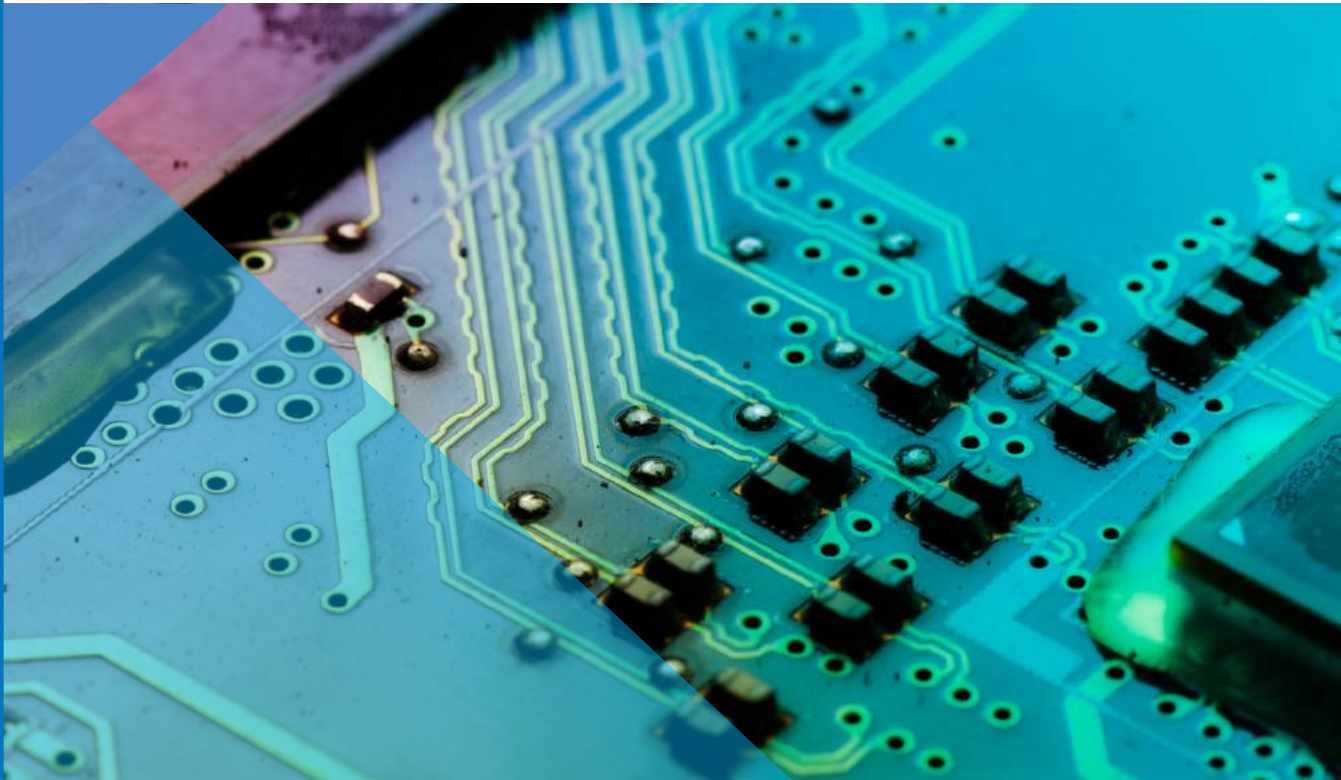


Master of Science Integrated Circuit Design

Technical
University
of Munich



NANYANG
TECHNOLOGICAL
UNIVERSITY



At A Glance

JOINT DEGREE BY

Technical University of Munich (TUM)
Nanyang Technological University (NTU)

TWO-YEAR FULL TIME PROGRAMME

Coursework in Singapore

PRACTICAL KNOWLEDGE

Compulsory Internship & Thesis

GLOBAL PROSPECTS

Internationally Recognized Degree

INTAKE

August Every Year

TO APPLY

Apply online from 15th October at
www.tum-asia.edu.sg

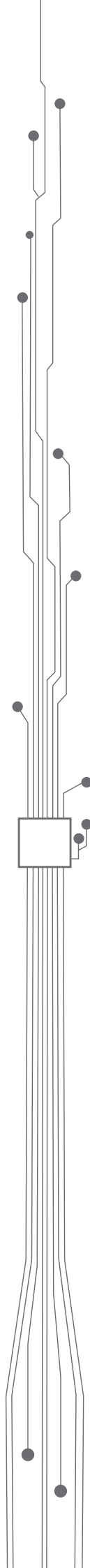
1 TUM is ranked as the #1
University in Germany⁺

1 NTU is ranked #1 in Asia
for Engineering⁺⁺

1 NTU is ranked #1 in the
world for industry income
and innovation^{*}

6 TUM ranked #6 in the
Global Employability
Survey[^]

50 Both TUM & NTU[#]
are in the world's
Top 50 Universities





Technical University of Munich (TUM)

Technical University of Munich (TUM) is one of Europe's leading research universities, with around 500 professors, 10,000 academic and non-academic staff, and more than 40,000 students. Its focus areas are the engineering sciences, natural sciences, life sciences and medicine, reinforced by schools of management and education.

TUM acts as an entrepreneurial university that promotes talents and creates value for society. In that it profits from having strong partners in science and industry. It is represented worldwide with a campus in Singapore as well as offices in Beijing, Brussels, Cairo, Mumbai, and São Paulo.

Nobel Prize winners and inventors such as Rudolf Diesel and Carl von Linde have done research at TUM. In 2006 and 2012 it won recognition as a German "Excellence University." In international rankings, TUM regularly places among the best universities in Germany.

Nanyang Technological University (NTU)

Inaugurated in 1991, Nanyang Technological University (NTU) has grown to become a full-fledged research university, and is ranked as one of the fastest-rising Asian universities in the world's top 50**. Hailing from more than 70 countries, NTU's 3,800 strong teaching and research staff contribute their dynamic perspectives and years of solid industry experience.

NTU's academic and research programmes, with real-world relevance, have reaped dividends in the form of strong support from major corporations and industry leaders, in terms of both research funding and partnerships as well as global internship opportunities for our students.

As the main Science and Technology university in Singapore, NTU has made substantial contributions to Singapore's drive for research and innovation, with the 2014 Quacquarelli Symonds (QS) ranking NTU at 10th in the World for Electrical & Electronic Engineering.

**As rated by 2013/2014 QS World University Ranking



Master of Science

Integrated Circuit Design

The joint TUM-NTU [Master of Science in Integrated Circuit Design](#) (MSc in ICD) equips students with the academic proficiency and hands-on knowledge required in the design, development, and manufacture of integrated circuit or integrated electronic products.

COURSE OUTLINE

12

Modules to be completed
(6 Core Technical Elective Modules,
4 Specialization Technical Elective
Modules, 2 Non-Technical Elective
Modules)

45

Contact hours for every Core and
Specialization Technical Elective
Module

2

Compulsory Laboratory Modules to be
completed by every student



JOINT DEGREE

Conferred by Technical University of Munich (Germany) and Nanyang Technological University (Singapore)



APPLICATION-FOCUSED

Full-time research and application focused programme, inclusive of 3-month internship experience and 6-month Master Thesis writing



INDUSTRY RELEVANCE

Our professors are actively involved in research and cooperation projects with leading industrial companies, allowing them to base the curriculum around the latest technological trends and knowledge



GLOBAL OPPORTUNITIES

You are able to complete your Internship and Thesis in Singapore or anywhere in the world with a company, university or research institute and look for job opportunities globally

Programme Timeline Overview



July

Arrival in
Singapore



Year 1

- Laboratory Modules
- Core Technical Elective Modules
- Specialization Technical Elective Modules
- Non-Technical Elective Modules



Year 2

- Non-Technical Elective Modules
- Internship
- Master Thesis at a company,
university or research institute
(Supervised by a NTU or TUM professor)



Graduation

End of
Programme

Note: This outline is a general reference to the duration of study. A student's actual duration of study may or may not follow this general reference. This outline is subject to change during the course timetable.

Module Synopsis

Compulsory Laboratory Modules

Laboratory 1 Analog IC Design

Design of a wide-band amplifier from schematic to layout verification.

Laboratory 2 Digital IC Design

Design, simulation, layout and synthesis of digital integrated circuits & systems.

Core Technical Elective Modules

(Choose minimum 6 out of 7 modules)

Digital IC Design

Review of integrated circuit fundamentals. Layout and design issues. CMOS digital circuits. BiCMOS digital circuits. Sub-system design in digital circuits. Design methodologies.

Analog IC Design

Review of fundamentals. Analog building blocks. Switched capacitor circuits. Current mode circuits. Continuous-Time filters. Data converters.

Mixed Signal Circuit Design

Fundamentals of discrete time signal processing. MOSFET as a switch. Sample & hold circuits, switched capacitor circuits. Data converter fundamentals. Nyquist rate D/A and A/D converters. Over sampling, noise shaping, A/D and D/A converters using sigma-delta modulators. Switched capacitor filters.

System-on-Chip Solutions & Architecture

The course addresses application-specific digital CMOS integrated circuits (ASICs) from a system's perspective. Covering multiple levels of abstraction from MOSFET transistor, to realization of combinational / sequential logic, finite state machines (FSM), memory (SRAM, DRAM, FLASH), to chip-level interconnect technology (busses, network-on-chip (NoC)). Furthermore, the course complements the understanding of digital integrated circuit design by investigating the architectural composition of multiple real-world case studies taken from existing SoC products in the area of Internet networking. We will investigate and compare generic RISC CPU platform architectures with network processor units (NPUs), LAN/SAN (Local area / System area network) switches and SONET/SDH transmission framers of wide area networks (WAN).

Design Methodology & Automation

Computer-aided design of integrated circuits. VLSI design flow overview: system level, algorithmic level, register transfer level, logic level, and circuit level. Detailed discussion of VLSI design methods especially for logic synthesis. Digital simulation, hardware description language, test development including design for testability. Techniques from discrete mathematics and computer science are explained and employed.

Digital Signal Processing

Introduction. Discrete Fourier transform (DFT) and fast Fourier transform (FFT). Z transform. Digital filters. Linear prediction and optimum linear filters. Power spectrum estimation.

IC Packaging

Packaging overview. Electrical packaging design and thermal management. Single chip, multichip and 3D packaging. IC assembling, sealing and encapsulation. IC packaging failure and reliability. Microsystems packaging and applications.

Specialization Technical Elective Modules

(Choose minimum 4 out of 7 modules)

RF IC Design

System design considerations. CMOS RF components and devices. Low-noise amplifier (LNA), Mixers, Voltage-controlled oscillators (VCOs). RF power amplifiers. Phase-Locked Loops and Frequency Synthesizers.

*Disclaimer: Elective modules available for selection are subject to availability. Unforeseen circumstances that affect the availability of the module include an insufficient number of students taking up the module and/or the unavailability of the professor. TUM Asia reserves the right to cancel or postpone the module under such circumstances.

IC Marketing / Business / Management

Trends in the IC industry: technology and manufacturing trends, demand applications and product trends. Market characteristics: the customers, business cycles, demand lead and supply lag (the bull-whip effect), IC industry, supply and value chain, stakeholders, geographical distribution of excellence centers, technology centers, design centers, fabrication centers, the dis-integration of the value chain, outsourcing trends. Managing the marketing function: the sources of product ideas, the role of standards, formats, and intellectual property. Strategic partnership, distributorship, demand forecast, matching supply with demand.

Advanced MOSEFT & Novel Devices

Historical development of mainstream MOSFETs until today: economical, technological and physical fundamentals. Properties of long channel and short channel MOSFETs, high-field effects, scaling rules. Basics of charge carrier transport, drift-diffusion, Boltzmann-Bloch equation, hydrodynamic transport, ballistics and consequences for IV-characteristics. Advanced MOSFETs, mobility-enhancement, metal-gate, FinFETs, MuGFETs. Hot-electron and ballistic transistors, Impact-MOSFETs, Spintronic devices. Tunneling-MOSFETs, single-electron transistors.

Nano-Electronics

Low dimensional structures: quantum wells, quantum wires and quantum dots. Electronic, optical, transport properties of nanostructures. Quantum semiconductor devices. Fabrication and characterization techniques of nanotechnology. Applications of nanostructures, nanodevices and nanosystems. The bottom-up approach to nanotechnology: introduction to molecular electronics and optoelectronics. Organic materials for electronics: self-assembled monolayers, conducting polymers, carbon nanotubes. Circuit implementations and architectures for nanostructures: quantum cellular automata and cellular non-linear networks. Introduction to quantum computing.

Embedded Systems

Basics of processor architectures. Memory organization and caches. Worst-Case Execution Time (WCET) Analysis. Compositional Timing Analysis for embedded systems. Embedded software platforms and tools for host-target-development. Performance analysis of embedded systems and design space exploration. Model-based design and code generation. Formal verification and validation of embedded systems. Real-Time Operating Systems. Power management for embedded systems.

Simulation and Optimization of Analog Circuits

Principles of circuit simulation: DC/AC/TR analysis. Basic analog optimization tasks: worst-case analysis, yield analysis, nominal design, design centering. Basic principles of optimization: optimality conditions, line search, Nelder-Mead method, Newton approach, Conjugate Gradient approach, Quadratic Programming, Sequential Quadratic Programming. Structural analysis of analog circuits.

Design for Testability of VLSI

Fault Models and Testability concepts. Test Generation and Fault Simulation Algorithms. Shift-register polynomial division. Pseudo-random sequence generators. Special purpose shift-register circuits. Random pattern BIST. Build-in boundary scan structure. Limitations and other concerns of random pattern test. Test techniques for automatic test equipment.

Non-Technical Elective Modules

(Choose minimum 2 out of 7 modules)

- Business Administration
- Industrial Marketing
- Innovation and Technology Management
- Legal and Safety Aspects in Industry
- International Intellectual Property Law
- Production Planning in industry
- Modern Developments in Industry

ADMISSION CRITERIA*

- You may apply to our programme if you have completed your Bachelor Degree Programme, or if you are in your final year of Bachelor Degree studies
- Hold or enrolled in a Bachelor Degree (completed in at least three years, depending on factors such as the rest of your education background) in **Electrical or Electronics Engineering** or in a closely related discipline
- Submit one **(1) notarised copy of Bachelor Degree Certificate or Enrolment Letter**** (if you have not completed your Bachelor Degree) and one **(1) notarised copy of Academic Transcripts or Mark Sheets****
- Submit **two (2) Recommendation Letters** from two (2) different Professors or Employers
- Submit **one (1) Statement of Purpose** that indicates the reason(s) you are interested in the programme you applied for
- Submit **one (1) Curriculum Vitae / Resume**
- Submit **TOEFL / IELTS test score** taken no more than two years ago from date of submission of online application
- Submit **Akademische Prüfstelle (APS)** certificate (Required for applicants who hold a degree from China, Vietnam, or Mongolia)

TOEFL test score requirements: At least 100 for the Internet-Based Test (TOEFL code: 7368)

IELTS test score requirements: Overall IELTS results of at least 6.5

* The full application process is available on www.tum-asia.edu.sg/application-process.

** Documents which are not in English must be translated by a certified translator. All applicants are also required to submit an additional of three (3) notarised copies of Official or Provisional Bachelor Degree Certificate, two (2) notarised copies of full, Official Academic Transcript, and three (3) passport-sized photographs when you have accepted the offer of admissions and are being matriculated into our programme.

TO APPLY

Applications open 15 October every year. Apply online at www.tum-asia.edu.sg

FINANCING YOUR STUDIES

APPLICATION

SGD 79 is payable for each application per programme

TUITION FEE

A total of SGD 34,240*

- The tuition fee will be divided into 3 installments for payment and may be further divided into SGD and EUR amounts.
- The tuition fee includes teaching fees, laboratory expenses and cost of mandatory events.
- The tuition fee does not include airfare, accommodation, living expenses, and NTU miscellaneous fees (inclusive of registration, IT facilities, matriculation, examination, amenities, copy right, sports, insurance and medical). These fees will be separately paid by the student.

* The tuition fee stated is accurate as of 1 August 2018. All fees are subject to revision due to currency fluctuations, at the discretion of TUM Asia. All fees quoted are inclusive of 7% Singapore's Government Goods & Services Tax. Please refer to our website for fee updates.





Studying With Us

“Talents Are Our Assets, Reputation Is Our Return”

Entrepreneurial Thinking and Engagement

Globalization is now an inevitable force that is here to stay. At TUM Asia, our classroom reflects this diversity with an enrolment of over 28 nationalities. This means that we foster a vibrant learning environment where the student learns not only from the textbook but also through the lives of their counterparts. Classroom ideas are synthesized across the diverse economic realities and students learn to see from multiple vantage points, creating a capacity to solve problems in creative ways. The unique joint degree programme not only equips the student with technical and scientific knowledge, but with an enriched curriculum consisting of business and cultural modules.

TUMCREATE

TUM is known for its research capabilities and strength in innovation. As such, TUM Asia spearheaded the set up of TUMCREATE as a base of research in Singapore. TUMCREATE is a joint programme between Technical University of Munich (TUM) and Nanyang Technological University (NTU). The electromobility institute brings together the expertise and innovation of Germany and Singapore, to drive innovation to shape the future of sustainable mobility by tackling issues ranging from the molecules to the megacity. **Graduates from the TUM Asia Master programmes have the opportunity to apply for positions at TUMCreate, especially if your interest lies in the area of transportation and mobility research.**

Highest International Standards

You will be studying with the world's best professors from TUM and NTU, as well as experts from the industry. Not only will the student benefit from professors who are actively involved in research, one will also receive a holistic learning experience with the engagement of local lecturers from academia and industry. Our TUM modules are covered by professors who fly in from Germany on an exclusive teaching basis, to ensure that students get the undivided attention of their lecturers.

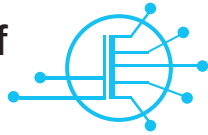
“**Our students are not just learning about Integrated Circuit Design. The joint TUM-NTU ICD Master programme equips you to become an excellent independent engineer for the rest of your professional life. We teach you to master the challenges!**”

Dr. Helmut Graeb

Professor, Technical University of Munich
Institute for Electronic Design Automation

DID YOU KNOW THAT A PART OF YOUR GADGET - COMPUTER, MOBILE PHONE, TABLET OR VIDEO CONSOLE - WAS DESIGNED OR MANUFACTURED IN SINGAPORE?

Electronics: The Core of Singapore's Progress



Since the 1960s, Singapore's electronics industry has been a major contributing sector to the nation's manufacturing output. Over the years, the electronics sector has continued to flourish and move up the manufacturing chain as companies started to pour into higher-end functions such as Research & Development (R&D). [Singapore aims to become a world class innovation-driven electronics hub, providing technology, manufacturing and business solutions and enabling the development of new growth areas.](#)

The Semiconductor Industry in Singapore

The global industry being dominated by USA, South Korea, Japan, Taiwan, Singapore, and European Union. Every year, chip makers and designers dramatically increase the performance of their products while decreasing prices, making high-end technology goods increasingly productive and affordable for consumers. Singapore's semiconductor industry has the highest growth potential and is currently the fastest growing industry sector in the country.

Our Graduates



Our graduates in Integrated Circuit Design are employed all over the world, such as in [Singapore \(77.6%\)](#), [Europe \(13.8%\)](#), [India \(8.6%\)](#).



The most commonly accepted positions are [Integrated Circuit Design Engineer](#), [Research Associate](#), [Engineer](#), and [PhD Researcher](#).



Our graduates are expected to have a high amount of job opportunities due to strong partnerships with the industry. Companies that we partner closely with include [Infineon](#), [Lantiq](#), and [STMicroelectronics](#).

1

Today, Singapore accounts for 1 out of 10 wafer starts in the world.

3

Three of the world's top six outsourced semiconductor assembly and test companies are located in Singapore.

15

15 of the world's top 25 fabless semiconductor companies, and close to 40 integrated circuit design centres are located in Singapore.

20

Today, Singapore is home to approximately 20 semiconductor assembly and test operations.

25

Electronics is the major industry underpinning Singapore's economic growth, it contributes 25% of the total manufacturing value-add.

40

40% of the global hard disk manufactured in Singapore.



The programme offered a module that was related to intellectual properties and invited a German professional patent attorney to teach it. The module opened a new window for me and helped me to discover a career path that I was passionate about.

[Minghui Sun](#)

Alumni, Master of Science in Integrated Circuit Design Technology Specialist, SHUSAKU-YAMAMOTO

When I look at the MSc in ICD interns, I see highly motivated individuals with a strong desire to learn and acquire new knowledge and skills. That mentality is very important in this dynamic industry.

[STMicroelectronics Asia Pacific Pte Ltd](#)

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German Institute of Science & Technology - TUM Asia Pte Ltd

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All information is accurate at the time of printing and is subject to change without prior notice.

Published in August 2018.

⁺ As rated by Academic Ranking of World Universities (Shanghai Ranking) 2011-2013, 2016 and 2015-2018 QS World University Ranking

⁺⁺ As rated by Academic Ranking of World Universities (Shanghai Ranking) 2016

^{*} As rated by the Times Higher Education University Ranking 2016

[^] As ranked in the Global University Employability Ranking 2017

[#] As ranked by Academic Ranking of World Universities (Shanghai Ranking) 2017/2018 and 2013/2014 QS World University Ranking