Introduction to LaTeX

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Outline

- Overview of LaTeX
- Systematic organization of a manuscript
  - Table of contents
  - The `\input{}` function
- Floating objects, labelling, and referencing
  - Types of floating objects
  - Labels and referencing
- Typing math equations using LaTeX
  - Different math equation formats
  - Labelling and referencing equations
- Setting up the bibliography
  - The JSON format
  - Making a bibfile
  - Referencing citations
- Creating diagrams and schematics with CircuiTikZ
  - The TikZ environment
  - CircuiTikz syntax

What is LaTeX?

"LaTeX is a high-quality typesetting system; it includes features designed for the production of technical and scientific documentation. LaTeX is the de facto standard for the communication and publication of scientific documents. LaTeX is available as free software."

-The LaTeX project
https://www.latex-project.org/

- Widely used by scientists to craft research manuscripts.
- Free for all.
- Does not use much processing power to type documents as it only needs a text editor.
- All files are compiled by the LaTeX processor to craft a PDF document with the manuscript as the output.

A LaTeX Document

Menu | IEEE | Using the Incident Signal as a Trigger to Measure S-parameters | Review | Share | Submit to IEEE | History | Chat

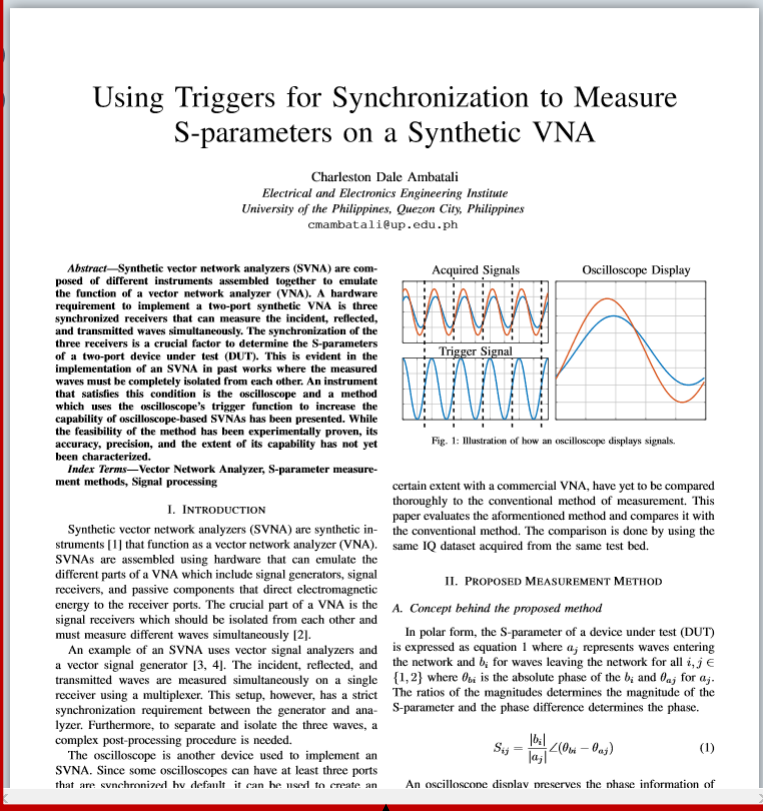
Source | Rich Text

- bibtex
- images
- old_ver
- bare_jrnl.tex
- bibfile.bib
- IEEEtran.bst

File outline

```
\hyphenation{op-tical net-works semi-conduc-tor}

\usepackage[backend=bibtex,bibstyle=ieee,citestyle=numeric-comp]{biblatex}
\addbibresource{bibfile.bib}
\usepackage{amsmath,amssymb,amsfonts}
\usepackage{circuitikz}
\usepackage{graphicx}
\usepackage{float}
\usepackage{array}
%\usepackage{tikz}
\usepackage{caption}
\usepackage[caption=false, font=footnotesize]{subfig}
\usepackage{pgfplots}
\usepackage{arydshln}
\usepackage{algorithm}
\usepackage{fancyhdr}
\usepackage{courier}
\usepackage{comment}
\usepackage[scaled]{helvet}
\usepackage[noend]{algpseudocode}
\usepackage[bottom=0.75in,top=0.75in,right=0.5in,left=0.5in]{geometry}

\DeclareCaptionFont{mysize}{\fontsize{8}{9.6}\selectfont}
\captionsetup{font=mysize}

\pgfplotsset{width=7cm,compat=1.5.1}
\renewcommand*{\bibfont}{\small}

\newcolumntype{L}[1]{>{\raggedright\let\newline\\\arraybackslash\hspace{0pt}}m{#1}}
\newcolumntype{C}[1]{>{\centering\let\newline\\\arraybackslash\hspace{0pt}}m{#1}}
\newcolumntype{R}[1]{>{\raggedleft\let\newline\\\arraybackslash\hspace{0pt}}m{#1}}

\newcommand\ddfrac[2]{\frac{\displaystyle #1}{\displaystyle #2}}
```

Recompile



Using Triggers for Synchronization to Measure S-parameters on a Synthetic VNA

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***Abstract*—Synthetic vector network analyzers (SVNA) are composed of different instruments assembled together to emulate the function of a vector network analyzer (VNA). A hardware requirement to implement a two-port synthetic VNA is three synchronized receivers that can measure the incident, reflected, and transmitted waves simultaneously. The synchronization of the three receivers is a crucial factor to determine the S-parameters of a two-port device under test (DUT). This is evident in the implementation of an SVNA in past works where the measured waves must be completely isolated from each other. An instrument that satisfies this condition is the oscilloscope and a method which uses the oscilloscope's trigger function to increase the capability of oscilloscope-based SVNAs has been presented. While the feasibility of the method has been experimentally proven, its accuracy, precision, and the extent of its capability has not yet been characterized.**

***Index Terms*—Vector Network Analyzer, S-parameter measurement methods, Signal processing**

I. Introduction

Synthetic vector network analyzers (SVNA) are synthetic instruments [1] that function as a vector network analyzer (VNA). SVNAs are assembled using hardware that can emulate the different parts of a VNA which include signal generators, signal receivers, and passive components that direct electromagnetic energy to the receiver ports. The crucial part of a VNA is the signal receivers which should be isolated from each other and must measure different waves simultaneously [2].

An example of an SVNA uses vector signal analyzers and a vector signal generator [3, 4]. The incident, reflected, and transmitted waves are measured simultaneously on a single receiver using a multiplexer. This setup, however, has a strict synchronization requirement between the generator and analyzer. Furthermore, to separate and isolate the three waves, a complex post-processing procedure is needed.

The oscilloscope is another device used to implement an SVNA. Since some oscilloscopes can have at least three ports

Fig. 1: Illustration of how an oscilloscope displays signals.

certain extent with a commercial VNA, have yet to be compared thoroughly to the conventional method of measurement. This paper evaluates the aforementioned method and compares it with the conventional method. The comparison is done by using the same IQ dataset acquired from the same test bed.

II. Proposed Measurement Method

A. Concept behind the proposed method

In polar form, the S-parameter of a device under test (DUT) is expressed as equation 1 where a_j represents waves entering the network and b_i for waves leaving the network for all $i, j \in \{1, 2\}$ where θ_{bi} is the absolute phase of the b_i and θ_{aj} for a_j. The ratios of the magnitudes determines the magnitude of the S-parameter and the phase difference determines the phase.

$$S_{ij} = \frac{|b_i|}{|a_j|}\angle(\theta_{bi} - \theta_{aj}) \quad (1)$$

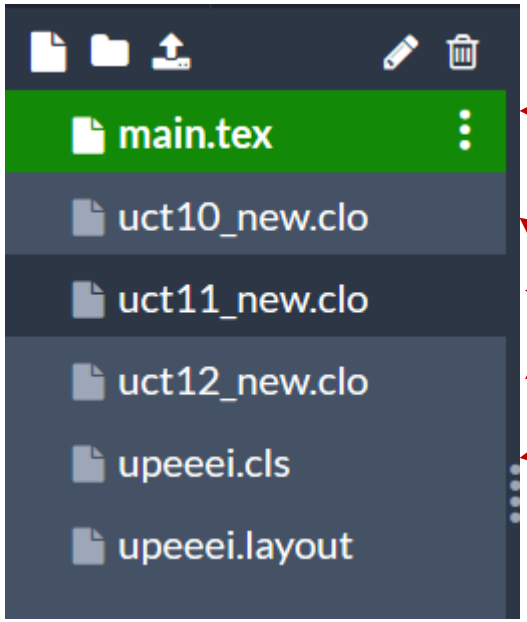
An oscilloscope display preserves the phase information of

Separate files for different parts of the document.

The main file where the manuscript is written

Compiled and formatted manuscript

Inside a LaTeX Document



Source file. The main code is what the LaTeX compiler runs.

Class option files. Files that supplement the class files.

Class file. This defines the formatting of the LaTeX document.

```
\documentclass[english]{upeeei}
```

- Only the tex file is needed to run a LaTeX document. It will compile to the default format of LaTeX.
- The cls file contains will compile the document in a different format to the default one.
  - UP EEEI has its own cls file and layout (by Dr. Louis Alarcón)
  - The IEEE two-column standard also has its own cls file.

Packages for Easier Encoding

```
\usepackage[latin9]{inputenc}
\setcounter{secnumdepth}{3}
\setcounter{tocdepth}{3}
\usepackage[active]{srcltx}
\usepackage{units}
\usepackage{parskip}
\usepackage{graphicx}
\usepackage{subfigure}
\usepackage{url}
%\usepackage{stfloats}
\usepackage{amsmath}
\usepackage{array}
\usepackage{caption}
\usepackage{afterpage}
\usepackage{textcomp}
\usepackage{lscape}
\usepackage{stfloats}
\usepackage{hyphenat}
\usepackage{makeidx}
\usepackage{amssymb}
%\usepackage{underscore}
\fnbelowfloat
\usepackage{times}
\usepackage{multirow}
%\usepackage{float}
\usepackage{circuitikz}
```

- Similar to the *#include<>* headers of the C programming language or the *import* function of Python.
- Packages will make some parts of the encoding process easier like:
  - Creating a bibliography (biblatex package)
  - Managing floating objects (stfloats package)
  - Encoding math functions (amsmath package)
- This is the first part of your LaTeX code.
- LaTeX will not compile your document if a package is missing.

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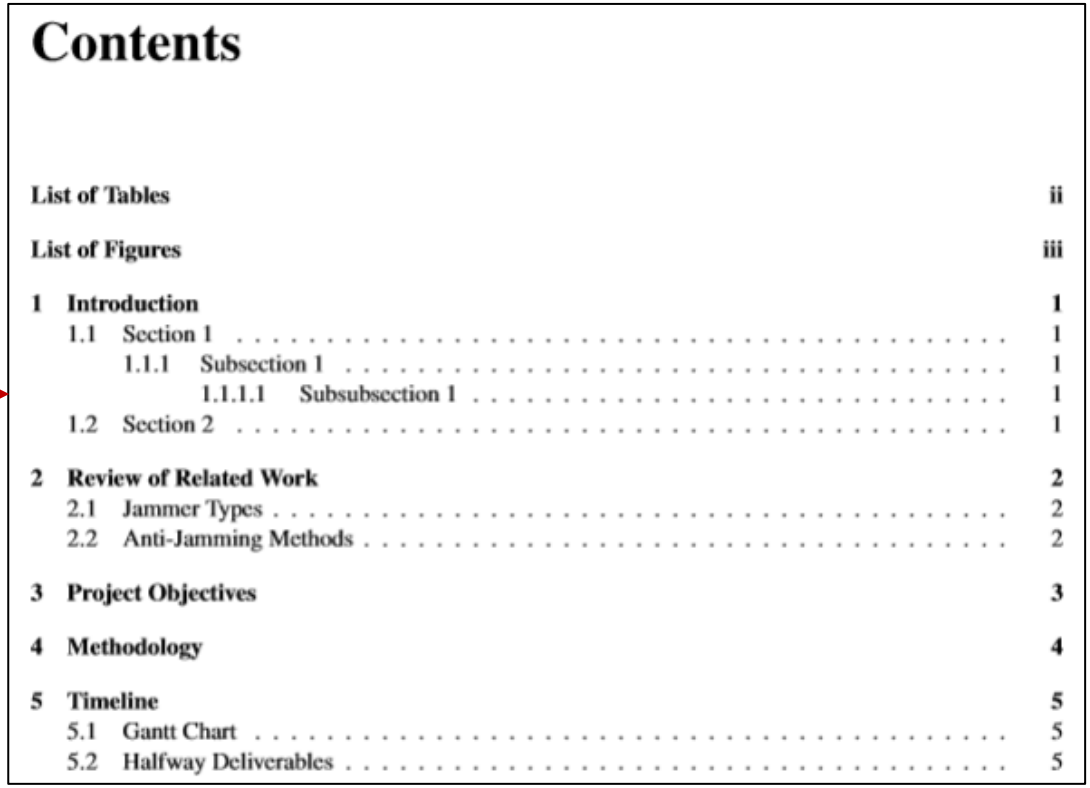
  - The TikZ environment
  - CircuiTikz syntax

The Table of Contents

- LaTeX automatically generates a table of contents, list of figures, and list of tables.
- It identifies chapters, sections, subsections and so on using the proper headers.

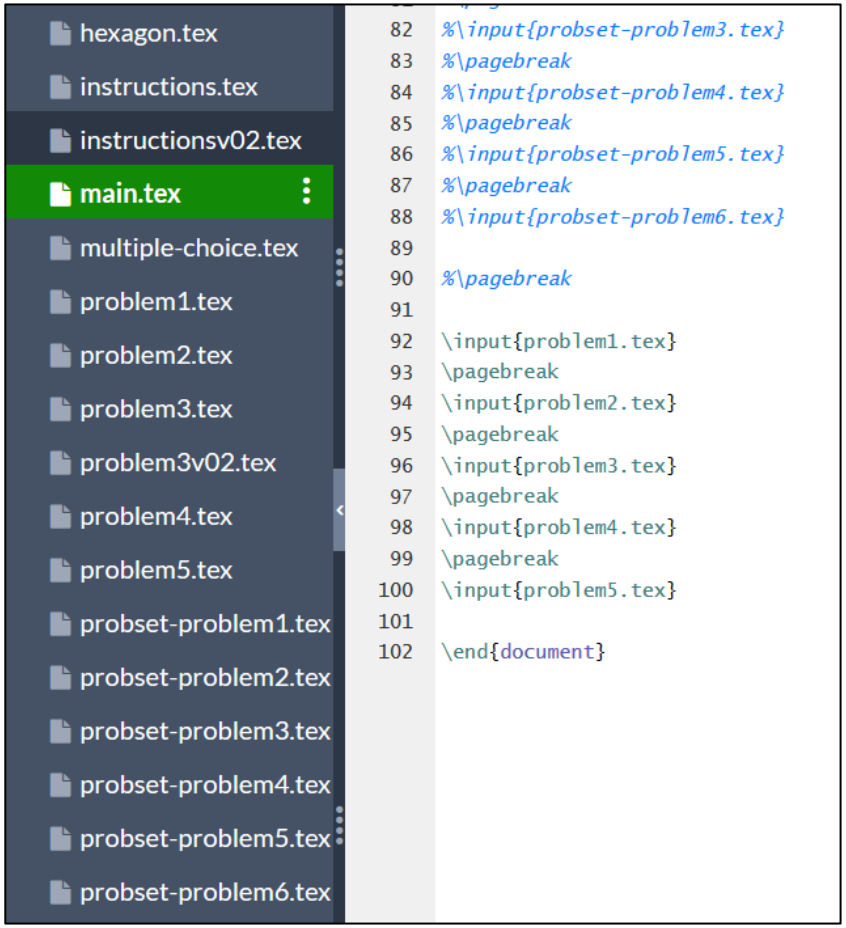
```
\chapter{Introduction}
\section{Section 1}
\subsection{Subsection 1}
\subsubsection{Subsubsection 1}
\section{Section 2}

\chapter{Review of Related Work}
\section{Jammer Types}
\section{Anti-Jamming Methods}

\chapter{Project Objectives}

\chapter{Methodology}

\chapter{Timeline}
\section{Gantt Chart}
\section{Halfway Deliverables}
```



Contents

Separating Files for Easier Coding

- Multiple tex files can be included inside the main tex file.
- By separating the documents, it is easier to keep track of the sections you are encoding.
- Using the `\input{}` function, a separate tex code can be included inside the main tex code as shown on the right.



Suggestion on Organizing

- Write a different tex code for each chapter and use the `\input{}` function for each chapter in the main code.
- An example tex code for a single chapter:

```
%%% This is an example chapter format. The file name
%%% is chapter01.tex
\chapter{Chapter Title}
Chapter body. Details about this chapter.
       \subsection{Subsection Title}
       Subsection body
```

- In the main tex document, you will simply include the line:

```
%%% This is part of the main tex document.
\input{chapter01.tex}
```

- The LaTeX compiler will simply run the chapter code before proceeding with the compilation.

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Floating Objects: Figures

- Floating objects are containers for things inside a document that cannot be broken over a page.
- LaTeX recognizes images and tables as floating objects.
- In a float environment, a caption can be encoded.
- An example floating environment:

```
\begin{figure}
    \centering
    \includegraphics[scale=0.335]{images/mag_mean_diff.png}
    \caption{Difference in magnitude measurement mean of the proposed method and
    the conventional method}
    \label{fig:meandiffcomparison}
\end{figure}
```

Centers the figure inside the floating object

Insert an image file with scaling

Include a caption

- The placement of the floating object is decided by the compiler but the user can set it to [h]ere, [t]op, or [b]ottom:

```
\begin{figure} [t]
```

Floating Objects: Figures

- The resulting floating object

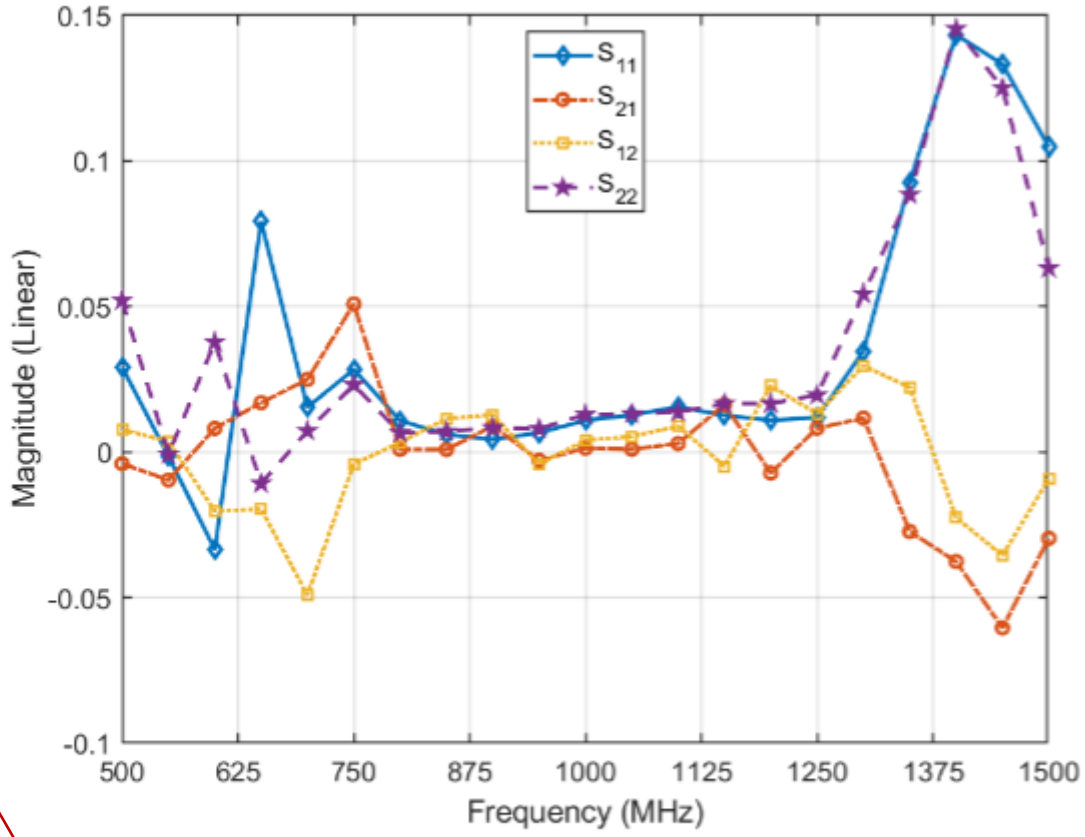

Figure number generation is automatic

Fig. 5: Difference in magnitude measurement mean of the proposed method and the conventional method

Caption

Floating Objects: Tables

- A table can be called by using the floating environment:

```
\begin{table} [t]
      %insert tabular object here
\end{table}
```

- However, a tabular object should be called as such:

```
\begin{tabular} [|c|c|]
      \hline
      first column, first row & second column \\
      first column, second row & asd \\
\end{tabular}
```

- The |c|c| header denotes the three column lines and two columns per row and 'c' means centered inside the cell.
  - Other options are 'l' and 'r' which stands for left and right.
- & denotes end of column and \\ denotes end of row.
- \hline calles for a line between rows.

Floating Objects: Tables

```
\begin{tabular} [|c|c|]
        \hline
        first column, first row & second column \\
        first column, second row & asd \\
\end{tabular}
```

Results into:

first column, first row	second column
first column, second row	asd

```
\begin{tabular} [|c|c|]
        \hline
        first column, first row & second column \\
        first column, second row & asd \\
        \hline
\end{tabular}
```

Results into:

first column, first row	second column
first column, second row	asd

Labels and References

- Labels are used for but not limited to: figures, tables, and equations.
- They are called or referenced in a different part of the document. Example:

```
\begin{figure}
    \centering
    \includegraphics[scale=0.335]{images/mag_mean_diff.png}
    \caption{Difference in magnitude measurement mean of the proposed method and
    the conventional method}
    \label{fig:meandiffcomparison}
\end{figure}
```

Inserts a label in a floating object

- To reference this, the code is:

Call the label inside a \ref{} function

```
\chapter{Review of Related Works}
According to figure \ref{fig:meandiffcomparison},
the measurements are accurate within a certain
bandwidth.
```

Labels and References

- From the previous example:

```
\chapter{Review of Related Works}
According to figure \ref{fig:meandiffcomparison},
the measurements are accurate within a certain
bandwidth.
```

- Let's say the figure is the fifth figure in the document. Then the code above results into:

> According to figure 5, the measurements are accurate within a certain bandwidth.

- If the user inserts a figure before this figure, LaTeX will automatically adjust the figure number accordingly.
- Same applies to other objects such as tables and equations.

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LaTeX Math

- Several packages in LaTeX makes typing mathematical equations easy.
- Two modes of mathematical writing:
  - **Inline mode** – formulas or expressions that are part of a paragraph.
  - **Display mode** – math text not part of a paragraph, can be numbered and labelled.
- Inline mode example:

```
The formula $V=IR$ is called Ohm's Law. Here,
\(V\) is the voltage, \[I\] is the current, and
$R$ is the resistance.
```

- The text enclosed in `$`, `\(\)`, and `\[\]` will be encoded as math equations.
- Use inline mode when talking about variables inside paragraphs.

LaTeX Math

- Display mode has two types: unnumbered and numbered.
- Numbered equations can be labelled and referenced in different parts of the code.
- The equation numbering will depend on the cls formatting.
- Unnumbered:

```
$$
V=IR
$$
```

- Numbered with label:

```
\begin{equation}
        V=IR
        \label{eq:ohms-law}
\end{equation}
```

Subscripts and Superscripts

- A subscript can be added using the _ identifier. Example:

```
$$
Q_{encl}
$$
```


$$Q_{encl}$$

- The whole subscript must be enclosed in a bracket, else

```
$$
Q_encl
$$
```


$$Q_encl$$

- Superscripts work the same way but uses the ^ identifier.

```
$$
e^{j2\pi f t}
$$
```


$$e^{j2\pi ft}$$

Greek Letters

- The code for Greek letters is straightforward. Some examples:

Code	Appearance	Code	Appearance
`$$\alpha$$`	α	`$$\Alpha$$`	$\Alpha$
`$$\beta$$`	β	`$$\Beta$$`	$\Beta$
`$$\gamma$$`	γ	`$$\Gamma$$`	Γ
`$$\omega$$`	ω	`$$\Omega$$`	Ω
`$$\epsilon$$`	ϵ	`$$\Epsilon$$`	$\Epsilon$
`$$\mu$$`	μ	`$$\Mu$$`	$\Mu$
`$$\delta$$`	δ	`$$\Delta$$`	Δ

- These codes are treated as individual letters. As such, subscripts and superscripts can be added.

Other Math Codes

- Fractions:

```
$$I=\frac{V}{R}$$
```

- Integrals

Code	Appearance
`$$\int$$`	$$\int$$
`$$\iint$$`	$$\iint$$
`$$\iiint$$`	$$\iiint$$
`$$\int_{a-b}^{a+b}$$`	$$\int_{a-b}^{a+b}$$
`$$\oint$$`	$$\oint$$

Matrices

- Can be coded in a similar way to tables but only within a math environment.
- Example:

```
\begin{equation}
        S=
        \begin{matrix}
                S_{11} & S_{21} \\
                S_{12} & S_{22} \\
        \end{matrix}
        \label{eq:two-port-s-parameters}
\end{equation}
```

- Result:

$$S = \begin{matrix} S_{11} & S_{21} \\ S_{12} & S_{22} \end{matrix}$$

Matrices

```
\begin{equation}
        S=
        \begin{bmatrix}
                S_{11} & S_{21} \\
                S_{12} & S_{22} \\
        \end{bmatrix}
\end{equation}
```

- Result:

$$S = \begin{bmatrix} S_{11} & S_{21} \\ S_{12} & S_{22} \end{bmatrix}$$

- For matrices, there is no need to specify the number of columns unlike tables.
- Matrices with parentheses instead or brackets can also be formed.

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Bibliography

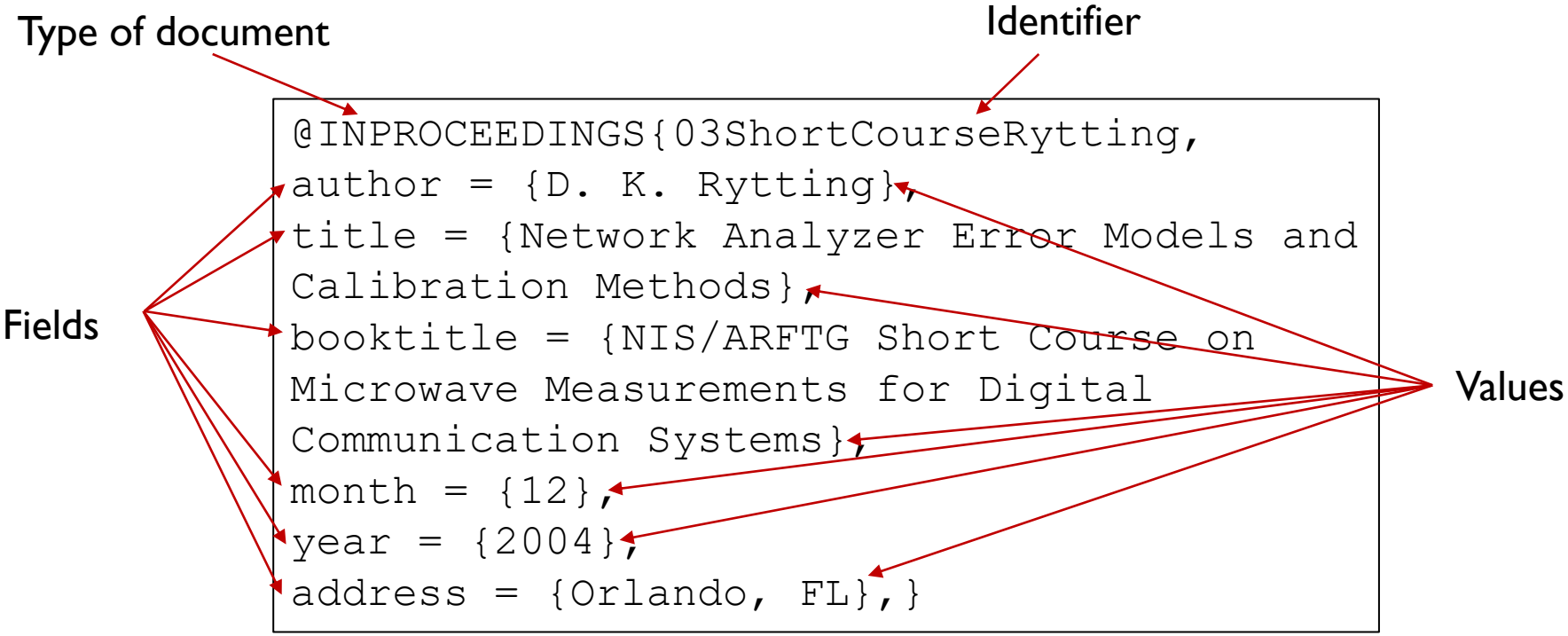
- A manuscript is not complete without the bibliography.
- LaTeX makes it easy to set it up through the 'biblatex' package:

```
\usepackage[backend=bibtex,bibstyle=ieee,citestyle=numeric-comp]{biblatex}
```

- Different citation styles can be configured. We will use the IEEE citation format (even in 198 manuscripts).
- A separate bib file is used as a repository of references.
- An entry in the bib file is in the JavaScript Object Notation (JSON) format.

JSON Format

- This is a flexible way to store information in a database since it does not have fixed fields.
- For the bibliography file, the JSON format looks like:



JSON Format

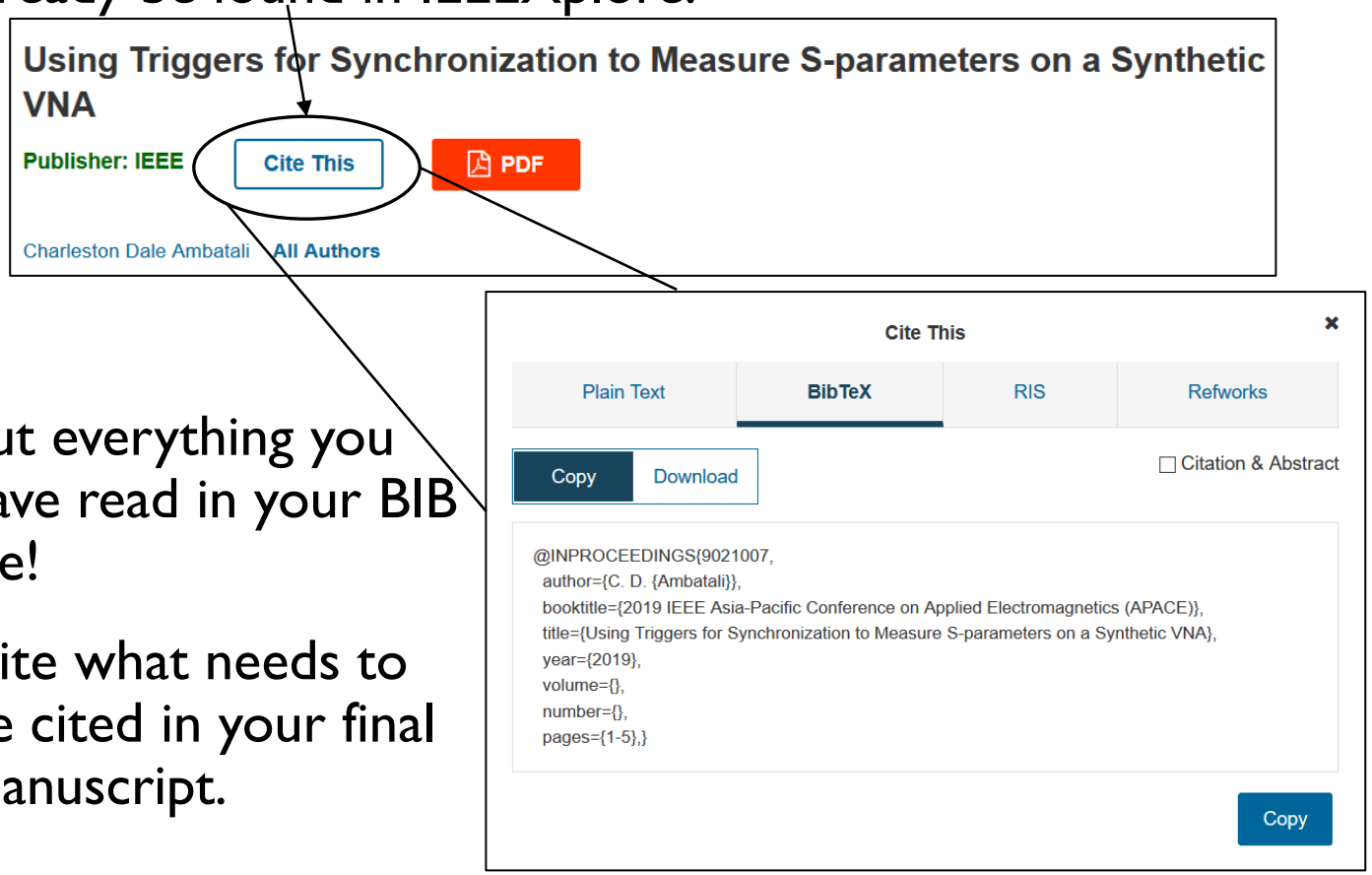
- **Type of document** – where the reference came from (conference proceedings, journal article, magazine article, book chapter, electronic, etc.)
- **Identifier** – a variable that is used to reference the bib entry. Similar function to a label.
- **Field** – information about the reference (author, title of article, book/journal title, publication date, address, etc.) and different types of documents have required fields.
- **Values** – string or numeric depending on the field, this is the information supplied on the fields.

A Typical BIB file

```
@TECHREPORT{01VNAbasics_Agilent,
author={{Agilent Technologies, Inc.}},
title={Understanding the Fundamental Principles of Vector Network Analysis},
publisher={Agilent Technologies, Inc.},
year={2012},}

@INPROCEEDINGS{03ShortCourseRytting,
author = {D. K. Rytting},
title = {Network Analyser Error Models and Calibration Methods},
booktitle = {NIS/ARFTG Short Course on Microwave Measurements for Digital Communication Systems},
month = {12},
year = {2004},
address = {Orlando, FL},
}

@ELECTRONIC{02WeiLiConsiderations,
author = {Wei Li and J. Vandewege},
organization = {University of Ghent},
address = {Ghent, Belgium},
title = {PRACTICAL DESIGN CONSIDERATIONS TO INCREASE MEASUREMENT ACCURACY IN A LOW COST VECTOR NETWORK ANALYZER},
url = {http://citeseerx.ist.psu.edu/viewdoc/download}
}

@ARTICLE{04Heuermann,
author={H. Heuermann and B. Schiek},
journal={IEEE Transactions on Instrumentation and Measurement},
title={Results of network analyzer measurements with leakage errors-corrected with direct calibration techniques},
year={1997},
volume={46},
number={5},
pages={1120-1127},
```

BIB Files

- At first, making a bib file sounds like a hassle.
- However, the BIB formats of numerous IEEE publications can already be found in IEEEXplore:



- Put everything you have read in your BIB file!
- Cite what needs to be cited in your final manuscript.

Referencing BIB Entries

- To reference an entry in the bib file, use the `\cite{}` function within a paragraph.

```
To build a VNA, the four-receiver architecture is
most commonly used \cite{01VNABasics_Agilent}.
```

- The biblatex package automatically sorts the references according to the order they appear in the document.
- Any references that are not cited but are still in the bib file will not appear in the final bibliography.
- **TIP:** structure your identifiers properly (don't use mine). I suggest using the structure:

  <first author last name>_<three keywords in title>

- **Example:** ambatali_synchronization_synthetic_vna

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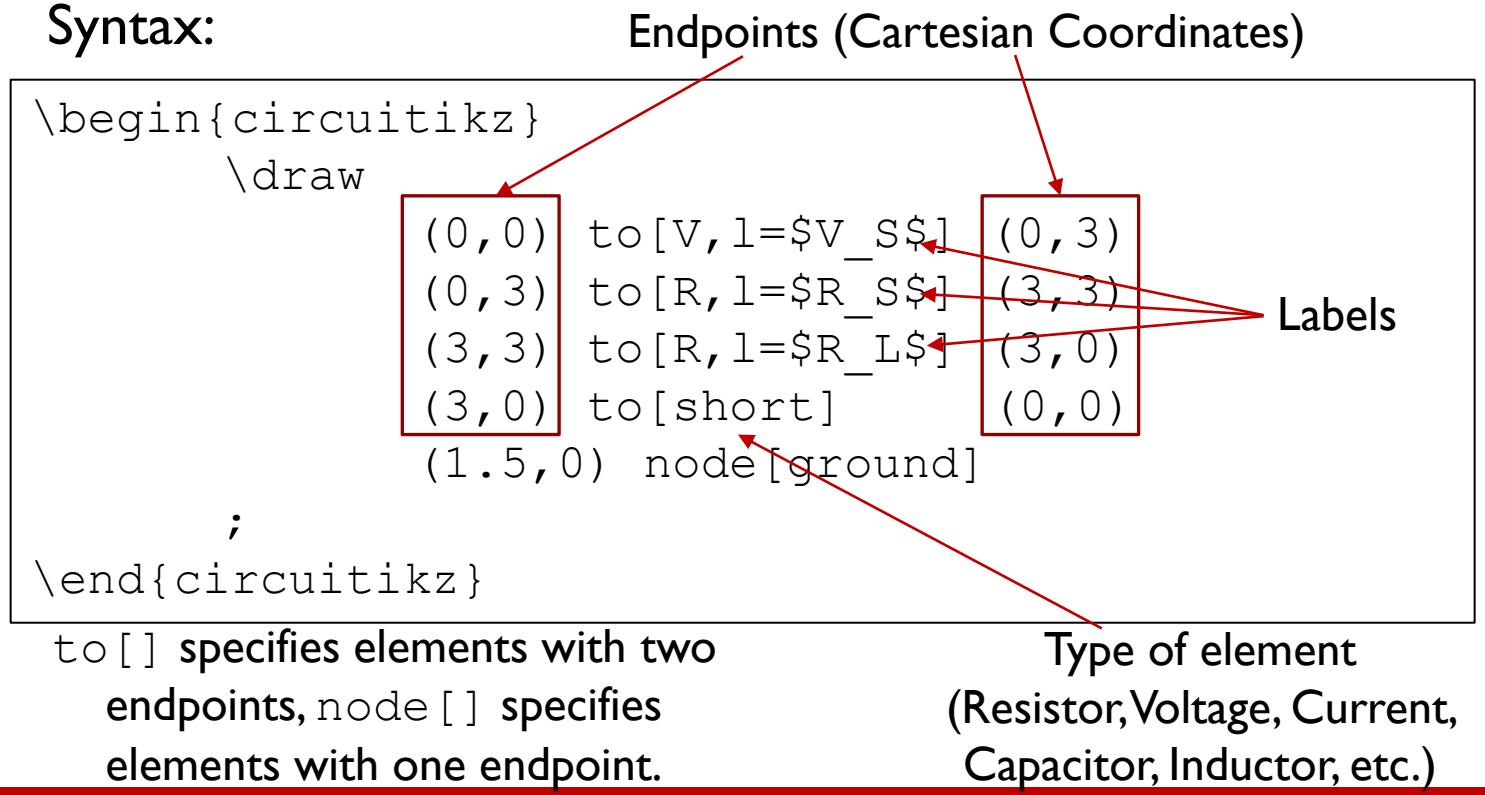
CircuitTikZ

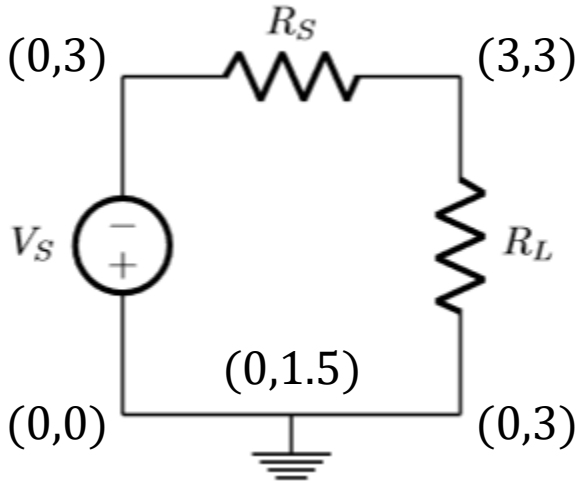
- This is an environment in which you can draw a circuit schematic or a system block diagram.
- It is based on the TikZ package and all figures drawn in TikZ can be drawn in CircuiTikZ.
- Syntax:



CircuiTikZ Examples

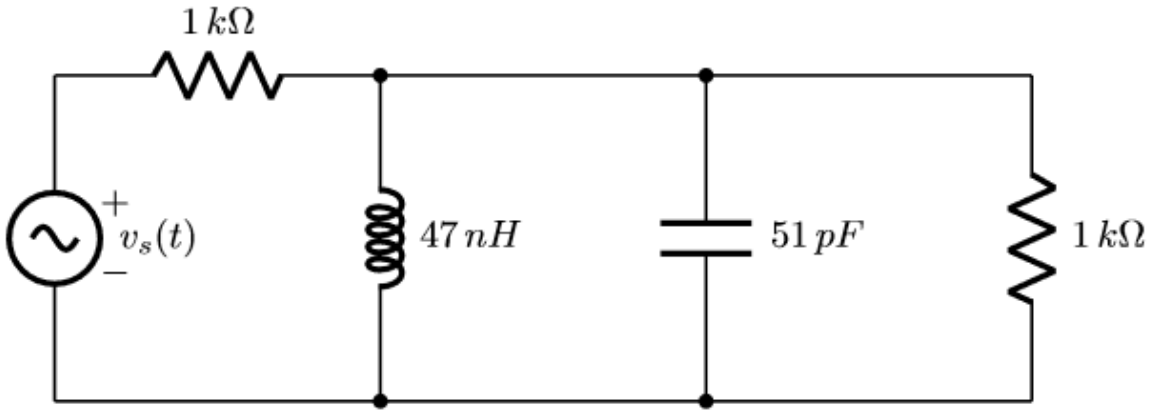
```
\begin{circuitikz}
      \draw
            (0,0) to[V,l=$V_S$] (0,3)
            (0,3) to[R,l=$R_S$] (3,3)
            (3,3) to[R,l=$R_L$] (3,0)
            (3,0) to[short]     (0,0)
            (1.5,0) node[ground]
      ;
\end{circuitikz}
```

- Result:



CircuiTikZ Examples

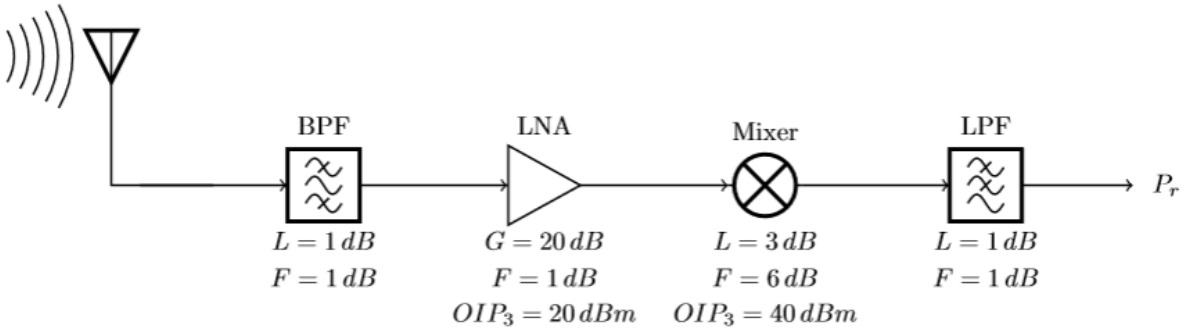
```
\begin{figure} [H]
    \centering
    \begin{circuitikz} [american voltages, american currents, cute inductors, thick]
        \draw
            (0,3) to[sV,v=$v_s(t)$] (0,0)
            (0,3) to[R,l=$1\,k\Omega$] (3,3)
            (3,3) to[L,*-*,l=$47\,nH$] (3,0)
            (6,3) to[C,*-*,l=$51\,pF$] (6,0)
            (9,3) to[R,l=$1\,k\Omega$] (9,0)
            (0,0) -- (9,0)
            (3,3) -- (9,3)
        ;
    \end{circuitikz}
\end{figure}
```



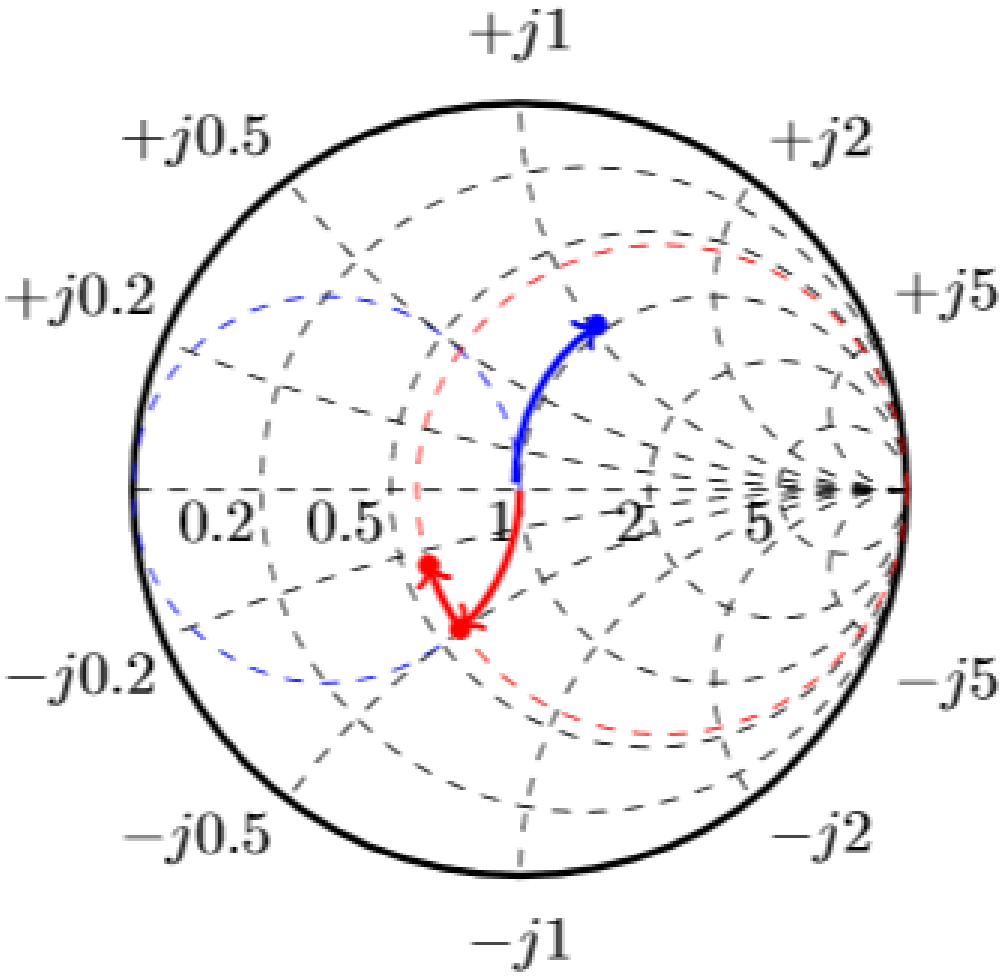
CircuiTikZ Examples

```
\begin{figure} [H]
    \centering
    \begin{circuitikz} [thick]
        \draw (1.5,0) node[rxantenna,xscale=-1]{};
        \draw (2.5,0) to[bandpass,l=BPF] (3.5,0);
        \draw (5.5,0) to[amp,l=LNA] (6.5,0);
        \draw (8.5,0) to[lamp,l=Mixer] (9.5,0);
        \draw (11.5,0) to[lowpass,l=LPF] (12.5,0);
        \draw [->] (0.5,0) -- (2.5,0);
        \draw [->] (3.5,0) -- (5.5,0);
        \draw [->] (6.5,0) -- (8.5,0);
        \draw [->] (9.5,0) -- (11.5,0);
        \draw [->] (12.5,0) -- (14,0);
        \draw
            (3,-0.75) node[]{$L=1\,dB$}
            (3,-1.25) node[]{$F=1\,dB$}

            (6,-0.75) node[]{$G=20\,dB$}
            (6,-1.25) node[]{$F=1\,dB$}
            (6,-1.75) node[]{$OIP_3=20\,dBm$}

            (9,-0.75) node[]{$L=3\,dB$}
            (9,-1.25) node[]{$F=6\,dB$}
            (9,-1.75) node[]{$OIP_3=40\,dBm$}

            (12,-0.75) node[]{$L=1\,dB$}
            (12,-1.25) node[]{$F=1\,dB$}

            (14,0) node[label={right:$P_r$}]{}
        ;
    \end{circuitikz}
\end{figure}
```

- A block diagram can also be made using CircuiTikZ.
- Nodes can be used to place text on a certain point in the plane.



CircuiTikZ Examples



Documentation of LaTeX

- Overleaf Documentation – LaTeX basics, LaTeX Math
- WikiBooks – LaTeX basics, LaTeX Math
- IEEE Citation Guidelines – how to use the biblatex package with the IEEE format
  - General Guidelines
  - How to use IEEE BIBTeX
- TikZ Documentation – basic figures in the TikZ environment and plotting in TikZ
- CircuiTikZ Manual – list of all elements that can be used in the CircuiTikZ package