EE1001 Introduction to Electrical Engineering

Medical Device Engineering

Greg Carpenter, Dan Landherr
Electrical Engineers
Boston Scientific Corp.
St. Paul, MN
20 Oct. 2015

Congratulations- You have all Chosen Wisely!

**EE Times**

Slideshow
10 Engineering Schools You Should Know But Don’t

Zevde Yentsnwerk
22/02/2014 8:43 AM EST

School List:

- 1. Ohio State University
- 2. Harvey Mudd College
- 3. Baskin School of Engineering at UC Santa Cruz
- 4. Samuel Ginn College of Engineering
- 5. California Polytechnic University
- 6. Rose-Hulman Institute of Technology
- 7. Valparaiso Technical Institute
- 8. New Mexico Institute of Mining and Technology
- 9. South Dakota State
- 10. University of Minnesota Duluth
Some Biomedical Electrical Engineering History

46- The first written document on medical electricity, Scribonius Largus recommended the use of torpedo fish for curing headaches and gouty arthritis. The electric fish remained the only means of producing electricity for electrotherapeutic experiments until the seventeenth century.

1781- The first documented experiment in neuromuscular electric stimulation by Luigi Galvani, professor of anatomy at the University of Bologna. His assistant accidentally touched the femoral nerve of a dissected frog with a scalpel at the same time sparks discharged in a nearby machine and muscular contractions occurred.

1872- T. Green described cardio-respiratory resuscitation using a battery of up to 200 cells generating about 300 volts. He applied this voltage between the neck and lower left ribs successfully on five patients who suffered sudden respiratory arrest and were without a pulse.

1887- The electrocardiogram (ECG) signals from electric activity of the human heart first measured by Augustus Waller.

1899- The first report on cardiac defibrillation by Jean Prevost and Frédéric Battelli. They found low-voltage electric shocks induced ventricular fibrillation whereas high-voltage shocks would defibrillate a fibrillating heart in animal experiments.

1930s- Modern ventricular defibrillation started with the work of William Kouwenhoven and his colleagues who used 60 Hz current to defibrillate a dog heart.

1947- The first human defibrillation was accomplished by Beck and his colleagues.

1952- Modern cardiac pacing started when Paul Zoll performed pacing for a duration of 20 min.

1958- Furman & Schwedel succeeded in supporting a patient for 96 days with cardiac pacing.

1958- First implantation of a cardiac pacemaker from engineer Rune Elmqvist at Karolinska Institute in Stockholm by surgeon Åke Senning. [Note development of the implantable pacemaker made possible by the invention of the transistor in 1948.]

1980- The first Implantable Cardiac Defibrillator (ICD) developed by Mirowski was implanted at Johns Hopkins Hospital.


Boston Scientific- Diverse Medical Engineering

Portfolio of more than 13,000 products!
Boston Scientific- Cardiac Rhythm Management

- Bradycardia -
  Pacemaker Systems

- Heart Failure -
  Cardiac Resynchronization Therapy (CRT) and Patient Management Systems

- Tachycardia, Sudden Cardiac Arrest -
  Implantable Cardioverter Defibrillators (ICD) Systems

NYC autopsy: Heart problems caused Shay's Olympic trials death [HCM]
18 March 2008
NEW YORK (AP) - Elite runner Ryan Shay died of an irregular heartbeat due to an enlarged heart after collapsing during the U.S. men's marathon Olympic trials, the New York City medical examiner said...About 125 athletes under 35 involved in organized sports die of sudden death in the United States each year.

Sweet 16, the girl who died 8 times as a baby
25 June 2008
(The Daily Express) - ...born with defective arteries and a hole in her heart. She 'died' eight times on the operating table during a five-hour procedure to try to repair her heart. But after life-saving surgery to install a pacemaker at 14 weeks...revolutionary technology has allowed Kirsty, now 15, to lead a normal healthy life without the need for a heart transplant.

109-year-old Boston Scientific Ingenio patient sets record as oldest pacemaker recipient
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109-year-old Boston Scientific Ingenio patient sets record as oldest pacemaker recipient 2012

Implantable Cardiac Devices

Pacemaker
ICD
CRT
Things EEs should learn during college…

Math/Science/Engineering fundamentals are essential…but also need:

- Verbal/written communications
- Project management
- Problem solving
- Test & Measurement
- Programming languages and design tools
- PCB Design
- Statistics

“…the field is so vast now that it is perhaps naive to suppose that one should be ready to do useful work upon graduation.”

“I was so mad, frustrated, and confused as to how academia has cheated me the 5 years I spent doing…mathematical analysis on circuit diagrams.”

“The degree means the engineer has the fundamental skills, ability, and confidence to learn how to do something and do it right and in a timely manner.”

“people going into the sciences…frequently had hands-on experience as hobbyists and tinkerers.”

1Adapted from “7 More Things Colleges Should Teach EEs,” Lou Frenzel– Electronic Design Blog, 8/25/13
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“The degree means the engineer has the skills, ability, and confidence to do something in a timely manner.”
The daily engineering routine…

Contrary to what you learn in class, the bulk of your day will NOT be solving circuit equations

- Most time is spent in meetings discussing designs or on administrative tasks like ordering parts, documentation, training, etc.

The delight of engineering: Pages of calculations predicting a result, the prediction turns out to be true, and when built it works!¹

- A good day for an engineer is one where your lab measurements match simulation predictions, get used to having very few good days

Design calculations and simulations are "necessary but insufficient" conditions¹

- "All simulations are wrong, but some are useful"

An engineer’s job is not done once the simulation runs

- The theory may be incomplete, the models inaccurate, and external factors may confound correct operation¹

If a design does not work on paper, then it is irresponsible to expect that it will work in practice¹

"Imagination is more important than knowledge” Albert Einstein

¹Adapted from “Perceptions and realities,” Peter Hiscocks -- EDN, 9/14/2006

The Cube office- get used to it!

Prairie-Dog Colony

Engineer Colony
The Lab- your home away from home!

Engineering Ethics

Integrity = Doing what’s right every time…even when no one is looking

Your work & personal ethics are paramount
  • Your decisions and quality of work will affect others
  • If it doesn’t look/work quite right, don’t pass/ship it.
    - It will come back to haunt both you and your customers
    - For medical or high-reliability designs, someone’s life can depend on your judgment call
    - Inevitably will not be enough time to do it right the first time, but always plenty of time to do it over again

Just say no to gifts, tickets, etc. from vendors and do not encourage this behavior by your own companies
  • Regulations had to be enacted to deal with this in medical industry
  • Avoid even the appearance of impropriety

Maintain a customer focus
  • Know who customers of your work are
  • Understand and empathize with your customers
  • Do what’s right for your customer, not what’s easy
Engineers are professionals like doctors and (sorry to say) lawyers

- You will be master of your time-use it wisely
  - One FTE costs your employer ~$200K/year no matter what the level (your pay check is only part of this number!)
  - Consulting fees of $100 to $250/hr are typical
- In charge of reporting your own costs and time
- Salaried employees do not usually get overtime
  - Expect to work anywhere from 40-60 hours/week
  - Expect to work at home as well as the office
  - The hours you work are not usually considered-your performance is judged on your accomplishments
- Don’t need to use vacation time for doctor, school, and other necessary reasons to miss work…but still need to complete your work even if gone
  - 2 weeks paid vacation/year 1st year
  - 3 weeks ~5th year
- Travel for work is work! Over the last 5 years colleagues and I have traveled to:
  - Lower 48 states, Alaska, Germany, Spain, France, Switzerland, Taiwan, China, Japan, Australia, Sweden, Argentina, England, Ireland, Israel, Belgium, Netherlands, Portugal, Italy, Canada, India, Iceland

Engineering as a career

**HOW MANY HOURS DURING THE TYPICAL WORK WEEK DO YOU SPEND AT YOUR OFFICE?**

<table>
<thead>
<tr>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 60 hours</td>
<td>2.5%</td>
</tr>
<tr>
<td>55-60 hours</td>
<td>5.0%</td>
</tr>
<tr>
<td>51-55 hours</td>
<td>5.3%</td>
</tr>
<tr>
<td>46-50 hours</td>
<td>13.7%</td>
</tr>
<tr>
<td>41-45 hours</td>
<td>34.5%</td>
</tr>
<tr>
<td>36-40 hours</td>
<td>14.5%</td>
</tr>
<tr>
<td>31-35 hours</td>
<td>3.2%</td>
</tr>
<tr>
<td>26-30 hours</td>
<td>2.6%</td>
</tr>
<tr>
<td>21-25 hours</td>
<td>2.9%</td>
</tr>
<tr>
<td>16-20 hours</td>
<td>2.0%</td>
</tr>
<tr>
<td>15 or fewer hours</td>
<td>7.7%</td>
</tr>
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</table>

**WORKING AT HOME?**

<table>
<thead>
<tr>
<th>Hours</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>More than 6 hours</td>
<td>0.0%</td>
</tr>
<tr>
<td>5-6 hours</td>
<td>0.7%</td>
</tr>
<tr>
<td>4-5 hours</td>
<td>0.4%</td>
</tr>
<tr>
<td>3-4 hours</td>
<td>1.0%</td>
</tr>
<tr>
<td>2-3 hours</td>
<td>1.2%</td>
</tr>
<tr>
<td>1-2 hours</td>
<td>1.7%</td>
</tr>
<tr>
<td>0-1 hours</td>
<td>0.8%</td>
</tr>
<tr>
<td>0</td>
<td>1.9%</td>
</tr>
<tr>
<td>1-2 hours</td>
<td>2.4%</td>
</tr>
<tr>
<td>3-4 hours</td>
<td>6.1%</td>
</tr>
<tr>
<td>5-6 hours</td>
<td>6.9%</td>
</tr>
<tr>
<td>7-8 hours</td>
<td>16.8%</td>
</tr>
<tr>
<td>9-10 hours</td>
<td>35.5%</td>
</tr>
<tr>
<td>None</td>
<td>23.9%</td>
</tr>
</tbody>
</table>
Engineering problems in the real world...

Defining / Identifying a problem is more difficult than solving a problem

Don’t make solutions more complex than the original problem
  • Simplifying converges on a solution
  • Complexity diverges from a solution and creates new problems

Double check your work and don’t be offended when others do
  • Catching errors early saves time, money, effort
    – In our business it saves lives
    – Finding issues early is ALWAYS better than seeing the consequences magnified later
  • It allows you peace of mind as you see your product built and shipped to locations and customers all over the world

Not everything you work on will become a product

• Eventually they will be used in a manner you did not foresee

Vets install pacemaker in search-and-rescue dog

23 May 2008
COLUMBIA, Mo. (AP) - After years of helping authorities look for murder victims and survivors of natural disasters, a search-and-rescue dog named Molly has been rescued herself.

Surgeons at the University of Missouri College of Veterinary Medicine on Thursday installed a pacemaker in the 5-year-old chocolate Labrador retriever's heart. She needed the surgery after being diagnosed with a complete electrical heart blockage.

Design your products to be unconditionally safe

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Do!

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Engineering solutions

Engineering solutions are rarely “digital” but rather have a full “analog” spectrum of possibilities

• There usually is no single correct answer - most problems have multiple solutions
• The trick is to pick the solution path which will work best for your situation
• Some things to consider are:
  - Risk of totally new invention vs. modification of previous design
  - Cost, Time, Resources
  - The available resource capabilities
  - Complexity vs. reliability
  - Previous experience
• This is why engineers with experience are valuable
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<table>
<thead>
<tr>
<th>Average Salaries By Years Of Engineering Experience</th>
<th>Base salary</th>
<th>Total compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-34 years</td>
<td>$108,137</td>
<td>$117,214</td>
</tr>
<tr>
<td>25-29 years</td>
<td>$106,136</td>
<td>$116,004</td>
</tr>
<tr>
<td>35-39 years</td>
<td>$105,664</td>
<td>$114,974</td>
</tr>
<tr>
<td>20-24 years</td>
<td>$101,106</td>
<td>$110,937</td>
</tr>
<tr>
<td>40 years or more</td>
<td>$93,217</td>
<td>$101,520</td>
</tr>
<tr>
<td>15-19 years</td>
<td>$92,483</td>
<td>$100,040</td>
</tr>
<tr>
<td>10-14 years</td>
<td>$90,015</td>
<td>$98,758</td>
</tr>
<tr>
<td>5-9 years</td>
<td>$73,156</td>
<td>$80,604</td>
</tr>
<tr>
<td>Less than 1 year</td>
<td>$69,318</td>
<td>$76,790</td>
</tr>
<tr>
<td>1-4 years</td>
<td>$69,139</td>
<td>$76,176</td>
</tr>
</tbody>
</table>

Engineering with others

Can’t we all just get along!

• Interpersonal skills are important (CareerBuilder.com 8/2011)
  – >60% of employers valued Emotional Intelligence higher than IQ
  – More likely to stay calm under pressure, Know how to resolve conflict effectively, Empathetic to their team members and react accordingly, Lead by example, Make more thoughtful business decisions
  – Valued traits: Admit/learn from mistakes, Keep emotions in check, Listen more than talk, Take criticism well, Show grace under pressure
• Effective engineers are able to work cross-functionally
  – You will typically be a member of a multi-disciplined team and will need to present your ideas and requirements to others
  – It is normal to “trade-off” requirements and specifications in order to come to an acceptable design solution
• Networking
  – Among students, teachers will help you find a job when you graduate
  – Cross-functionally outside your team exposes you to other career path possibilities
• Find yourself a mentor to discuss career moves with, help you understand your company’s idiosyncrasies, help you broaden or deepen your technical knowledge
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Engineering product planning

When defining a product today, the expected technologies available when its launched must be factored in
- Don’t include today’s technology into tomorrow’s product or the product will be obsolete before starting production
- This means you need to foresee technology 4-6 yrs into future
- It’s common to “design in” products/components that are not yet available themselves

Most companies have entire departments who plan product “portfolios”
- Maps showing all the product lines and their expected new product releases over the next 10 or more years in medical industry
- Show relationships across technologies and product lines
- Used to find future product gaps and highlight areas of investment

Products are often staged 1-2 yrs apart
- It’s common for 4-5 generations of products to be in development at one time
- You will work on multiple projects at the same time
Medical device life cycle

It takes time to bring new products to market

- Consumer electronics development cycle can be <1 year
- Medical products include stringent regulatory approval cycles & clinical testing
  - The bigger the company, usually the longer it takes

Example:

- 1-2 yrs in definition of product, pre-clinicals
- 2-3 yrs in design, testing
- 1 yrs in regulatory/clinical approval
- 3-5 yrs in production
- 5-10 yrs in support

10 - 20 year time before any product is ever “done”

So…always write everything down and never throw anything away - you may need it 10 - 20 years from now!

Engineering documentation

Keeping complete documentation is important

- Patents require invention disclosures, signatures and dates…not just a clever idea
- Usually ideas are kept in an official Lab Notebook
- Process: Your Big Idea 0 years
  - Record of Invention +2 months
  - Decision to Patent +6 months
  - Draft Application +1 year
  - Patent granted +5 years
  - Takes ~5 years from idea to a successful patent grant
  - “You know your idea is good when others take credit for it”

Medical devices require significant traceability

- Lot & serial number tracking are typical for all parts and equipment

Not enough to do the work- must be able to prove you have done it and document it so it can be repeated

*Boston Scientific has more than 15,000 patents*
Your engineering education impacts the rest of your life

- You’ll see same equations for next 40 years, you better like them!

You’re a geek, but that’s OK! (according to US Department of Commerce, 2011)

- STEM careers projected to grow 17% over 2008 to 2018 (9.8% for non-STEM)
- STEM degree holders enjoy higher earnings in STEM or non-STEM jobs

You’ll find getting a big paycheck will not make you happy in the long run

- Starting salary for BSEE is ~$55K, MSEE is ~$65K, PhD is ~$80K

What makes people get out of bed in the morning is a job which is:

- Challenging, rewarding, & part of a well balanced life
- One in which they feel they make a difference
- Opportunity for technical and personal growth

**Engineering for life**

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Engineering education doesn’t stop when you graduate

No matter the job, technology changes- don’t get left behind!

• Continuing education keeps you on top of your field & builds confidence
  – Learn more = Earn more!
  – Examples are MS/PhD degrees, trade shows, seminars, MBA, conferences like IEEE, SPIE
• Employers typically pay for continuing education because they see benefits in a highly trained workforce
• Continuing education allows you to network with others in your field
• Learn from others around you
• Learning from things that don’t work can be more valuable than when everything goes according to plan
• Read trade journals, books, internet to stay current:
  “Design of CMOS RFICs,” Lee; “Analog IC Design,” Johns & Martin
You are never done being graded!

Typically every year you have a performance review...

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outstanding</td>
<td>Clearly and consistently both exceeds objectives and demonstrates exceptional accomplishments; Sought after for their skills, expertise and results; Recognized as exceptional by others both within and outside their group.</td>
</tr>
<tr>
<td>Valued</td>
<td>Achieves objectives and demonstrates competency in critical performance dimensions; Meets high standards of performance, and at times may go beyond acceptable but demanding performance standards; Recognized as adding value, especially in key areas of responsibility.</td>
</tr>
<tr>
<td>Improvement Required</td>
<td>Achieves some, but not all objectives of the job with a reasonable degree of proficiency; Need for further development and improvement is clearly recognized by their management; Improvement in performance is required.</td>
</tr>
</tbody>
</table>

**Performance Rating**

<table>
<thead>
<tr>
<th>Position in MRP</th>
<th>Improvement Required</th>
<th>Valued</th>
<th>Outstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>0%</td>
<td>1.0 - 4.0%</td>
<td>5.0 - 9.0%</td>
</tr>
<tr>
<td>At or Below</td>
<td>0 - 1.0%</td>
<td>2.0 - 5.0%</td>
<td>6.0 - 10.0%</td>
</tr>
</tbody>
</table>

Your first “Real” job...

**Landing the Offer**

- Before graduation: 40%
- Within one month of graduating: 21%
- Within 6 months of graduating: 20%
- Within a year of graduating: 6%
- It took more than a year: 7%
- It’s been over a year, still no luck: 7%

**Factors Recent Graduates Rate Most Important In Choosing Their First Job**

1. Opportunity for advancement
2. Opportunity to benefit society
3. Salary
4. Hours required
5. Taxed less to tax return
6. Health benefits
7. Retirement
8. Benefits
9. 401(k) or matching
10. Recreational opportunity
11. Safety environment
12. Profit sharing
13. Stock options

Electronic Design Magazine 2011 Annual Salary Survey Report
# Setting Salary Expectations

## Average Starting Income of Recent Grads by Company Size

<table>
<thead>
<tr>
<th>Company Size</th>
<th>Base Salary</th>
<th>Total Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small firm (fewer than 100 employees)</td>
<td>$33,647</td>
<td></td>
</tr>
<tr>
<td>Medium-size company (100 to 999 employees)</td>
<td>$39,405</td>
<td></td>
</tr>
<tr>
<td>Large organization (more than 1000 employees)</td>
<td>$44,808</td>
<td></td>
</tr>
</tbody>
</table>

## Average Salaries by Geographic Region

### Base salary: $115,003 - $90,065

### Total compensation: $126,269 - $97,584

<table>
<thead>
<tr>
<th>Geographic Region</th>
<th>Base salary</th>
<th>Total compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific</td>
<td>$115,003</td>
<td>$126,269</td>
</tr>
<tr>
<td>New England</td>
<td>$105,900</td>
<td>$115,893</td>
</tr>
<tr>
<td>West South Central</td>
<td>$105,752</td>
<td>$115,473</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>$99,881</td>
<td>$108,409</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>$98,295</td>
<td>$107,124</td>
</tr>
<tr>
<td>East South Central</td>
<td>$98,767</td>
<td>$106,058</td>
</tr>
<tr>
<td>East North Central</td>
<td>$91,831</td>
<td>$99,542</td>
</tr>
<tr>
<td>Mountain</td>
<td>$90,938</td>
<td>$99,180</td>
</tr>
<tr>
<td>West North Central</td>
<td>$90,065</td>
<td>$97,584</td>
</tr>
</tbody>
</table>

## 2011-2012 PayScale College Salary Report

- **BSEE degrees are top earners!**

## Computer Science (CS)

- Starting Median Pay: $41,698
- Mid-Career Median Pay: $91,052

## Software Engineering

- Starting Median Pay: $44,806
- Mid-Career Median Pay: $97,089

## BSEE degrees are top earners!

- Chemical Engineering (CE)
  - Starting Median Pay: $46,599
  - Mid-Career Median Pay: $93,685
- Electrical Engineering
  - Starting Median Pay: $41,506
  - Mid-Career Median Pay: $93,000
- Materials Science & Engineering
  - Starting Median Pay: $40,410
  - Mid-Career Median Pay: $93,000
- Aerospace Engineering
  - Starting Median Pay: $46,788
  - Mid-Career Median Pay: $93,000
- Computer Engineering (CE)
  - Starting Median Pay: $41,698
  - Mid-Career Median Pay: $91,052
- Physics
  - Starting Median Pay: $48,405
  - Mid-Career Median Pay: $90,065
- Applied Mathematics
  - Starting Median Pay: $53,649
  - Mid-Career Median Pay: $90,065

## Average Salaries by Industry & Base Salary

<table>
<thead>
<tr>
<th>Industry</th>
<th>Base Salary</th>
<th>Total Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT and Systems Administration</td>
<td>$130,634</td>
<td>$140,831</td>
</tr>
<tr>
<td>Software</td>
<td>$111,500</td>
<td>$123,414</td>
</tr>
<tr>
<td>Computer systems/boards/ peripherals/software</td>
<td>$111,889</td>
<td>$122,297</td>
</tr>
<tr>
<td>Government/Military</td>
<td>$110,598</td>
<td>$116,377</td>
</tr>
<tr>
<td>Medical electronics</td>
<td>$100,611</td>
<td>$108,484</td>
</tr>
<tr>
<td>Aerospace/mechanical/electrical systems</td>
<td>$101,909</td>
<td>$108,668</td>
</tr>
<tr>
<td>Communications systems/equipment</td>
<td>$97,603</td>
<td>$106,794</td>
</tr>
<tr>
<td>Automotive electronics</td>
<td>$97,940</td>
<td>$106,540</td>
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<tr>
<td>Test and measurement equipment</td>
<td>$96,189</td>
<td>$105,274</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>$92,586</td>
<td>$102,117</td>
</tr>
<tr>
<td>Research &amp; development</td>
<td>$91,632</td>
<td>$101,063</td>
</tr>
<tr>
<td>Components and subassemblies</td>
<td>$91,934</td>
<td>$99,954</td>
</tr>
<tr>
<td>Industrial controls systems/equipment</td>
<td>$90,400</td>
<td>$99,289</td>
</tr>
<tr>
<td>Consumer electronics</td>
<td>$87,401</td>
<td>$90,306</td>
</tr>
<tr>
<td>Consultant</td>
<td>$88,372</td>
<td>$92,465</td>
</tr>
<tr>
<td>Contract design or manufacturing</td>
<td>$83,045</td>
<td>$88,506</td>
</tr>
</tbody>
</table>
### Setting Salary Expectations continued

<table>
<thead>
<tr>
<th>Field</th>
<th>2011-2012</th>
<th>2012-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refined Science (Nursing)</td>
<td>$39,500</td>
<td>$50,600</td>
</tr>
<tr>
<td>Biotechnology</td>
<td>$48,000</td>
<td>$74,900</td>
</tr>
<tr>
<td>International Relations</td>
<td>$46,500</td>
<td>$79,400</td>
</tr>
<tr>
<td>Occupational Health and Safety</td>
<td>$46,400</td>
<td>$78,600</td>
</tr>
<tr>
<td>American Studies</td>
<td>$48,400</td>
<td>$78,600</td>
</tr>
<tr>
<td>Information Technology</td>
<td>$48,500</td>
<td>$78,100</td>
</tr>
<tr>
<td>Finance</td>
<td>$48,200</td>
<td>$78,100</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>$37,300</td>
<td>$70,100</td>
</tr>
<tr>
<td>Urban Planning</td>
<td>$42,300</td>
<td>$70,100</td>
</tr>
<tr>
<td>Accounting</td>
<td>$46,700</td>
<td>$73,700</td>
</tr>
<tr>
<td>Philosophy</td>
<td>$39,800</td>
<td>$75,600</td>
</tr>
<tr>
<td>Zoology</td>
<td>$39,000</td>
<td>$73,200</td>
</tr>
<tr>
<td>Marketing &amp; Communications</td>
<td>$36,100</td>
<td>$73,300</td>
</tr>
<tr>
<td>Literature</td>
<td>$37,500</td>
<td>$75,200</td>
</tr>
<tr>
<td>Fashion Design</td>
<td>$36,300</td>
<td>$72,400</td>
</tr>
<tr>
<td>Global &amp; International Studies</td>
<td>$37,800</td>
<td>$72,000</td>
</tr>
<tr>
<td>Biology</td>
<td>$37,500</td>
<td>$71,200</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>$40,300</td>
<td>$71,200</td>
</tr>
<tr>
<td>Linguistics</td>
<td>$37,000</td>
<td>$70,700</td>
</tr>
<tr>
<td>Business</td>
<td>$46,000</td>
<td>$70,700</td>
</tr>
<tr>
<td>Microbiology</td>
<td>$36,300</td>
<td>$70,100</td>
</tr>
<tr>
<td>Nursing</td>
<td>$52,700</td>
<td>$89,300</td>
</tr>
<tr>
<td>forestry</td>
<td>$37,000</td>
<td>$89,300</td>
</tr>
<tr>
<td>Social Administration</td>
<td>$48,400</td>
<td>$80,000</td>
</tr>
<tr>
<td>Health Management</td>
<td>$36,200</td>
<td>$69,700</td>
</tr>
<tr>
<td>Forestry</td>
<td>$37,000</td>
<td>$89,300</td>
</tr>
<tr>
<td>Multimedia and Web Design</td>
<td>$48,400</td>
<td>$53,900</td>
</tr>
<tr>
<td>Animal Science</td>
<td>$32,000</td>
<td>$53,700</td>
</tr>
<tr>
<td>Forestry/Lawn</td>
<td>$31,300</td>
<td>$55,000</td>
</tr>
<tr>
<td>Art</td>
<td>$33,300</td>
<td>$53,500</td>
</tr>
<tr>
<td>Theology</td>
<td>$35,600</td>
<td>$53,500</td>
</tr>
<tr>
<td>Public Health (PhD)</td>
<td>$35,900</td>
<td>$53,700</td>
</tr>
<tr>
<td>Athletics Coaching</td>
<td>$36,300</td>
<td>$53,900</td>
</tr>
<tr>
<td>Culinary Arts</td>
<td>$25,900</td>
<td>$46,000</td>
</tr>
<tr>
<td>Social Work (5yr)</td>
<td>$22,200</td>
<td>$46,200</td>
</tr>
<tr>
<td>Elementary Education</td>
<td>$31,400</td>
<td>$54,000</td>
</tr>
</tbody>
</table>

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**Note:** The data above is from the 2011-2012 PayScale College Salary Report, downloaded 8/2011.
**Typical Engineering Levels***

<table>
<thead>
<tr>
<th>Program Management</th>
<th>Functional Management</th>
<th>Technical Ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vice President, Program Mgmt</td>
<td>Vice President</td>
<td>Corporate Distinguished Fellow</td>
</tr>
<tr>
<td>Director, Program Mgmt</td>
<td>Director</td>
<td>Senior Fellow</td>
</tr>
<tr>
<td>Senior/Project Manager (Manager 2, Project Mgmt)</td>
<td>Manager 2</td>
<td>Fellow</td>
</tr>
<tr>
<td>Project Manager (Manager 1, Project Mgmt)</td>
<td>Manager 1</td>
<td>Principal Engineer / Scientist</td>
</tr>
<tr>
<td>Associate Project Manager (Supervisor, Project Mgmt)</td>
<td>Supervisor</td>
<td>Senior Engineer / Scientist</td>
</tr>
<tr>
<td><strong>Engineer 2 / Scientist 2</strong></td>
<td><strong>Engineer 1 / Scientist</strong></td>
<td><strong>Associate level</strong></td>
</tr>
</tbody>
</table>

"Technology is dominated by 2 types of people: Those who manage what they do not understand and Those who understand what they do not manage."

Putt's Law and the Successful Technocrat, A. Putt, 1981

* See end of presentation for more details…

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**Some Engineering Careers***

- Applications
- Electronic
- Failure Analysis
- Field Clinical
- Industrial
- Manufacturing
- Quality
- Materials
- Process
- Product Performance
- R&D/Systems
- Reliability
- Software/Firmware
- Supplier

* See end of presentation for more details…”

---
### What Employers look for...

#### Impact
- Positive first impression, command attention and respect, show confidence & interest

#### Business/Technical Skills
- Technical/Professional knowledge and skills
- Ability to use technical / business / professional information
- Customer orientation

#### Leadership
- Guiding individuals or groups towards task and goal accomplishments

#### Communication
- Understanding others and expressing yourself

#### Interpersonal skills
- Team orientation, interact and collaborate effectively with a variety of people
- Building trust

#### Decision making
- Identifying problems, evaluating relevant facts, generating ideas / alternatives, reaching sound conclusions, and taking appropriate actions
- Analysis, judgment, problem solving and decisiveness

#### Initiative / Effort
- Self-starter rather than passive acceptance
- Willing to take calculated risks
- Adaptability
- Quality and results orientation

#### Planning / Organizing
- Setting a course of action to accomplish a goal
- Planning allocation of resources
- Managing work, using time wisely

#### Motivational Fit
- Organizations corporate and individuals personal needs both met
Make yourself more “employable”

Internships, co-op positions & other practical experiences are extremely important

• Experience in what you want and (more importantly) don’t want to do
• Helps with education by focusing future course work
• Separates you from applicants with no experience

GPA & School engineering program reputation

• GPA used as a filter for entry level positions for lack of other clear predictor
• Both become less important over time as experience builds

Clubs, organizations, extracurricular activities

• Have something more fun to discuss than work!
• Hobbies related to your desired career indicate a passion for your field
• A way to demonstrate leadership prior to entering the workforce
• Networking w/others will expose you to more opportunity

Thank You!

Back-up information slides

- Reference –

Some typical career details and job descriptions
Typical Engineering Responsibilities

Key Engineer Responsibilities

- Designs, develops, debugs, modifies, and tests electrical circuits and systems by using current tools, analysis techniques, and technologies.
- Documents electrical development by writing documents, reports, memos, change requests. Methods used are determined by approved procedures and standards.
- Tracks electrical development effort by creating and maintaining records in the approved tracking management tool.
- Solves engineering problems by analyzing the situation and recommending corrective or alternative actions.
- Analyzes, evaluates, verifies, requirements, circuits, and systems by using engineering practices.
- Investigates, researches, selects electronic circuits, components, tools, equipment and practices.

Job Description: Associate Engineer

JOB CODE / TITLE: Engineer, Electronic LEVEL: Entry/Associate

JOB SKILLS

- Experience/Education- Bachelor's degree plus 0-2 years of related work experience with a basic understanding of specified functional area, or an equivalent combination of education and work experience.
- Technical/Business Knowledge (Job Skills)- Basic technical knowledge of concepts, practices and procedures. Limited understanding of business unit/group function. Will perform this job in a quality system environment. Failure to adequately perform tasks can result in noncompliance with governmental regulations.
- Cognitive Skills- Learns to use professional concepts and company policies and procedures to solve routine problems. Works on problems of limited scope. Minimal independent decision making.
- Influence/Leadership- Begins developing a network of internal resources to facilitate completion of tasks. Individual influence is typically exerted at the peer level.
- Planning/Organization- Completes daily work to meet established schedule with guidance from supervisor on prioritization of tasks.
- Decision Making/Impact- May exercise authority within pre-established limits and approval. Failure to achieve results can normally be overcome without serious effect on schedules and programs.
- Supervision Received- Work is closely supervised. Follows specific, detailed instructions
- Supervision Provided- N/A
**Job Description: Engineer**

**JOB CODE / TITLE:** Engineer, Electronic  
**LEVEL:** Intermediate

**JOB SKILLS**

- **Experience/Education** - Bachelor's degree plus 2-5 years of related work experience with a good understanding of specified functional area, or Master's degree with 0-2 years of related work experience, or an equivalent combination of education and work experience.
- **Technical/Business Knowledge (Job Skills)** - Working technical knowledge and application of concepts, practices and procedures. General understanding of business unit/group function. Will perform this job in a quality system environment. Failure to adequately perform tasks can result in noncompliance with governmental regulations.
- **Cognitive Skills** - Works on problems of moderate scope where analysis of situations or data requires a review of identifiable factors. Exercises judgment within defined procedures and practices to determine appropriate action. Has a broad knowledge of technical alternatives and an understanding of their impact on the systems environment.
- **Influence/Leadership** - Cultivates a wide range of internal networks and begins to develop an extensive external network of resources to facilitate completion of tasks. May lead a project team of moderate scope. Provides guidance to less experienced staff. Acts as a mentor to lower level individual contributors. Influence exerted at peer level and occasionally at first levels of management.
- **Planning/Organization** - Plans, organizes, and prioritizes own daily work routine to meet schedule.
- **Decision Making/Impact** - Exercises authority and judgment within defined limits to determine appropriate action. Failure to achieve results or erroneous decisions or recommendations may cause delays in program schedules and may result in the allocation of additional resources.
- **Supervision Received** - Works under general supervision. Follows established procedures. Work is reviewed for soundness of technical judgment, overall adequacy and accuracy.
- **Supervision Provided** - May provide limited work direction and guidance to exempt and/or skilled nonexempt levels of employees; may be asked to evaluate performance of and assist in career development planning for subordinates.

**Job Title: Electrical Engineer**

As a electrical engineer, you could work in a variety of departments on these types of projects:
- Analog or digital design, Logic synthesis, Simulation of low-power CMOS ASICs for implantable pacemakers and defibrillators

Your development tasks may require you to:
- Design analog and digital test hardware, develop software test programs, participate in the development and enhancement of tests for new and released products, establish design for testability features

**Electrical Engineering Roles**

- **Product Development Team Member** - Performs system integration testing, works with hardware, firmware, and software to understand the root cause of failures and recommend corrective design changes
- **Manufacturing Process Engineer** - Provides engineering support for a pacemaker and defibrillator manufacturing process, drives electrical test and design revisions to enhance manufacturability and product performance
- **Advanced Manufacturing Engineer** - Evaluates corrective action to improve yields for all products
- **Reliability Engineer** - Identifies potential product failure mechanisms, develops methods to assure failure mechanisms are eliminated or prevented in current products and future designs
- **Research Engineer** - Designs systems and devices for acquiring data, signal processing, and therapy control; responsible for areas such as sensing amplifier, automatic gain control, A/D, D/A, control systems, microprocessor implementation and interfacing, telemetry, and simulation
Job Title: Product Development Engineer

PURPOSE STATEMENT- Responsible for providing electrical and electronic engineering support and expertise in the definition, design, development and test of products.

KEY RESPONSIBILITIES- Designs, develops, debugs, modifies, and tests electrical circuits and systems by using current tools, analysis techniques, and technologies. Documents electrical development by writing documents, reports, memos, and change requests. Methods used are determined by approved procedures and standards. Tracks electrical development effort by creating and maintaining records in the approved tracking management tool. Analyzes, evaluates, verifies, requirements, circuits, and systems by using engineering practices. Investigates, researches, selects electronic circuits, components, tools, equipment and practices.

Job Title: Biomedical Engineer

Biomedical engineers identify new sensors or algorithms to improve current therapy and to treat new patient indications. As a biomedical engineer, you will also generate clinical and preclinical protocols and collect and analyze acquired physiologic signals. A solid knowledge of statistics and the ability to interact with patients, physicians, and other clinical support staff are a big asset in this job.

Biomedical Engineering Roles

Advanced Technology Engineer:
- Performs research aimed at directly transferable concepts to new products
- May develop polymers, metals, and coatings
- May participate in the development of mechanical test methods and modeling capabilities, as well as biomechanics studies aimed at determining the in-vivo conditions under which devices operate

Applied Research Engineer:
- Performs fundamental research directed at cardiac arrhythmia detections and therapy
- Handles many projects including sensing algorithms, waveforms, sensors, electrodes, and modeling
Job Title: R&D Engineer

**PURPOSE STATEMENT** - Responsible for providing engineering support in the creation and the development of new medical device products (invasive and non-invasive).

**KEY RESPONSIBILITIES** - Researches, develops, designs, and evaluates mechanical and electromechanical materials, components, assemblies, processes and/or equipment. Conducts feasibility studies to verify capability and functionality. Develops new concepts from initial design to market release. Directs support personnel and coordinates project activities. Write and submit intellectual property (patents). Maintains detailed documentation throughout all phases of research and development. Investigates and evaluates existing technologies. Reviews or coordinates vendor activities to support development.

Job Title: Software Engineer

As a software engineer, you will:
- Develop fault-tolerant, real-time, mission-critical embedded software for implantable pacemakers and defibrillators
- Develop graphical user interface software for external medical instrumentation

Your development tasks may require you to:
- Develop new and enhance existing software products
- Analyze and resolve system and software issues
- Develop and improve R&D software tools, processes, procedures, techniques, and methodologies throughout the software life cycle
- Work with OOA OOD tools to develop reusable feature components
- Work with various dedicated teams to develop new techniques and gather feedback to improve them

Your verification duties may be to:
- Verify software
- Prepare plans
- Analyze requirements
- Develop test protocols and test code
- Debug and execute the tests and analyze test results

Your test system duties may require you to:
- Maintain software
- Troubleshoot systems and software enhancements to the test tool systems
- Work with dedicated product development teams to develop new advanced test tool systems
Job Title: Product Development Software Engineer

PURPOSE STATEMENT: Develops software systems, applications, firmware, and/or provides software systems testing and validation in support of R&D and/or Manufacturing Process Engineering. Performs any of the following: Applications: Responsible for analyzing, designing, programming, debugging, and modification of local, network/internet-related computer programs for commercial or end user applications (i.e. materials management, financial management, HRIS, or desktop applications products). May interface with users to define system requirements and/or necessary modifications. Product Applications: Responsible for analyzing, designing, programming, debugging, and modification of real-time applications. Requires knowledge of real-time operating systems and software. Work often involves knowledge of modeling and simulation software. May interface with users to define system requirements and/or necessary modifications. Firmware: Responsible for the analysis, design, programming, debugging and modification of firmware applications. Work often involves analog and digital hardware and software operating systems. Position requires knowledge and exposure to hardware design. Internal Systems: Responsible for designing, developing, troubleshooting and debugging software programs for internal technical end users. May include software tools, utilities, databases and internet-related tools, etc. Position requires knowledge of hardware compatibility and/or hardware design. Programmers who are developing applications for technical end users should be matched here. Systems Verification: Responsible for developing, applying and maintaining quality standards for software products.

KEY RESPONSIBILITIES: Designs, develops, debugs, modifies, tests software programs by using current programming languages, methodologies and technologies. Documents software development and/or test development by writing documents, reports, memos, and change requests. Methods used are determined by approved procedures and standards. Tracks software development effort by creating and maintaining records in the approved tracking management tool. Analyzes, evaluates, verifies requirements, software and systems by using software engineering practices. Investigates, researches, selects software designs, operating systems and/or practices. Continuously improves process and work methodologies by interfacing with peers/cross-functional groups and analyzing activities to improve workflow and work processes.

Job Title: Manufacturing Engineer

PURPOSE STATEMENT: Provides support to the Manufacturing organization to facilitate efficient operations within the production area, to optimize existing processes, and to ensure that production goals are met. Monitors performance of equipment, machines and tools and corrects equipment problems or process parameters that produce non-conforming products, low yields or product quality issues. Interfaces with Quality and Research and Development organizations to integrate new products or processes into the existing manufacturing area.

KEY RESPONSIBILITIES: Initiates and completes technical activities leading to new or improved products or process, for current programs, next generation programs and to meet strategic goals and objectives of the company. Prepares reports, publishes, and makes presentations to communicate findings. Analyzes and solves problems from basic engineering principles, theories and concepts through to a wide range of complex and advanced problems which require novel and new innovative approaches or a major breakthrough in technology. Understands engineering principles theories, concepts, practices and techniques. Develops knowledge in a field to become a recognized leader or authority in an area of specialization and applies this knowledge in leadership roles in the company. Incorporates business policies and procedures into task completion. Understands the business needs of the company, and has knowledge of the customer needs of our business. Understands the business cycle and foresight of emerging technologies trends. Cultivates internal and external network of resources to complete tasks. Serves as a resource in the selection orientation and training of new engineers and employees. May lead a project team, determining goals and objectives for the projects. Mentors employees by sharing technical expertise and providing feedback and guidance. Interacts cross functionally and with internal and external customers. Serves as a consultant for engineering or scientific interpretations and advice on significant matters. Acts as a spokesperson to customers on business unit current and future capabilities.
Job Title: Quality/Process Engineer

PURPOSE STATEMENT- Provide Process/Quality Engineering support to manufacturing, helping to ensure delivery of highest quality product to the customer. Provide Process/Quality Engineering support to product development teams, helping to ensure development of highest quality new products.

KEY RESPONSIBILITIES- Learns to identify Manufacturing process defects (scrap, nonconforming material, customer complaints) by dispositioning non-conforming material, assisting in identification of primary root causes and understanding corrective and preventative actions. May be responsible for working with process owner to bound product stops and document release criteria. Gains understanding of product quality plans, documents and systems by reviewing product specifications, quality specifications, and working with quality systems. May be responsible for learning risk analyses and FMEAs. Learns Process Monitoring Systems by becoming familiar with systems applications and critical process steps; and through familiarization with methods used to reduce process variation. Becomes familiar with Product/Process improvement efforts by understanding current quality metric data and learning the various analysis methods used to enhance sustaining product design and new product development. Learns Quality Tools & Training Materials by gaining knowledge of prevalent tools used and by reviewing & utilizing available training materials.

Presenter Bios

Greg P. Carpenter, Boston Scientific Corporation, St. Paul, MN, USA
Greg Carpenter (BS '87) is an electrical engineer with over 25 years of medical industry experience. He is a research fellow at Boston Scientific Corporation since 2001. His current research interests include MRI compatibility of implanted devices, implanted and near patient sensors, energy harvesting and wireless telemetry design for medical systems. He has done research, design, and product development for various medical diagnostic instrumentation platforms including blood glucose and coagulation monitoring. He holds 10 patents, has 1 publication and is a member of IEEE and ISMRM.

Daniel Landherr, Boston Scientific Corporation, St. Paul, MN, USA
Daniel Landherr (UMD BECE '98) is an electrical engineer with 17 years of industry experience. He has served in a variety of medical device quality, operations and design roles since 2003 and currently is a Principal RF Design Engineer at Boston Scientific Corporation. His current projects include various wireless telemetry designs for both implantable and near patient medical devices. He previously worked as a design/development engineer for Emerson Process Management and IBM. He is a FIRST LEGO League coach, FIRST Tech Challenge judge and a member of IEEE.

For more info: www.BostonScientific.com