodes	setResponsivity	double(t_real)	$\in$ [0,1]
Amplification (of the TI amplifier)	setAmplification	double(t_real)	Positive real number
Noise amplitude (introduced by the TI amplifier)	setNoiseAmplitude	double(t_real)	Real number greater than zero
Samples to skipe	setSamplesToSkip	int(t_integer)	
Save internal signals	setSaveInternalSignals	bool	True or False
Sampling period	setSamplingPeriod	double	Givem by *symbolPeriod/samplesPerSymbol*

Table 1: List of input parameters of the block MQAM receiver

Methods

HomodyneReceiver(vector<Signal *> &inputSignal, vector<Signal *> &outputSignal) (**constructor**)

void setIqAmplitudes(vector<t_iqValues> iqAmplitudesValues)

vector<t_iqValues> const getIqAmplitudes(void)

void setLocalOscillatorSamplingPeriod(double sPeriod)

void setLocalOscillatorOpticalPower(double opticalPower)

void setLocalOscillatorOpticalPower_dBm(double opticalPower_dBm)

void setLocalOscillatorPhase(double lOscillatorPhase)

void setLocalOscillatorOpticalWavelength(double lOscillatorWavelength)

void setSamplingPeriod(double sPeriod)

void setResponsivity(t_real Responsivity)

void setAmplification(t_real Amplification)

void setNoiseAmplitude(t_real NoiseAmplitude)

void setImpulseResponseTimeLength(int impResponseTimeLength)

void setFilterType(PulseShaperFilter fType)

void setRollOffFactor(double rOffFactor)

void setClockPeriod(double per)

void setSamplesToSkip(int sToSkip)

Input Signals

Number: 1

Type: Optical signal

Output Signals

Number: 1

Type: Binary signal

Example

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2 Local Oscillator

This block simulates a local oscillator which can have shot noise or not. It produces one output complex signal and it doesn't accept input signals.

Input Parameters

- opticalPower{ 1e-3 }
- wavelength{ 1550e-9 }
- frequency{ SPEED_OF_LIGHT / wavelength }
- phase{ 0 }
- samplingPeriod{ 0.0 }
- shotNoise{ false }

Methods

LocalOscillator()

LocalOscillator(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig){};

void initialize(void);

bool runBlock(void);

void setSamplingPeriod(double sPeriod);

void setOpticalPower(double oPower);

void setOpticalPower_dBm(double oPower_dBm);

void setWavelength(double wlength);

void setPhase(double lOscillatorPhase);

void setShotNoise(bool sNoise);

Functional description

This block generates a complex signal with a specified phase given by the input parameter *phase*.

It can have shot noise or not which corresponds to setting the *shotNoise* parameter to True or False, respectively. If there isn't shot noise the the output of this block is given by $0.5 * \sqrt{OpticalPower} * ComplexSignal$. If there's shot noise then a random gaussian distributed noise component is added to the *OpticalPower*.

Input Signals

Number: 0

Output Signals

Number: 1

Type: Optical signal

Examples

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3 Optical hybrid

This block simulates an optical hybrid. It accepts two input signals corresponding to the signal and to the local oscillator. It generates four output complex signals separated by 90° in the complex plane. Figure 3 shows a schematic representation of this block.

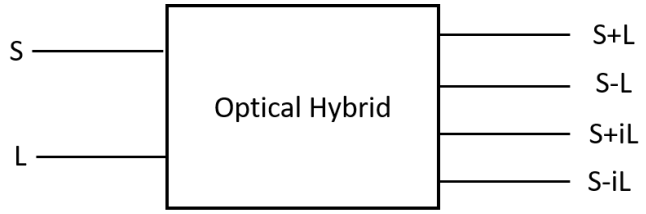

Figure 3: Schematic representation of an optical hybrid

Input Parameters

- outputOpticalPower{ 1e-3 }
- outputOpticalWavelength{ 1550e-9 }
- outputOpticalFrequency{ SPEED_OF_LIGHT / wavelength }
- powerFactor{0.5}

Methods

OpticalHybrid()

OpticalHybrid(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setOutputOpticalPower(double outOpticalPower)

void setOutputOpticalPower_dBm(double outOpticalPower_dBm)

void setOutputOpticalWavelength(double outOpticalWavelength)

void setOutputOpticalFrequency(double outOpticalFrequency)

void setPowerFactor(double pFactor)

Functional description

This block accepts two input signals corresponding to the signal to be demodulated (S) and to the local oscillator (L). It generates four output optical signals given by $powerFactor \times (S + L)$, $powerFactor \times (S - L)$,$powerFactor \times (S + iL)$, $powerFactor \times (S - iL)$. The input parameter *powerFactor* assures the conservation of optical power.

Input Signals

Number: 2

Type: Optical (OpticalSignal)

Output Signals

Number: 4

Type: Optical (OpticalSignal)

Examples

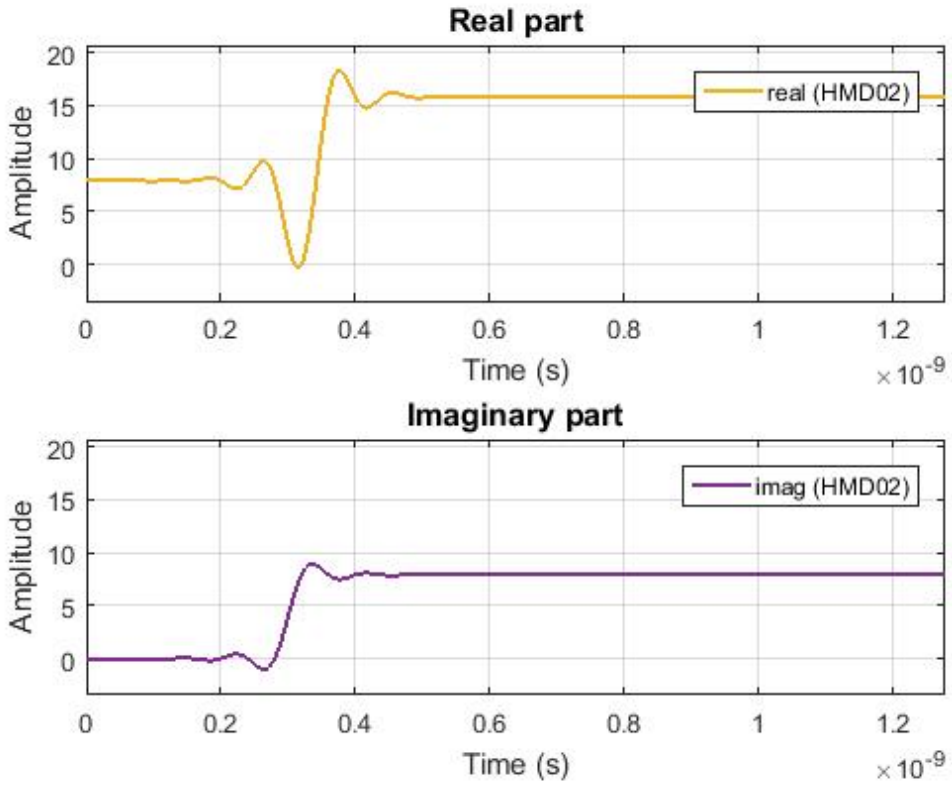

Figure 4: Example of one of the output signals of this block for a binary sequence 01

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4 Photodiode

This block simulates a block of two photodiodes assembled like in figure 5. It accepts two optical input signals and outputs one electrical signal. Each photodiode converts an optical signal to an electrical signal. The two electrical signals are then subtracted and the resulting signals corresponds to the output signal of the block.

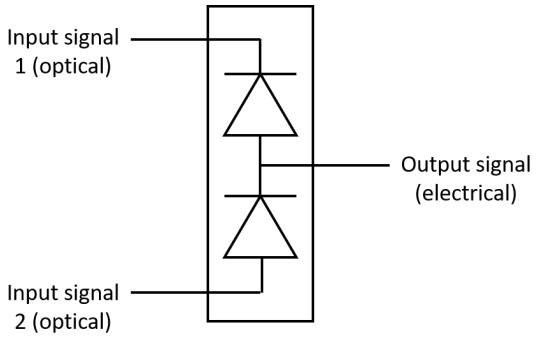

Figure 5: Schematic representation of the physical equivalent of the photodiode code block

Input Parameters

- responsivity{1}
- outputOpticalWavelength{ 1550e-9 }
- outputOpticalFrequency{ SPEED_OF_LIGHT / wavelength }

Methods

Photodiode()

Photodiode(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setResponsivity(`t_real` Responsivity)

Functional description

This block accepts two input optical signals. It computes the optical power of the signal (given by the absolute value squared of the input signal) and multiplies it by the *responsivity* of the photodiode. This product corresponds to the current generated by the photodiode. This is done for each of the input signals. The two currents are then subtracted producing a single output current, that corresponds to the output electrical signal of the block.

Input Signals

Number: 2

Type: Optical (OpticalSignal)

Output Signals

Number: 1

Type: Electrical (TimeContinuousAmplitudeContinuousReal)

Examples

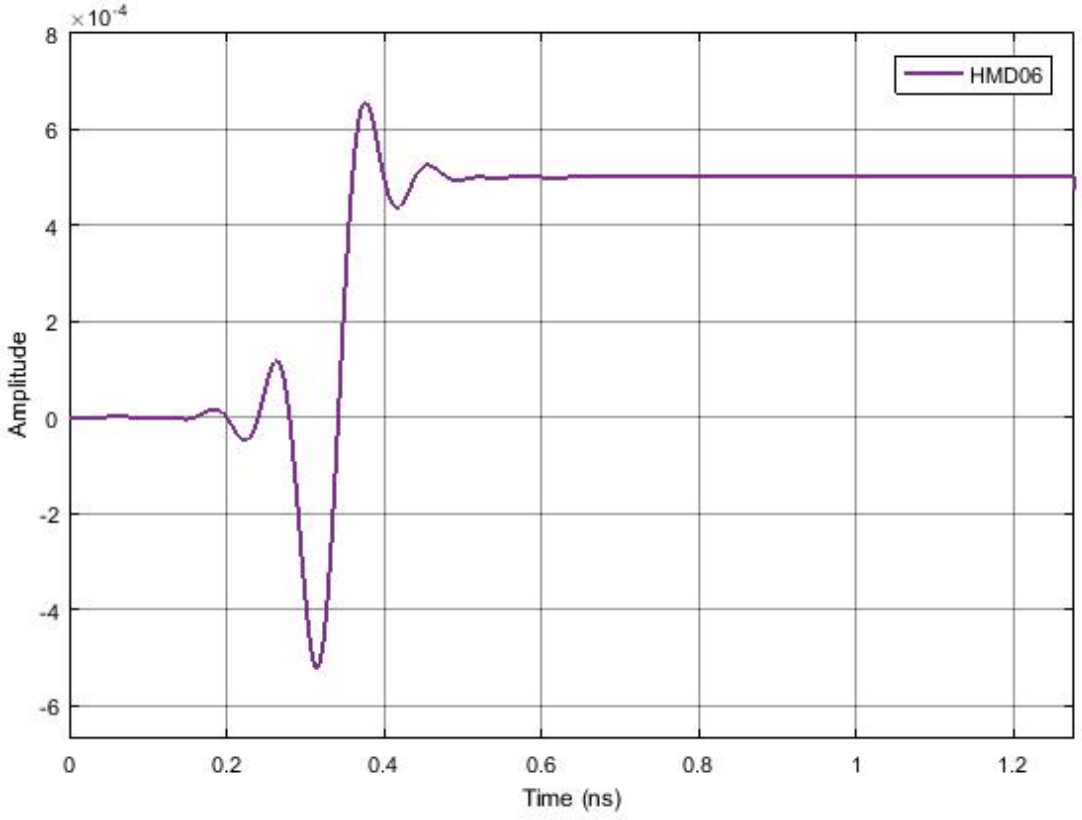

Figure 6: Example of the output singal of the photodiode block for a bunary sequence 01

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5 TI Amplifier

This block has one input signal and one output signal both corresponding to electrical signals. The output signal corresponds to the amplification of the input signal with added noise.

Input Parameters

- amplification{1e6}
- noiseamp{ 1e-4 }

Methods

TIAmplifier()

TIAmplifier(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setAmpplification(`t_real` Amplification)

void setNoiseAmpplitude(`t_real` NoiseAmplitude)

Functional description

The output signal is the product of the input signal with the parameter *amplification* plus a component that corresponds to the noise introduced by the amplification of the signal.

Input Signals

Number: 1

Type: Electrical (TimeContinuousAmplitudeContinuousReal)

Output Signals

Number: 1

Type: Electrical (TimeContinuousAmplitudeContinuousReal)

Examples

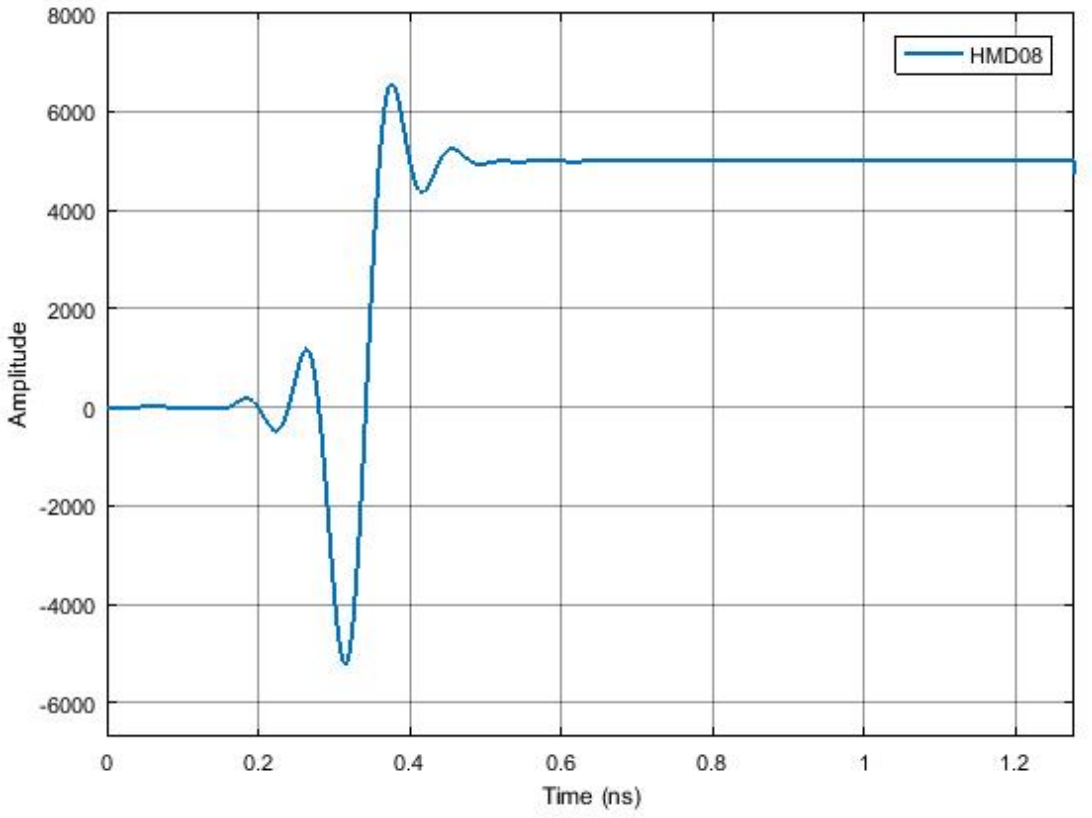

Figure 7: Example of the output signal of the amplifier block for a binary sequence 01. Note the scale of the y axis in comparison to the one in the output signal of the photodiode. The shape of the signal is the same as expected

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6 Pulse shaper

This block applies an electrical filter to the signal. It accepts one input signal that is a sequence of Dirac delta functions and it produces one output signal continuous in time and in amplitude.

Input Parameters

- filterType{RaisedCosine}

- impulseResponseTimeLength{16}
  (int)
  (This parameter is given in units of symbol period)
- rollOfFactor{0.9}
  (real $\in$ [0,1])

Methods

PulseShaper(vector<Signal *> &InputSig, vector<Signal *> OutputSig) :FIR_Filter(InputSig, OutputSig){};

void initialize(void);

void setImpulseResponseTimeLength(int impResponseTimeLength)

int const getImpulseResponseTimeLength(void)

void setFilterType(PulseShaperFilter fType)

PulseShaperFilter const getFilterType(void)

void setRollOffFactor(double rOffFactor)

double const getRollOffFactor()

Functional Description

The type of filter applied to the signal can be selected trough the input parameter *filterType*. Currently the only available filter is a raised cosine.

The filter's transfer function is defined by the vector *impulseResponse*. The parameter *rollOfFactor* is a characteristic of the filter and is used to define its transfer function.

Input Signals

Number : 1

Type : Sequence of Dirac Delta functions (ContinuousTimeDiscreteAmplitude)

Output Signals

Number : 1

Type : Sequence of impulses modulated by the filter (ContinuousTimeContinuousAmplitude)

Example

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Include other types of filters.

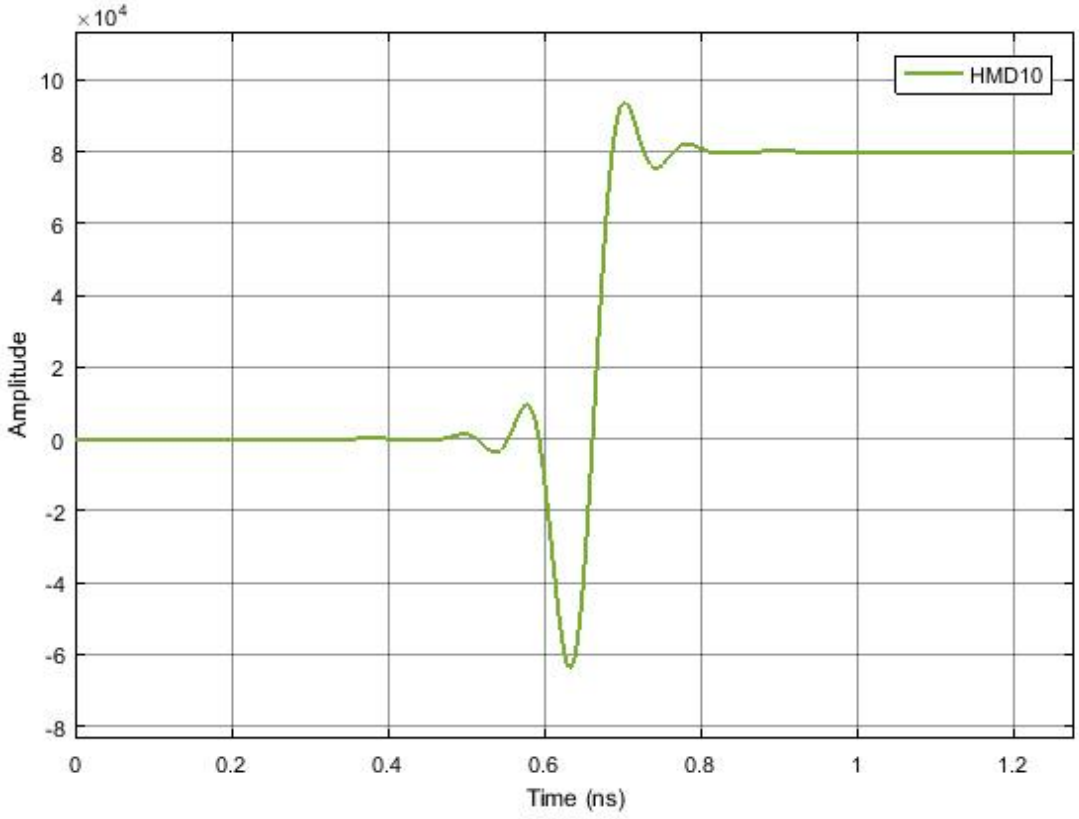

Figure 8: Example of a signal generated by this block for the initial binary signal 0100...

7 Sampler

This block can work in two configurations: with an external clock or without it. In the latter it accepts two input signals one being the clock and the other the signal to be demodulated. In the other configuration there's only one input signal which is the signal.

The output signal is obtained by sampling the input signal with a predetermined samplig rate provided either internally or by the clock.

Input Parameters

- samplesToSkip{ 0 }

Methods

Sampler()

Sampler(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setSamplesToSkip(`t_integer` sToSkip)

Functional description

This block can work with an external clock or without it.

In the case of having an external clock it accepts two input signals. The signal to be demodulate which is complex and a clock signal that is a sequence of Dirac delta functions with a predetermined period that corresponds to the sampling period. The signal and the clock signal are scanned and when the clock has the value of 1.0 the correspondent complex value of the signal is placed in the buffer corresponding to the output signal.

There's a detail worth noting. The electrical filter has an impulse response time length of 16 (in units of symbol period). This means that when modulating a bit the spike in the signal corresponding to that bit will appear 8 units of symbol period later. For this reason there's the need to skip the earlier samples of the signal when demodulating it. That's the purpose of the *samplesToSkip* parameter.

Between the binary source and the current block the signal is filtered twice which means that this effect has to be taken into account twice. Therefore the parameter *samplesToSkip* is given by $2 * 8 * samplesPerSymbol$.

Input Signals

Number: 1

Type: Electrical real (TimeContinuousAmplitudeContinuousReal)

Output Signals

Number: 1

Type: Electrical real (TimeDiscreteAmplitudeContinuousReal)

Examples

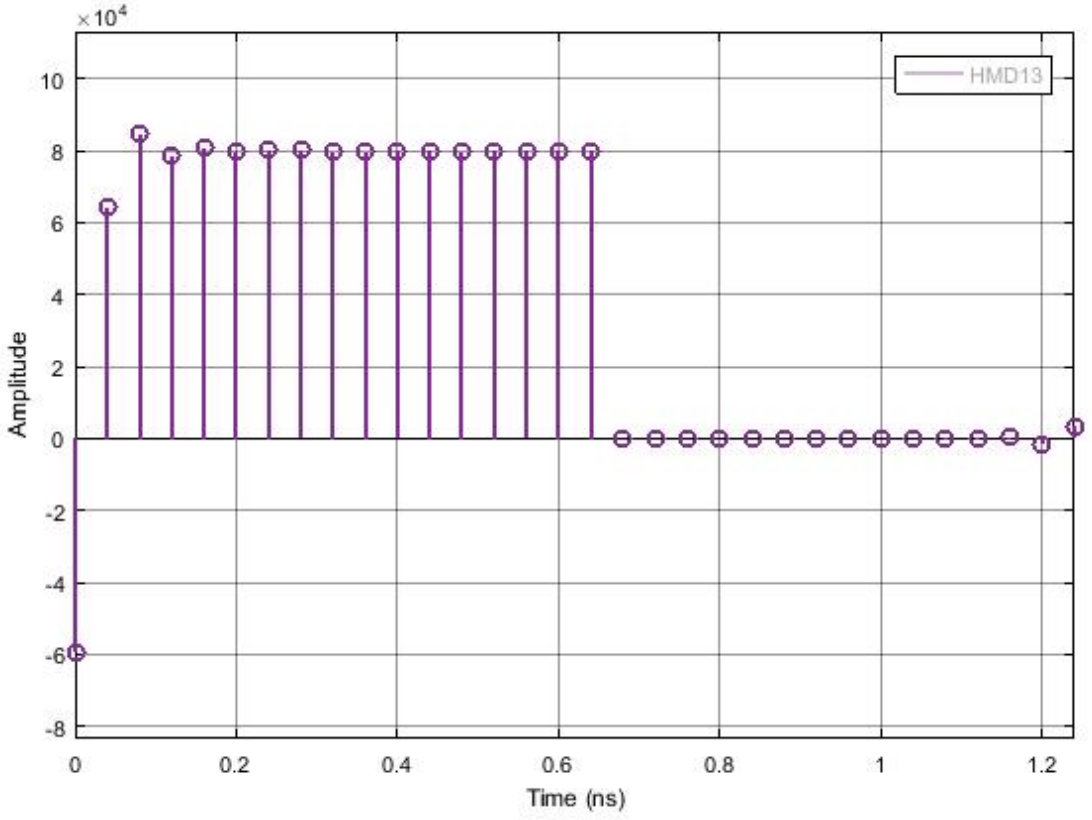

Figure 9: Example of the output signal of the sampler

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8 Clock

This block doesn't accept any input signal. It outputs one signal that corresponds to a sequence of Dirac's delta functions with a user defined *period*.

Input Parameters

- period{ 0.0 };
- samplingPeriod{ 0.0 };

Methods

Clock()

Clock(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setClockPeriod(double per)

void setSamplingPeriod(double sPeriod)

Functional description

Input Signals

Number: 0

Output Signals

Number: 1

Type: Sequence of Dirac's delta functions. (TimeContinuousAmplitudeContinuousReal)

Examples

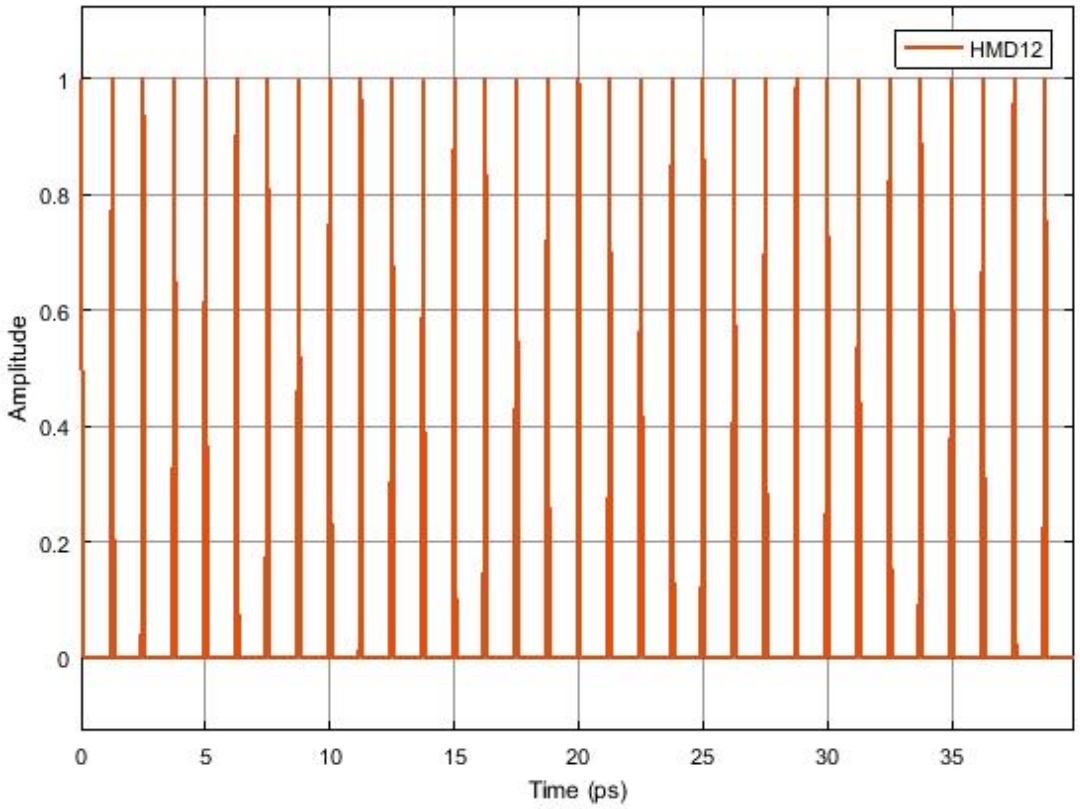

Figure 10: Example of the output signal of the clock

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9 Decoder

This block accepts a complex electrical signal and outputs a sequence of binary values (0's and 1's). Each point of the input signal corresponds to a pair of bits.

Input Parameters

- `t_integer` m{ 4 }
- vector<`t_complex`> iqAmplitudes{ { 1.0, 1.0 },{ -1.0, 1.0 },{ -1.0, -1.0 },{ 1.0, -1.0 } };

Methods

Decoder()

Decoder(vector<Signal *> &InputSig, vector<Signal *> &OutputSig) :Block(InputSig, OutputSig)

void initialize(void)

bool runBlock(void)

void setM(int mValue)

void getM()

void setIqAmplitudes(vector<`t_iqValues`> iqAmplitudesValues)

vector<`t_iqValues`>getIqAmplitudes()

Functional description

This block makes the correspondence between a complex electrical signal and pair of binary values using a predetermined constellation.

To do so it computes the distance in the complex plane between each value of the input signal and each value of the *iqAmplitudes* vector selecting only the shortest one. It then converts the point in the IQ plane to a pair of bits making the correspondence between the input signal and a pair of bits.

Input Signals

Number: 1

Type: Electrical complex (TimeContinuousAmplitudeContinuousReal)

Output Signals

Number: 1

Type: Binary

Examples

As an example take an input signal with positive real and imaginary parts. It would correspond to the first point of the *iqAmplitudes* vector and therefore it would be associated to the pair of bits 00.

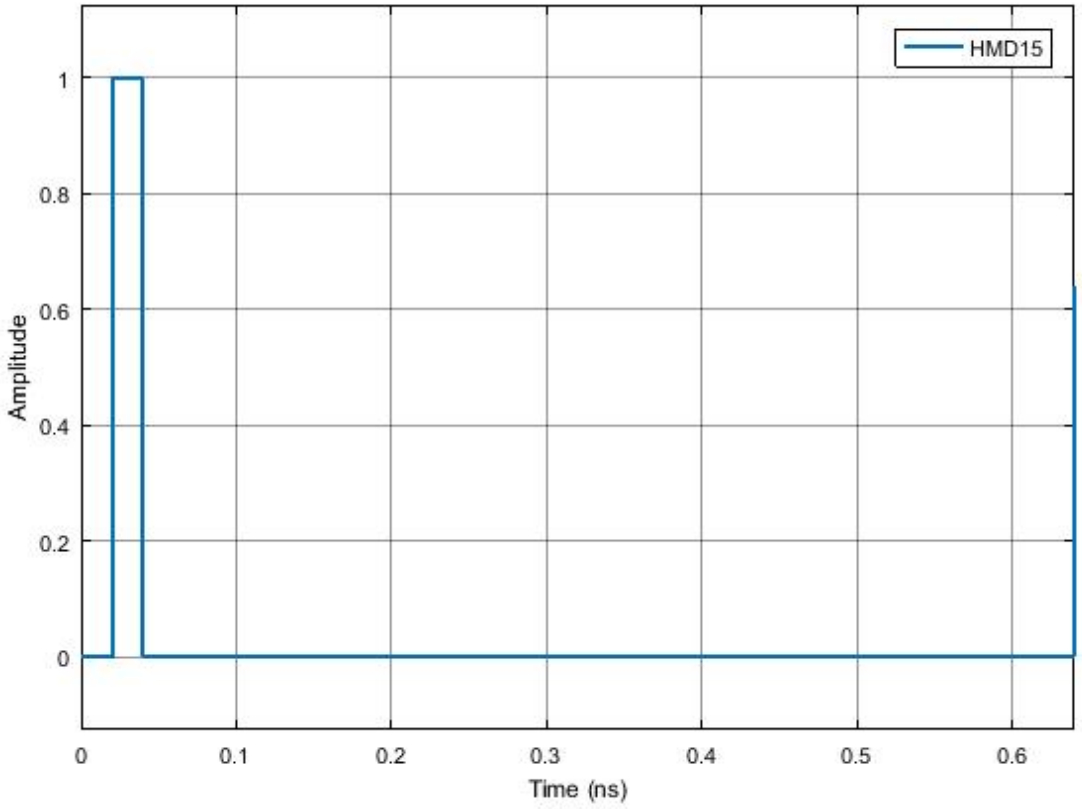

Figure 11: Example of the output signal of the decoder for a binary sequence 01. As expected it reproduces the initial bit stream

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