

# **Smart Power Module for Distributed Sensor Power Network of an Unmanned Ground Vehicle**

*Christian Raphael Roa*

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in  
partial fulfillment of the requirements for the degree of

**Master of Science**

**Alfred L. Wicks  
Kathleen Meehan  
Stephen C. Southward**

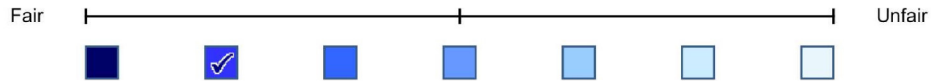
June 9, 2014  
Blacksburg, Virginia

**Keywords:**

unmanned ground vehicle, sensor power, high efficiency, current limiting,  
current sensing, internal compensation

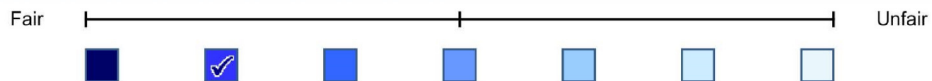
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

The copyrighted work is a datasheet for the TPS 54331. The datasheet is intended to be used as a design aid and application guide.



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the block diagram and application schematic of the TPS 54332 are reproduced in the thesis work as Figures 24 and 25.



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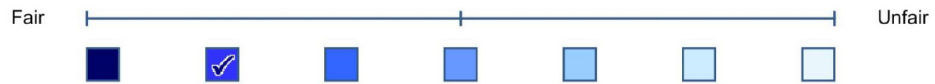
This thesis work explains both the advantages and shortcomings of the externally compensated TPS 54331. No detrimental effect to the market or potential value of this product should result.



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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Automated Golf Carts Head To War
<b>Copyright Holder:</b>	Robot Living
<b>Publication Status:</b>	N/A
<b>Publisher:</b>	Robot Living
<b>Place of Publication:</b>	Online
<b>Publication Year:</b>	2010
<b>Description of Work:</b>	
<b>Date of Evaluation:</b>	June 30, 2014
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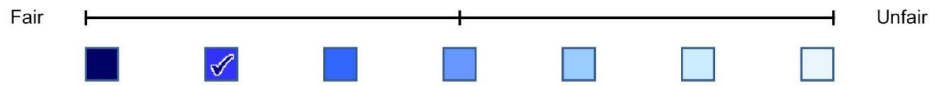
Describe the **Purpose** and Character of Your Intended Use:

Provide an illustration of the Ground Unmanned Support Surrogate (GUSS) vehicle.



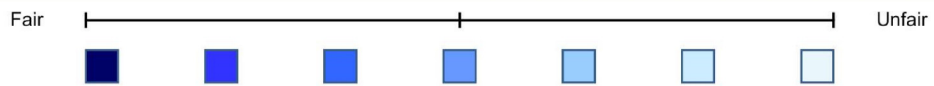
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

This is an image of the GUSS vehicle.



Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

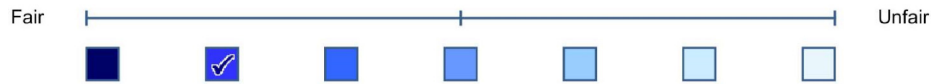
use of this image will have no detrimental effect on the its value or market.



The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[see tool disclaimer for important clarifying information]:



Based on the information and justification I have provided above, I, Christian Roa, am asserting this use is **FAIR** under Section 107 of the U.S. Copyright Code.

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Date of Signature: 6/30/14

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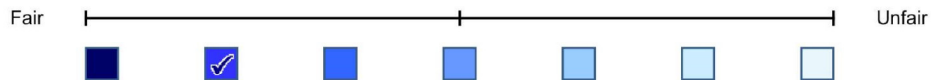
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Current Shunt Monitors
<b>Copyright Holder:</b>	Texas Instruments
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2014
<b>Description of Work:</b>	application guide for current shunt monitors
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 27, 2014

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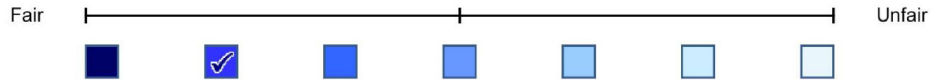
Describe the **Purpose** and Character of Your Intended Use:

one figure from this work is used to illustrate the output error of current shunt amplifiers. The work is intended as a guide for selecting an appropriate amplifier for a specific application. the thesis work achieves the same purpose explaining how a current shunt amplifier was selected for measurement needs.



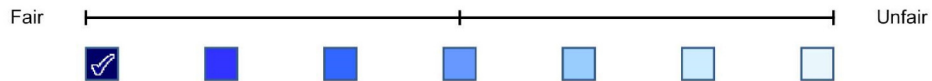
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

The copyrighted work is an online application guide for the selection of current shunt amplifiers. It is available to any designer looking to select a shunt amplifier.



Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

One figure related to total error is copied, appearing as Figure 34 in the thesis work.



Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

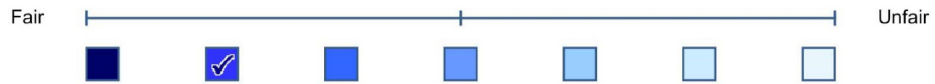
The use of this material will have no detrimental effect on the market and potential value of the products advertised in the copyrighted work.



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Date of Signature: 6/30/14

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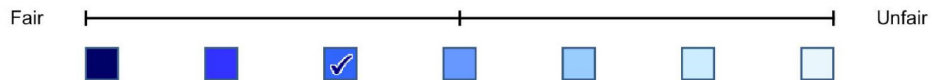
---

<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Design And Application Guide For High Speed MOSFET Gate Drive Circuits
<b>Copyright Holder:</b>	Laszlo Balogh
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2001
<b>Description of Work:</b>	
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 26, 2014

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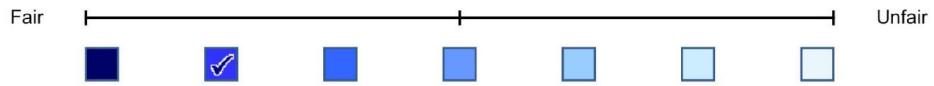
Describe the **Purpose** and Character of Your Intended Use:

"Design And Application Guide For High Speed MOSFET Gate Drive Circuits" was written to provide a detailed and comprehensive overview of MOSFET gate drive and switching behavior. The work was intended to serve as a reference for design engineers.



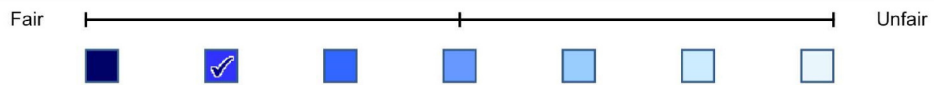
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

This work is written to present a systematic approach to designing high performance gate drivers.



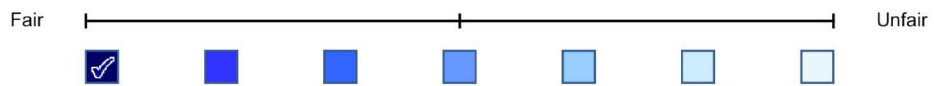
Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

Four figures ( 2, 3, 4 and 5) from "Design And Application Guide For High Speed MOSFET Gate Drive Circuits" are used in section 2.4 of this thesis, figure numbers 14-17.



Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

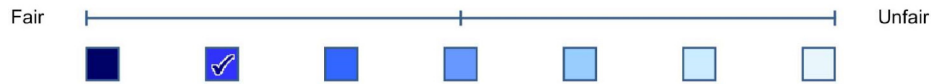
Use of the copyrighted work in this thesis has no detrimental effect on its potential value and market.



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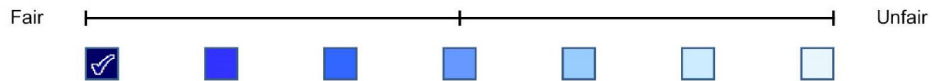
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	INA21x Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitors
<b>Copyright Holder:</b>	Texas Instruments
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2014
<b>Description of Work:</b>	Datasheet for INA21x current shunt amplifiers
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 27, 2014

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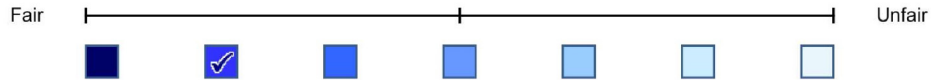
Describe the **Purpose** and Character of Your Intended Use:

one figure is used from the datasheet to show the gain bandwidth product of the INA213. This current shunt amplifier was used in the designs presented in this thesis work.



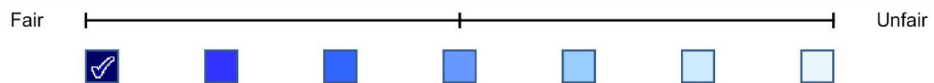
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

The copyrighted work is a data sheet and user manual for the INA21x series of amplifiers. The datasheet is available for designers and was used as a design aid in this thesis work.



Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

One image (Figure 7) describing the specific device characteristics of the INA213 is copied in the thesis work as Figure 68.



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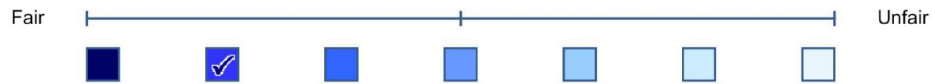
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The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[see tool disclaimer for important clarifying information]:



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Signature: Chris Roa

Date of Signature: 6/30/14

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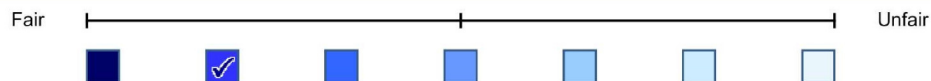
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Loop Stability Analysis of Voltage Mode Buck Regulator With Different Output Capacitor Types – Continuous and Discontinuous Modes
<b>Copyright Holder:</b>	Daniel Meeks
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2008
<b>Description of Work:</b>	
<b>Date of Evaluation:</b>	June 26, 2014
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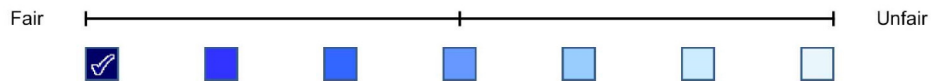
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One figure is used from this work to illustrate how a pulse width modulator is formed in a DC-DC converter.



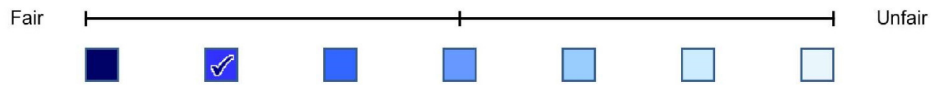
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

"Loop Stability Analysis of Voltage Mode Buck Regulator With Different Output Capacitor Types – Continuous and Discontinuous Modes" is an application note intended to provide a complete set of design equations for calculating the buck converter loop gain and phase in both continuous and discontinuous modes. It is an educational work that is being used to provide background in this thesis.



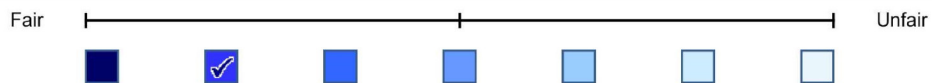
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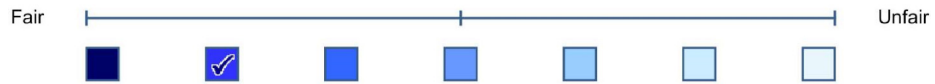
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[see tool disclaimer for important clarifying information]:



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*Christian Roa*

Date of Signature:

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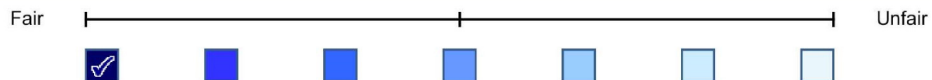
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	LTM8027 60V, 4A DC/DC $\mu$ Module Regulator
<b>Copyright Holder:</b>	Linear Technology
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Linear Technology
<b>Place of Publication:</b>	Milpitas, CA
<b>Publication Year:</b>	2009
<b>Description of Work:</b>	Datasheet for LTM8027
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 26, 2014

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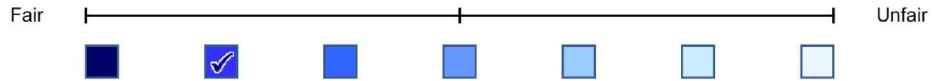
Describe the **Purpose** and Character of Your Intended Use:

The LTM8027 was the central component of the designs in this thesis work. Two figures are used from the LTM8027 datasheet to illustrate the design process within the thesis work.



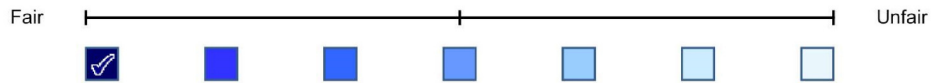
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

The work is a datasheet for the LTM8027. It is intended to serve as a design and application guide for the user of the LTM8027 converter.



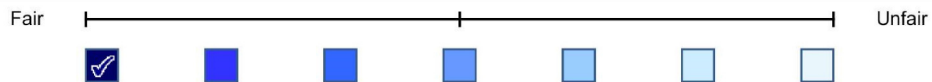
Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

The block diagram and typical application circuit are copied in the thesis work as Figures 31 and 32.



Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

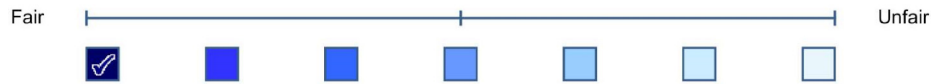
This thesis work presents favorable results using the LTM8027. No detrimental effects to the potential value or market of this product will result. If anything, this thesis work will positively contribute to the value of this product.



The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[see tool disclaimer for important clarifying information]:



Based on the information and justification I have provided above, I, Christian Roa, am asserting this use is **FAIR** under Section 107 of the U.S. Copyright Code.

Signature: Christian Roa

Date of Signature: 6/30/14

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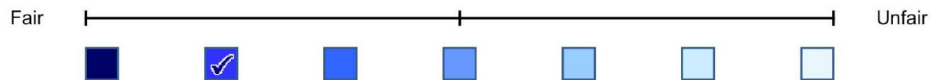
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Optimizing Low-Power DC / DC Designs – External versus Internal Compensation
<b>Copyright Holder:</b>	Michael Day
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2004
<b>Description of Work:</b>	
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 26, 2014

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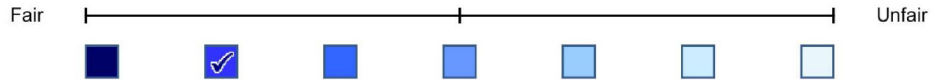
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A figure from this work is reproduced in this thesis describing the three basic feedback compensation schemes. The three compensation types are a standard convention in the electronics industry and have been reproduced from this work for the clarity of its figures.



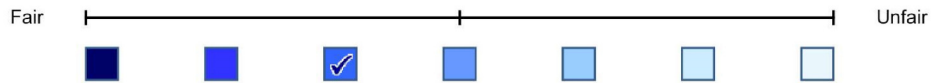
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The copyrighted work is part of a seminar given by Texas Instruments for educational purposes. The figure has been reproduced for the same purpose, to provide background to the reader about basic compensation schemes.



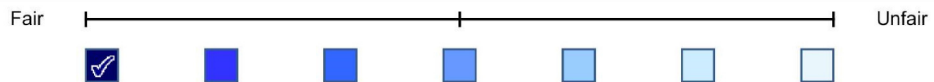
Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

Figure 4 from the copyrighted work has been reproduced as Figure 23 of the thesis.



Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

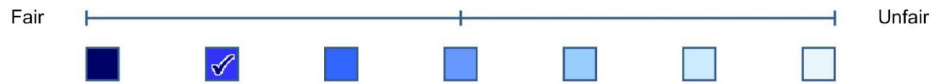
The use of this copyrighted work has no detrimental effect on the value or market of the work. The material used relates to an industry convention.



The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[see tool disclaimer for important clarifying information]:



Based on the information and justification I have provided above, I, Christian Roa, am asserting this use is **FAIR** under Section 107 of the U.S. Copyright Code.

Signature: Chris Roa

Date of Signature: 6/30/14

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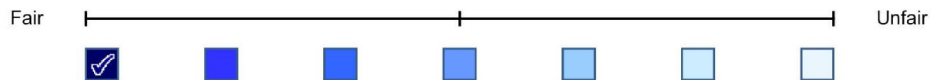
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<b>Name:</b>	Christian Roa
<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	PI33XX-X0 8V to 36Vin Cool-Power ZVS Buck Regulator
<b>Copyright Holder:</b>	Vicor Corporation
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<b>Publisher:</b>	Vicor Corporation
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2013
<b>Description of Work:</b>	Datasheet for Cool-Power ZVS Buck Regulator
<b>Date of Evaluation:</b>	June 26, 2014
<b>Date of Intended Use:</b>	June 26, 2014

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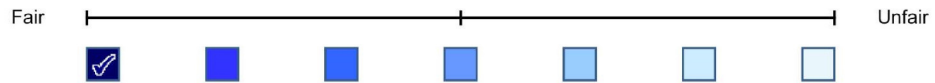
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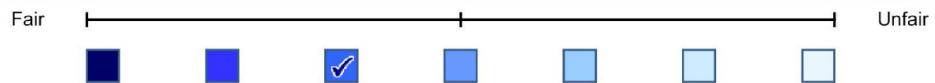
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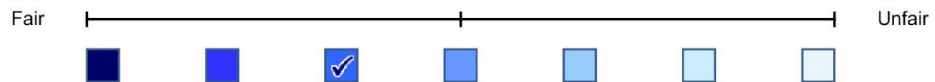
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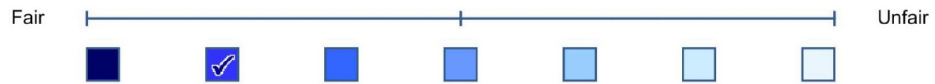
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<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Practical switching power supply design
<b>Copyright Holder:</b>	Marty Brown
<b>Publication Status:</b>	N/A
<b>Publisher:</b>	Academic Press
<b>Place of Publication:</b>	San Diego
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<b>Description of Work:</b>	
<b>Date of Evaluation:</b>	June 30, 2014
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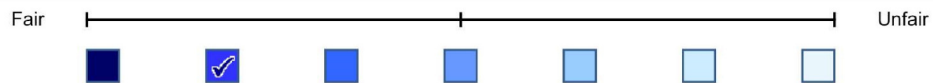
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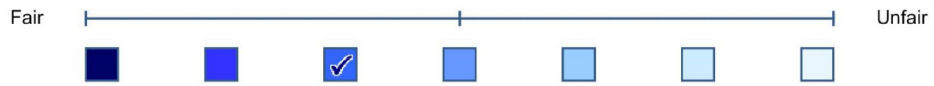
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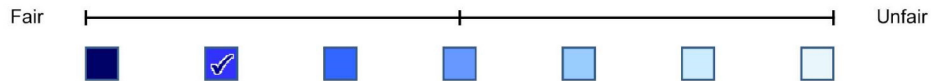
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<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	SI96-01 TVS Diode Application Note
<b>Copyright Holder:</b>	Semtech
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Semtech
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2000
<b>Description of Work:</b>	Application note
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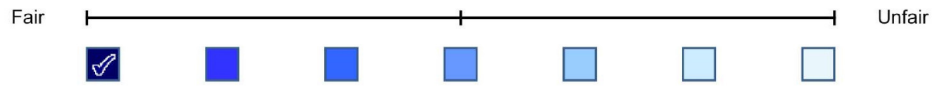
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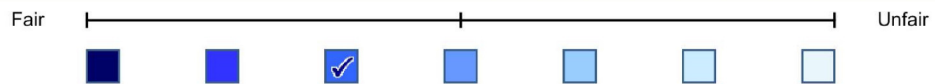
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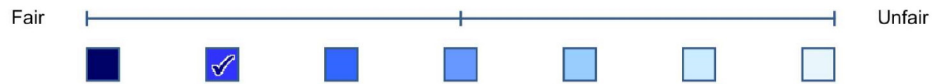
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<b>Job Title:</b>	Graduate Research Assistant
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	TPS54331EVM-232 3-A , SWIFT TM Regulator Evaluation
<b>Copyright Holder:</b>	Texas Instruments
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Texas Instruments
<b>Place of Publication:</b>	Dallas
<b>Publication Year:</b>	2008
<b>Description of Work:</b>	Evaluation board user guide
<b>Date of Evaluation:</b>	June 26, 2014
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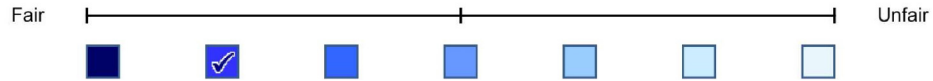
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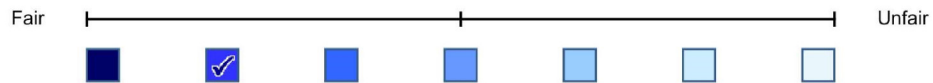
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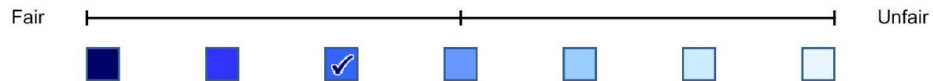
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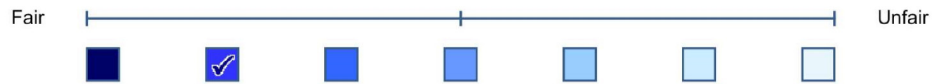
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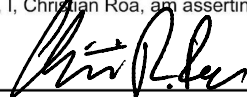
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