2023

8. Analog vs. Digital

R2: SCRAPY Guide

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1 Introduction

We live in an analogue world. There is an infinite amount of colours to paint an object (even if the difference is indiscernible to our eye), there are an infinite number of tones we can hear, and there are an infinite number of smells we can smell. The common theme among all of these analogue signals is their infinite possibilities.

Digital signals and objects deal in the realm of the discrete or finite, meaning there is a limited set of values they can be. That could mean just two total values, 255, 4,294,967,296, or anything as long as it's not ∞ (infinity).

Real-world objects can display data and gather inputs by either analogue or digital means. (From left to right): Clocks, multimeters, and joysticks can all take either form (analogue above, digital below).

Working with electronics means dealing with both analogue and digital signals, inputs and outputs. Our electronics projects have to interact with the real, analogue world in some way, but most of our microprocessors, computers, and logic units are purely digital components. These two types of signals are like different electronic languages; some electronic components are bi-lingual, and others can only understand and speak one of the two.

In this lesson, we'll cover the basics of both digital and analogue signals, including examples of each. We'll also talk about analogue and digital circuits and components.

2 Analog Signals

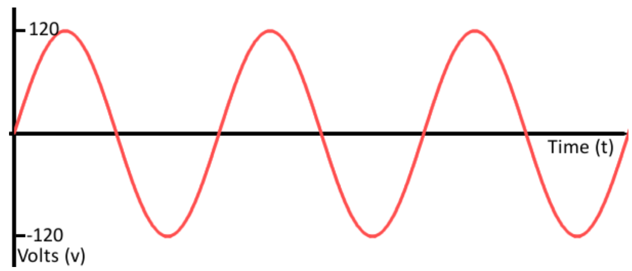
Define: Signals

Before going too much further, we should talk a bit about what a signal is, electronic signals specifically (as opposed to traffic signals, albums by the ultimate power trio, or a general means of communication). The signals we're talking about are time-varying "quantities" which convey some sort of information. In electrical engineering, the quantity that's time-varying is usually voltage (if not that, then usually current). So, when we talk about signals, just think of them as a voltage that's changing over time.

Signals are passed between devices to send and receive information, which might be video, audio, or some sort of encoded data. Usually, the signals are transmitted through wires, but they could also pass through the air via radio frequency (RF) waves. Audio signals, for example, might be transferred between your computer's audio card and speakers, while data signals might be passed through the air between a tablet and a Wi-Fi router.

2.1 Analog Signal Graphs

Because a signal varies over time, it's helpful to plot it on a graph where time is plotted on the horizontal, x-axis, and voltage on the vertical, y-axis. Looking at a graph of a signal is usually the easiest way to identify if it's analogue or digital; a time-versus-voltage graph of an analogue signal should be smooth and continuous.



Analog Signal Graphs

While these signals may be limited to a range of maximum and minimum values, there are still an infinite number of values within that range. For example, the analogue voltage coming out of your wall socket might be clamped between -120V and +120V, but, as you increase the resolution more and more, you discover an infinite number of values that the signal can be (like 64.4V, 64.42V, 64.424V, and infinite, increasingly precise values).

2.2 Example Analog Signals

Video and audio transmissions are often transferred or recorded using analogue signals. The composite video coming out of an old RCA jack, for example, is a coded analogue signal usually ranging between 0 and 1.073V. Tiny changes in the signal have a huge effect on the colour or location of the video.

Pure audio signals are also analogue. The signal that comes out of a microphone is full of analogue frequencies and harmonics, which combine to make beautiful music.

3 Digital Signals

Digital signals must have a finite set of values. The number of values in the set can be anywhere between two and a-very-large-number-that's-not-infinity. Most commonly digital signals will be one of two values -- like either 0V or 5V. Timing graphs of these signals look like square waves.

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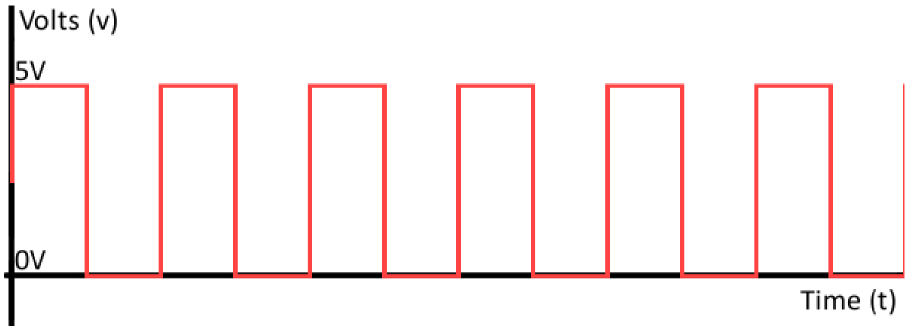
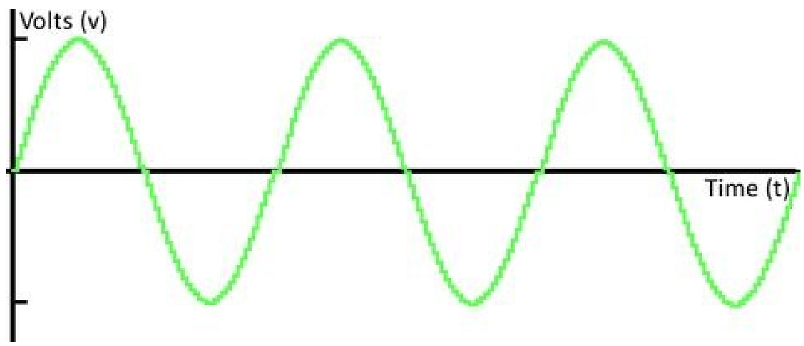


Digital Signals

representation of an analogue waveform. Viewed from afar, the wave function below may seem smooth and analogue, but when you look closely there are tiny discrete steps as the signal tries to

approximate values:



Analog Signals

That's the big difference between analogue and digital waves. Analogue waves are smooth and continuous, digital waves are stepping, square, and discrete.

3.1 Example Digital Signals

Not all audio and video signals are analogue. Standardized signals like HDMI for video (and audio) and MIDI, I2S, or AC'97 for audio are all digitally transmitted.

Most communication between integrated circuits is digital. Interfaces like serial, I2C, and SPI all transmit data via a coded sequence of square waves.

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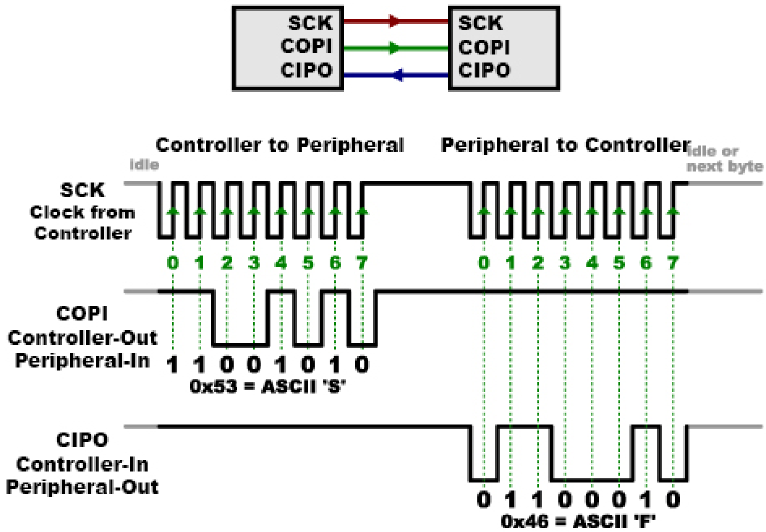
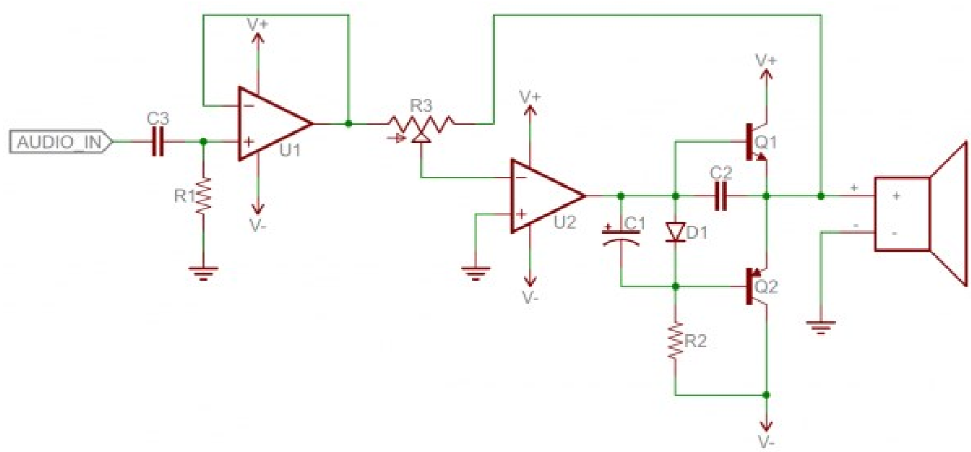


The serial peripheral interface (SPI) uses many digital signals to transmit data between devices.

4. Analog and Digital Circuits

Analog Electronics

Most of the fundamental electronic components -- resistors, capacitors, inductors, diodes, transistors, and operational amplifiers -- are all inherently analogue. Circuits built with a combination of solely these components are usually analogue.



Analogue circuits are usually complex combinations of op amps, resistors, caps, and other foundational electronic components. This is an example of a class B analogue audio amplifier.

Analogue circuits can be very elegant designs with many components, or they can be very simple, like two resistors combining to make a voltage divider. In general, though, analogue circuits are much more difficult to design than those which accomplish the same task digitally. It takes a special kind of analogue circuit wizard to design an analogue radio receiver or an analogue battery charger; digital components exist to make those designs much simpler.

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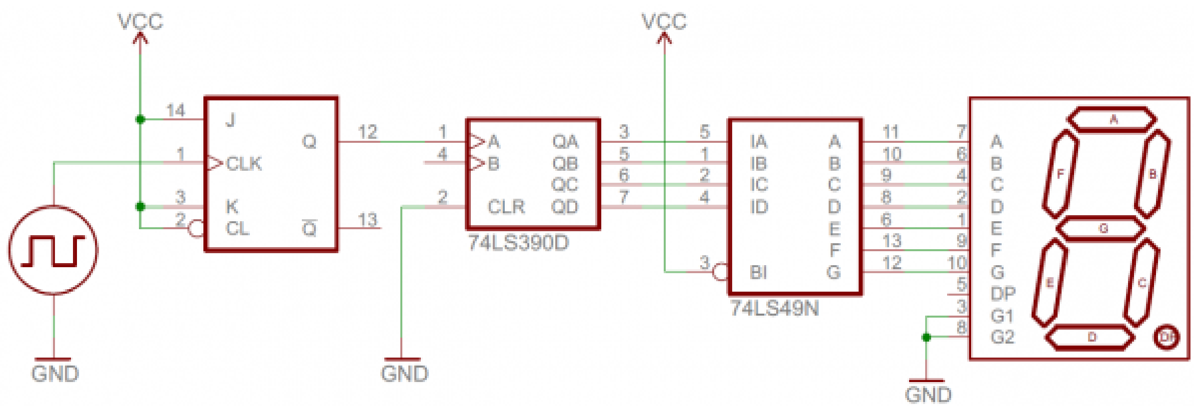
Analogue circuits are usually much more susceptible to noise (small, undesired variations in voltage). Small changes in the voltage level of an analogue signal may produce significant errors when being processed.

4.1 Digital Electronics

Digital circuits operate using digital, discrete signals. These circuits are usually made of a combination of transistors and logic gates and, at higher levels, microcontrollers or other computing chips. Most processors, whether they're big beefy processors in your computer, or tiny little microcontrollers, operate in the digital realm.



Digital circuits make use of components like logic gates, or more complicated digital ICs (usually represented by rectangles with labelled pins extending from them).

Digital circuits usually use a binary scheme for digital signalling. These systems assign two different voltages as two different logic levels -- a high voltage (usually 5V, 3.3V, or 1.8V) represents one value and a low voltage (usually 0V) represents the other.

Although digital circuits are easier to design, they do tend to be a bit more expensive than an equally tasked analogue circuit.

4.2 Analog and Digital Combined

It's not rare to see a mixture of analogue and digital components in a circuit. Although microcontrollers are usually digital beasts, they often have internal circuitry which enables them to interface with analogue circuitry (analogue-to-digital converters, pulse-width modulation, and digital-to-analogue converters. An analogue-to-digital converter (ADC) allows a microcontroller to connect to an analogue sensor (like photocells or temperature sensors), to read in an analogue voltage. The less common digital-to-analogue converter allows a microcontroller to produce analogue voltages, which is handy when it needs to make a sound.

5 Conclusion

Now that you know the difference between analogue and digital signals, we'd suggest checking out the Analog to Digital Conversion. Working with microcontrollers, or any logic-based electronics, means working in the digital realm most of the time. If you want to sense

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light, and temperature, or interface a microcontroller with a variety of other analogue sensors, you'll need to know how to convert the analogue voltage they produce into a digital value.

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