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RF Reed Relays Part I

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Introduction

Purpose

- Present the RF characteristics and why the reed relay is so good as an RF switch

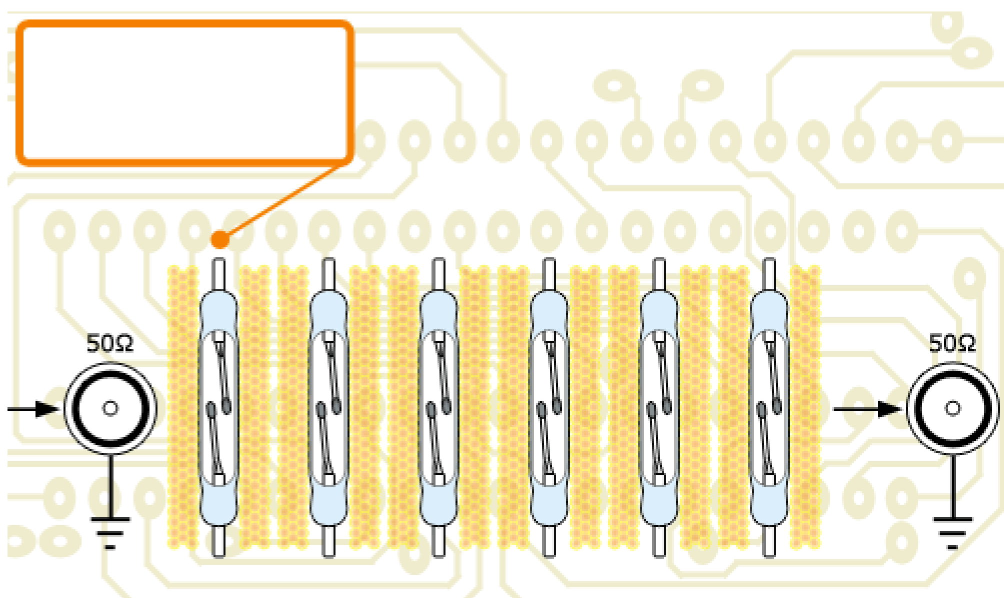
Objectives

- Introduce RF and its parameters
- Introduce fast digital pulse technology
- Define key functions and key terms
- Define the RF signal impediment’s when going through a reed relay.

Where is RF Used?

› RF is used in the following applications:

Applications	
Radio transmitters and receivers	Cell phones
Radar tracking systems	RF component testers
RF test and measurement equipment	And more



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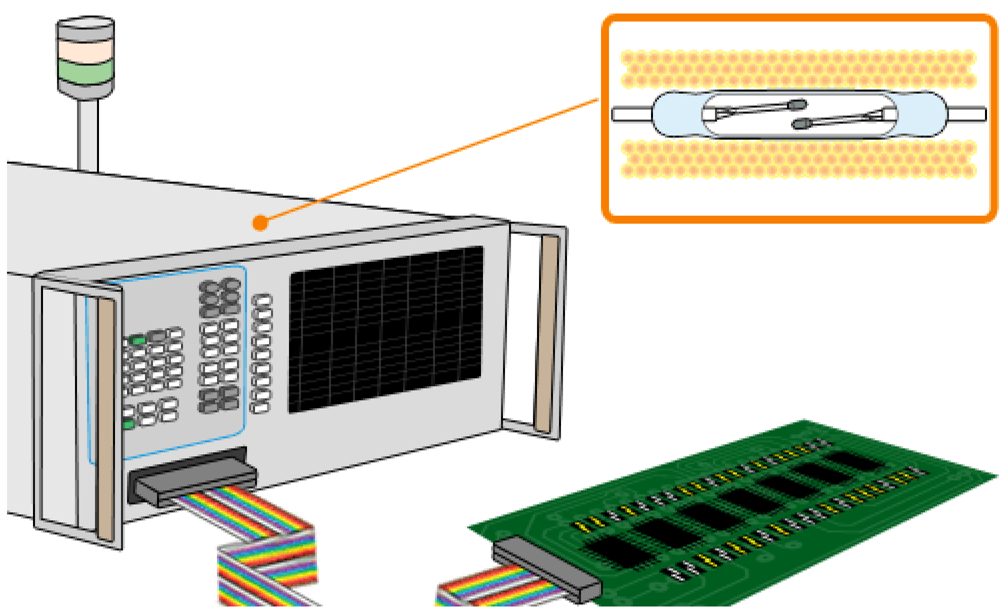
Where are Fast Digital Pulses Used?

› Fast digital pulses are used in the following

Applications	
Computer systems	Functional PCB test equipment
Laptop computers	Integrated circuit testers
Digital components in cell phones	Digital component testers
Digital telephone systems	Any digital system



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Where are Fast Digital Pulses Used?

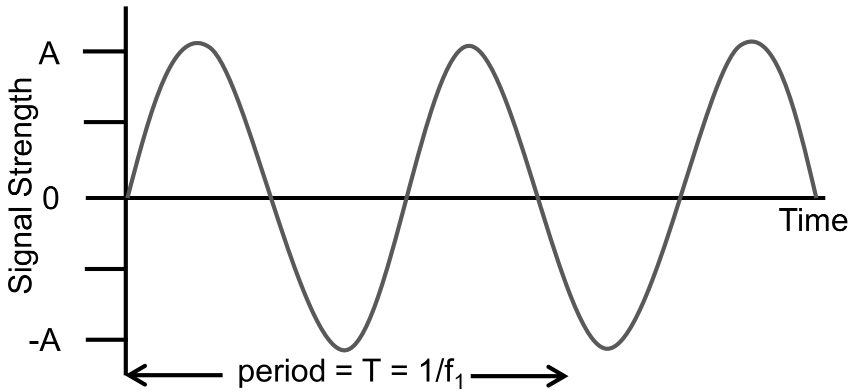
- Computer processors run computers.
- A processor running at 2 Gigahertz or GHz (2 billion pulses per second) is processing digital pulses at that rate.
- Processors are running faster and faster?
- The faster the run rates of these processors or clocks the faster the computers will process information.
- Continued push to make computers (semiconductor processors) run faster

DC to RF Comparison

- DC and RF have similar characteristics and quite different characteristics
- Both have currents, voltages, resistance and power associated with them
- DC stands for direct current.
- When using DC it does not vary in voltage, current, and wattage it remains steady

DC to RF Comparison

- The voltage, current, and wattage for RF is always changing at any given instant in time.
- The changes in time can occur slowly or very rapidly in time.
- The changes in time occur in a periodic way or as a wave motion.
- The wave motion is like the wave motion you see when a stone is dropped in still water.



(a) Sine Wave

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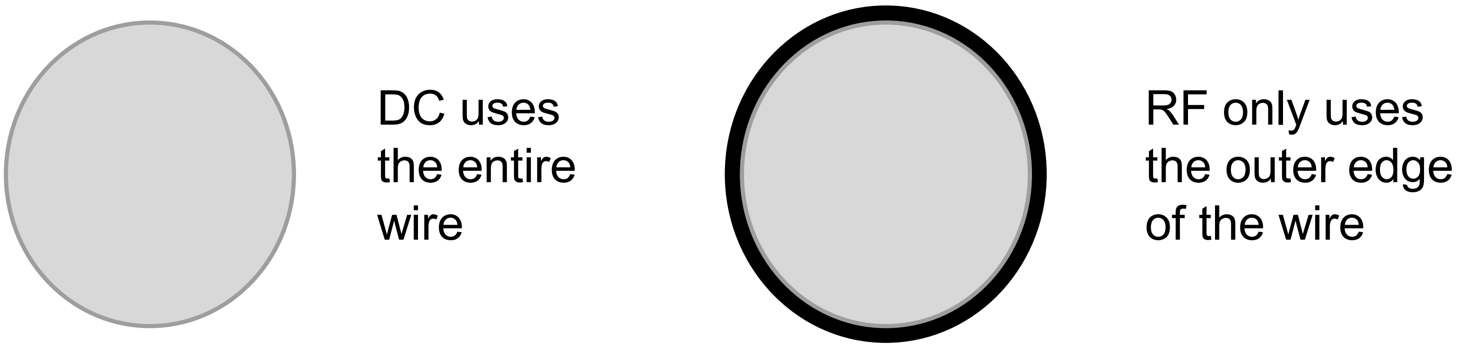
DC to RF Comparison

- DC obeys the simple rules of flowing through copper wire.
- The DC stays within the confines of the copper wire.
- RF flows on the surface of the copper wire.
- RF prefers gradual turns as it flows down a wire.
- RF can be transmitted into the air not needing copper wire



What is RF?

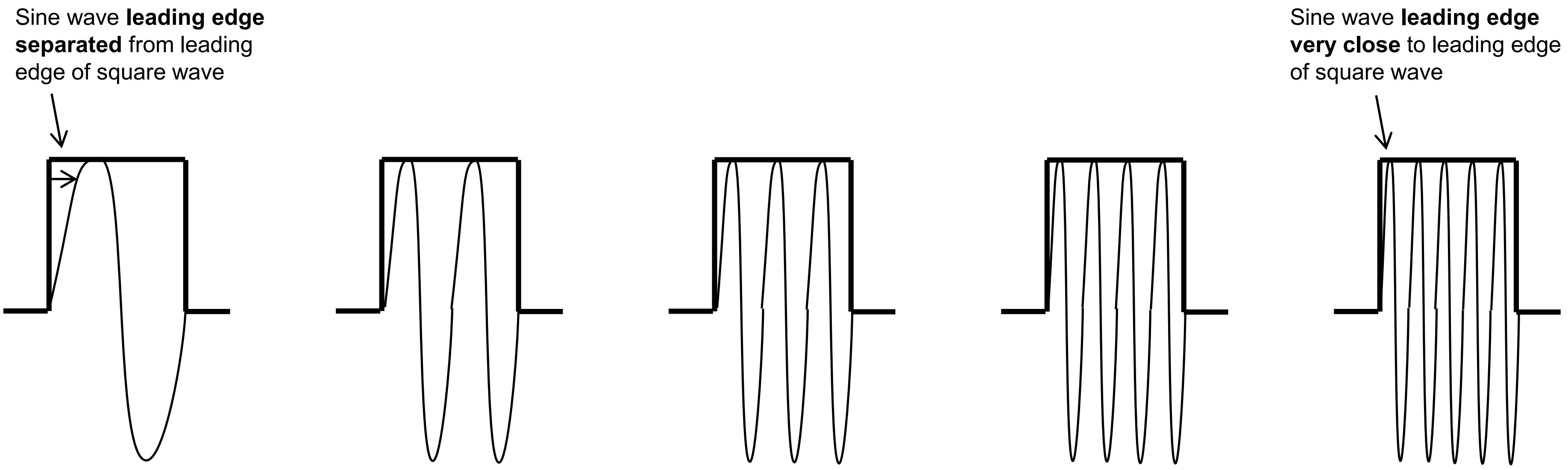
- RF is considered RF when the waves exceed one million waves occurring in one second.
- These waves or cycles have a voltage component, a current component and a power (or wattage) component.
- The changing voltages and currents give rise to an electric field and a magnetic field which are perpendicular to each other.

RF and Fast Digital Pulses

- Why do we consider RF and fast digital pulses together?
  - The electronic circuitry is similar when processing RF or fast digital pulses
  - The frequencies dealt with are of the same order
- RF is represented as continuous wave or sine wave

RF and Fast Digital Pulses

- To make up a digital pulse or square wave takes a minimum of 5 harmonics of a sine wave.



- Square wave
- Sine wave

RF and Fast Digital Pulses

- What does the 5 harmonics mean in the practical world?
- It means: if you have a computer processor running at 2 GHz it is processing digital pulses at that rate.
- If you add in the 5 harmonics - this means that components have to be capable of passing 2 x 5 or 10 GHz.

Other Important RF Parameters

- With RF we consider a whole new set of conditions and parameters

RF (Continuous Wave)	Fast Digital Pulse
Insertion loss →	"same as RF continuous wave"
Isolation →	"same as RF continuous wave"
Characteristic Impedance →	"same as RF continuous wave"
VSWR	Rise time
Return loss	Slew rate

RF Continuous Wave Parameters

Insertion Loss

- Insertion loss is one of the most important parameters
- Insertion loss defines how much signal passes through a given component (for example, like a reed relay).
- It’s measured by passing a known signal down a given strip of wire and measuring its signal strength from the beginning to the end.
- Now the component is added to the exact circuit and the signal strength is measured at the end.

RF Continuous Wave Parameters

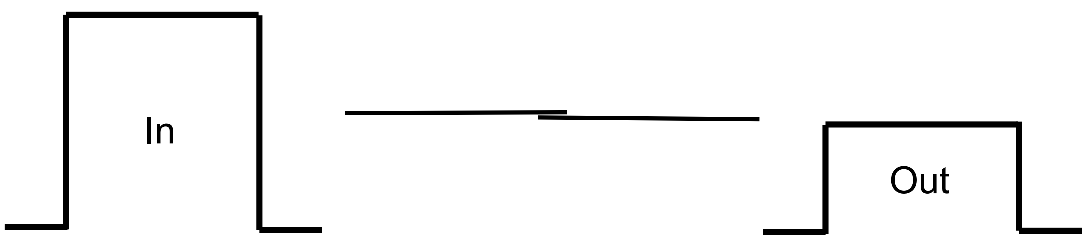
Insertion Loss

- The signal is measured in decibels (dB)
- Insertion loss is defined as 10 x log10(Ratio of the signal transmitted before component insertion to the signal transmitted after component insertion)

RF Continuous Wave Parameters

Insertion Loss

- A loss of 3 dB is equivalent to a 50% loss in signal.
- Any level beyond a 3 dB loss is considered an unusable signal strength



50% loss through the relay

RF Continuous Wave Parameters

Isolation

- Isolation is a measure of how well a component isolates a signal from the rest of the circuit.
- With reed relays isolation is measured by isolating the signal from the input to the output contact.
- In this case, some of the signal will be coupled across the open contacts.
- RF and DC characteristics clearly differ.
- DC signals do not cross open contacts.

RF Continuous Wave Parameters

Isolation

- For a reed relay, the gap between two reed contacts and their overlap determine the extent of the isolation.
- This directly relates to the physical nature of the contacts.
- There is a direct correlation between the geometric configuration of a component and its RF characteristics in an RF circuit.
- Understanding RF is easier understood when thinking of the signal as it traverses a geometric configuration.

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RF Continuous Wave Parameters

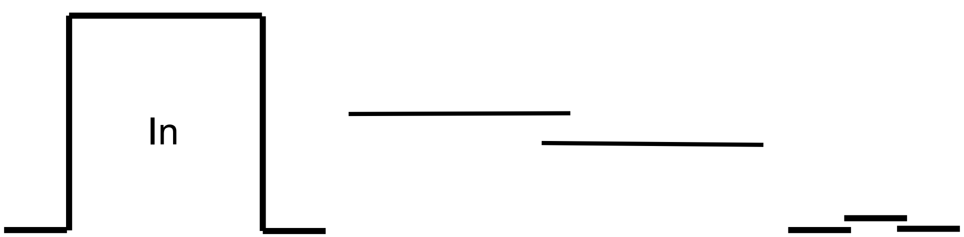
Isolation

- Isolation is also measured in dB.
- Isolation = the amount of signal transmitted through the open contacts measured in dB.
- An isolation of -65 db is considered the point where a signal cannot be reconstituted.
- Most circuits accept -20 dB as a reasonable working number. Some circuits can work with less than 20 dB isolation.

RF Continuous Wave Parameters

Isolation

- Reed relays typically isolate signals down to -40 dB at lower frequencies (1 MHz to 200 MHz); and fall off to 20 dB in the 2 GHz to 3 GHz.



Signal crosses over the open contacts at higher frequencies

RF Continuous Wave Parameters

Characteristic Impedance

- Characteristic impedance (Z) is probably the most important RF parameter.
- Characteristic impedance is dramatically influenced by the geometry of the components and circuit patterns
- Characteristic impedance must be consistent in impedance level.
- Most RF circuits today are 50 Ohms (Ω).

RF Continuous Wave Parameters

Characteristic Impedance

› The characteristic impedance is a vector and is composed of 3 components:

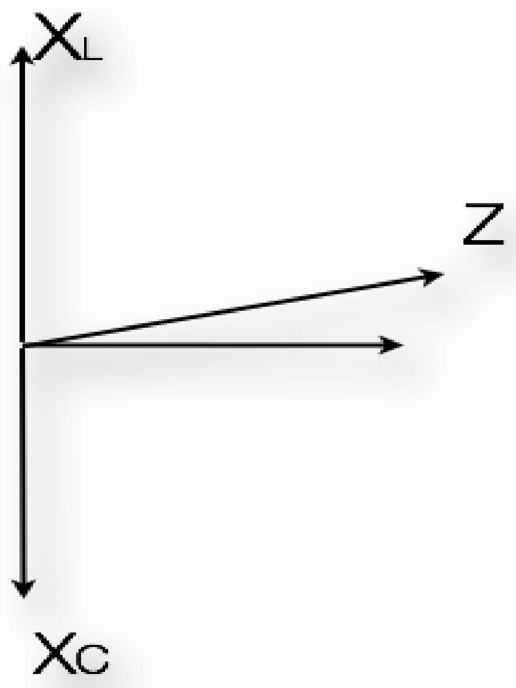
1. Pure resistance of the circuit
2. The capacitive reactance
3. The inductive reactance

RF Continuous Wave Parameters

Characteristic Impedance

› The impedance is given by the following equation:

	$Z = \sqrt{(R^2 + (XL - Xc)^2)}$
Here:	
	$XL = 2\pi f L$
	$Xc = 1/(2\pi f C$
Where:	
XL	is the inductive reactance in Ω
Xc	is the capacitive reactance in Ω
R	is the DC resistance in Ω
Z	is the impedance in Ω
ƒ	is the frequency
L	is the Inductance
C	is the capacitance



RF Continuous Wave Parameters

Characteristic Impedance

- RF looks at the distributed impedance along the signal path
- When the RF comes upon a change in impedance it will reflect part of its signal backwards. This results in an actual loss in signal strength.

RF Continuous Wave Parameters

Characteristic Impedance

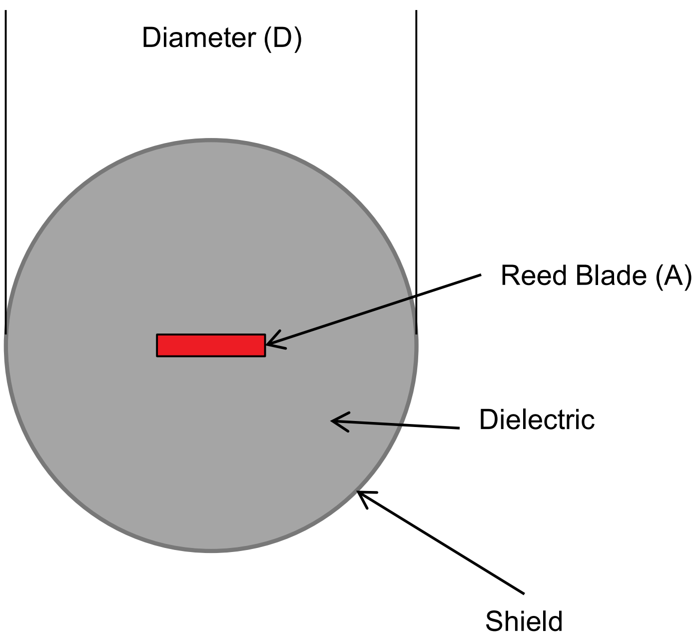
- Signal path length is critical
- Consistent impedance is critical
- A consistent shield is very important (the shield is part of the signal path)
- It is the signal path, the shield and the material between them that makes up the impedance

RF Continuous Wave Parameters

Characteristic Impedance

Here:	
	$Z = 60/(\sqrt{(e)}) \ln((D)/A)$
Where:	
Z	is the impedance in Ω
e	is the dielectric constant
D	is the diameter of the shield
A	Is the cross-sectional area of the reed blade
In	is the natural logarithm

Flat Reed Switch Blade



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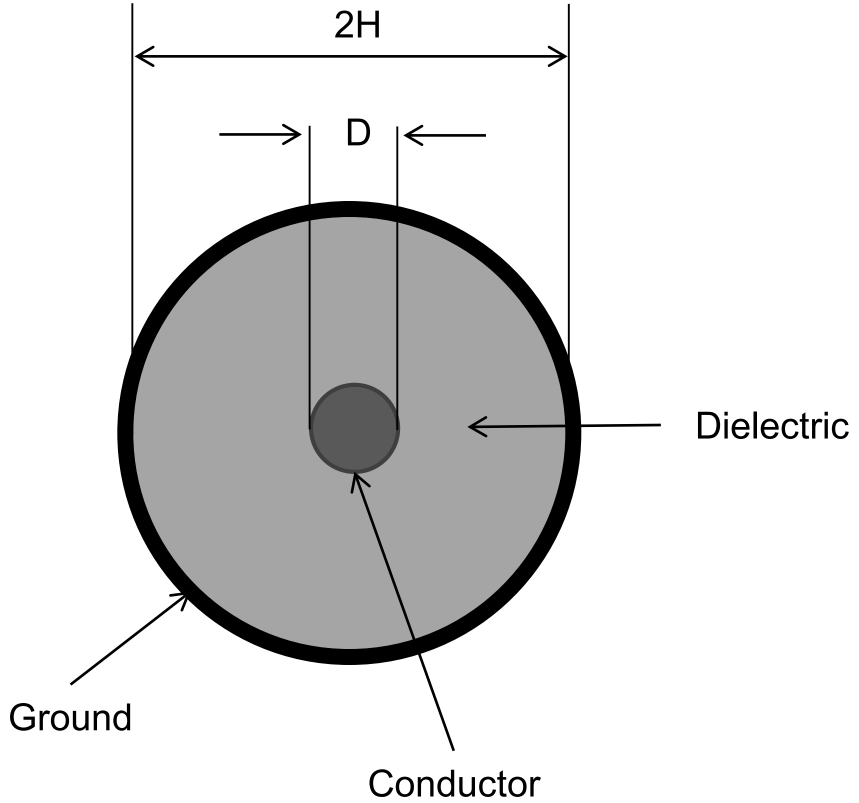
RF Continuous Wave Parameters

Characteristic Impedance



$$Z_0 = \frac{60}{\sqrt{E_R} + \ell_n \left(\frac{2h}{d}\right)}$$

E_R is the dielectric

RF Continuous Wave Parameters

Characteristic Impedance

- Signal reflections increase the insertion loss and can be caused by the following:

Detailed potential change	Parameter Affected	Resistance
Path resistance	Resistance change along the signal path	Contact resistance change; resistance change along the signal path
Capacitive reactance	Change in the distributed capacitance along the signal path	The capacitance between the signal path and the shield changes
Inductive reactance	Change in the distributed inductance along the signal path	The inductance between the signal path and the shield changes

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RF Continuous Wave Parameters

VSWR

- Voltage Standing Wave Ratio (VSWR) is a unit-less mathematical expression
- VSWR = (EI + ER)/(EI – ER)
- Where EI is the incident signal energy and ER is the reflected signal energy

RF Continuous Wave Parameters

VSWR

- VSWR presents signals that form a standing wave within a circuit or component. It is used primarily with RF continuous wave circuitry.
- VSWRs are usually plotted for a given group of frequencies. Ideally a plot remaining close to 1.0 is best.

RF Continuous Wave Parameters

Return Loss

- Return loss is another mathematical expression that some engineers like to calculate.
- This term is essentially another way of expressing insertion loss.
- Return Loss (in dB) = 20 Log10(VSWR)

Fast Digital Pulse Parameters

- Characteristic impedance (same as RF continuous wave)
- Insertion loss (same as RF continuous wave)
- Isolation (same as RF continuous wave)
- Rise time
- Slew rate

Fast Digital Pulse Parameters

Rise Time

- Rise time along with the characteristic impedance are the two critical parameters in the digital world
- Rise time is the time it takes for the leading edge of a pulse or square wave to go from 10% to 90% of its final height

Fast Digital Pulse Parameters

Rise Time

- Components or circuits need specify their rise time for digital usage
- From the known rise time of a given component the designer will know if it is fast enough for his circuit.

Fast Digital Pulse Parameters

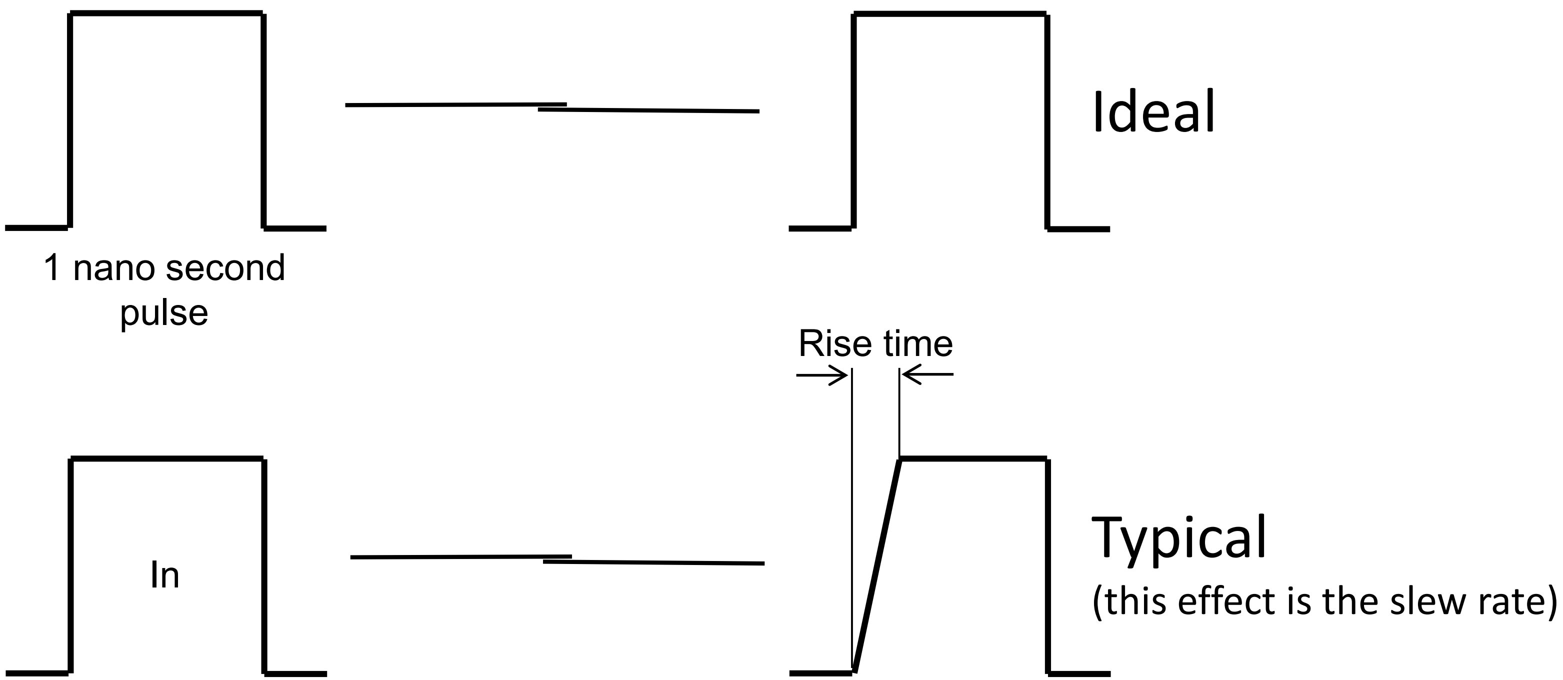
Slew Rate

- Slew rate is related to rise time.
- Consider a reed relay with closed contacts with a pulse incident upon the contacts.
- The pulse rise time is measured as it exits the relay.
- The rise time change is considered the slew rate.

Fast Digital Pulse Parameters

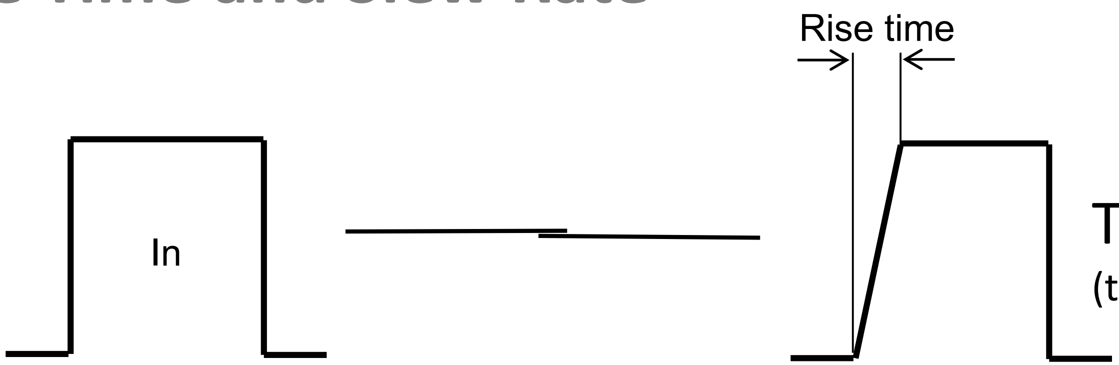
Rise Time and Slew Rate

- These examples help clarify the definitions



Fast Digital Pulse Parameters

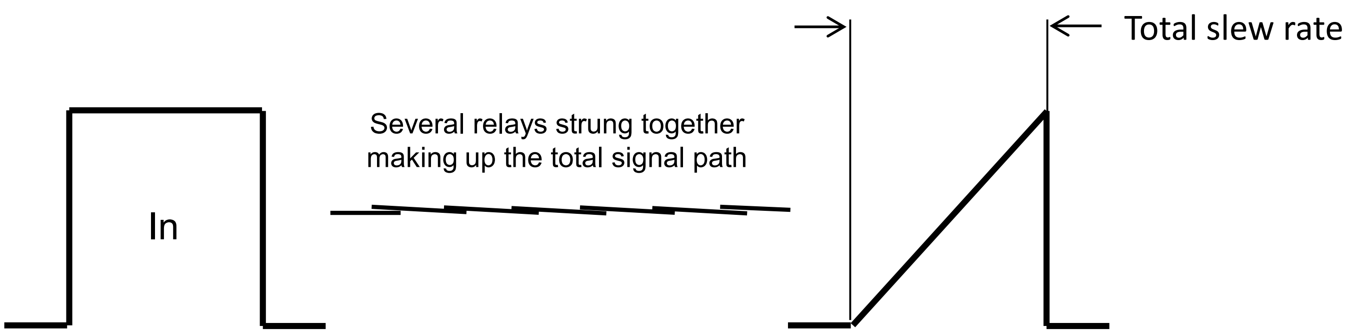
Rise Time and Slew Rate



Typical

(this effect is the slew rate)

So if one has the slew rate shown, the square wave may result in the following:



Summary

- One does not have to understand all RF details.
- Knowing what parameters are most important and what controls them is the key
- Component and circuit geometry also help to better understand RF.
- RF part two will focus on the physical geometric aspects of RF

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