



Successful
Instrumentation
and Control
Systems Design

Second Edition

Michael D. Whitt



Setting the Standard for Automation™

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DEDICATION

I would like to dedicate this book to my wife Mary and son Elliot, who have continually supported me through the travails of writing this book—I'm truly blessed; my parents, who instilled in me a love for reading, and, by extension, writing; and Jesus Christ, who is my inspiration and through whom all things are possible.

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- <http://betsy.wesleychapelcomputerrepair.com/library/Matrix-Computations--3rd-Edition---Johns-Hopkins-Studies-in-Mathematical-Sciences-.pdf>
- <http://www.netc-bd.com/ebooks/Nebula-Awards-Showcase-2012.pdf>