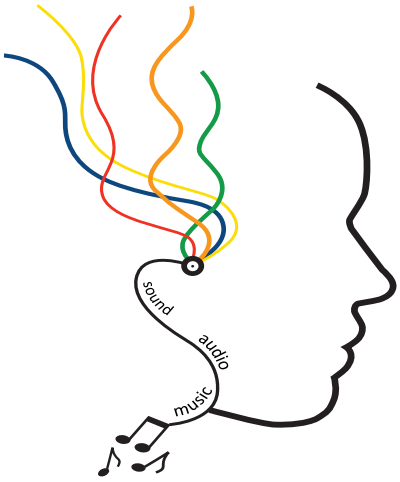
AME



Revised Audio and Music Engineering Curriculum Guide
Class of 2023 and beyond.

The Hajim School of Engineering and Applied Sciences
University of Rochester

Fall/Spring 2022/2023

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PROGRAM DESCRIPTION

The Audio and Music Engineering (AME) major combines studies in engineering and applied sciences with music and audio production to give students a technically rigorous, design-based education in the field of audio, music and sonic engineering. The curriculum is built on a foundation of basic math and science and integrates elements of music, audio content production, acoustics, fundamental engineering science, signal processing hardware and software, electronics, and software engineering. Through a series of design and project courses integrated with their other course work, students build a project portfolio throughout their studies capped by a senior design project. The Bachelor of Science in AME (BS AME) is offered. Students also may earn a Bachelor of Arts in Engineering Science (BA-ES) with a program focus in AME. It also is possible to complete a minor in AME.

INTRODUCTION

The Department of Electrical and Computer Engineering coordinates the program in Audio and Music Engineering. Currently the Bachelor of Science and a Minor in AME are offered. A Bachelor of Arts major in AME is not offered, however it is possible to complete a Bachelor of Arts in Engineering Science with a program focus on Audio and Music Engineering. The MSEE and Ph.D. degrees with a concentration and research in Acoustics, Audio and Music Signal Processing are available through the ECE Department as well. AME students may choose to earn a Master of Science degree in Electrical Engineering with as little as one additional year of study following completion of the AME BS program. Participation in the GEAR (Graduate Engineering at Rochester) program is open to all incoming First Years. If accepted into this program, an undergraduate is assured admission to the EE masters program provided an undergraduate GPA of 3.3 is achieved in their undergraduate studies.

The Audio and Music Engineering (AME) program provides students a multi-disciplinary education combining studies in engineering and applied science with music and audio arts. It serves a wide range of students, from those wishing to gain a technically rigorous, design-based engineering education in the field of audio engineering to students of music and the humanities wishing to increase their knowledge and skills in the technology of music and audio media creation to complement their other studies. Experiential hands-on learning, design, and the creative process are the foundation of the program. The central pillar of each student's education is their design/creative project portfolio built over the course of their studies to illustrate their engineering skills and creative abilities.

The field of audio and music engineering extends far beyond the traditional music recording industry. Career paths for program graduates span hundreds of companies representing industries such as: computer hardware and software manufacturing, audio software development, music and audio recording and production, core audio and signal processing technologies and component manufacturing, musical instruments and audio equipment manufacturing, video gaming, automotive, architectural acoustics, urban planning, industrial noise monitoring and control, consumer product design, and research and development in acoustics.

Our students also have the opportunity to participate in research, working closely with faculty members in department research programs during the academic year and in summer internships.

Students planning to pursue a double degree should consult their advisor early in their studies to plan their program. Multiple student advising resources are available including: the primary faculty advisor assigned to each AME student in their first year, the AME Program Undergraduate Coordinator (Barbara Dick), the AME Program Director (Mark Bocko). Students requiring assistance should first consult their primary faculty advisor or the AME Program Undergraduate Coordinator. Faculty advisors are available to help students plan their programs of study, declare a major or minor, drop and add courses, transfer credits from another institution, register for independent study credits, explore study abroad options, arrange internships and fellowships, and to petition for cluster exceptions. The AME Program Director must review and approve all transfer courses.

PROGRAM OBJECTIVES AND STUDENT OUTCOMES ADMISSION

Bachelor of Science in Audio and Music Engineering - Program Objectives

- Graduates of the University of Rochester's Bachelor of Science program in Audio and Music Engineering will, within a few years of graduating, be on paths to becoming leaders in their chosen professions.
- Our graduates will be valued for their creativity, technical proficiency, teamwork, and ability to communicate effectively.
- Throughout their careers our graduates will demonstrate their commitment to professional growth through the pursuit of advanced degrees, continued education and training, and adaptability within their work environments.
- Our graduates will appreciate the many ways that engineering skills may be applied to solve a wide range of problems, both within and outside of engineering, and will be equipped to explore alternate career paths that align with their interests and maximize their contributions to society.
- Our graduates appreciate their ethical responsibilities and the relationship and obligations of engineering and science to the public and the environment.

Bachelor of Science in Audio and Music Engineering - Student Outcomes

To prepare our graduates to enter the professional practice of engineering the Bachelor of Science in Audio and Music Engineering program of the University of Rochester will attain the following outcomes:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ADMISSION

Students wishing to declare a major in AME must file a completed "AME Curriculum Planning Form" along with the Concentration Approval Form. This usually is completed during the fourth semester of study. The minimum requirements for admission to the AME BS program are completion of the following:

1. AME 140, AME 141, AME 191, ECE 113 with a minimum cumulative GPA of 2.3.
2. MATH161, 162, 164, and 165 or equivalent math sequence such as MATH 141,142,143,165,164
3. PHYS 121 and 122 or PHYS 113 and 114
4. University primary writing requirement, usually satisfied by taking WRT 105.
5. Students may not be admitted to the major if they are on Academic Probation in the College

Under special circumstances, such as transfer from another institution or change of intended major, students may not have completed all the requirements for BS AME program admission by the end of the sophomore year. Such students may qualify for conditional admission by submitting a petition form available from the AME Undergraduate Coordinator. The petition for conditional admission and an up-to-date AME Curriculum Planning form should be submitted to the AME Undergraduate Program Coordinator. The application must present a realistic plan, approved by the student's advisor, for completion of all AME program admission requirements within one year. Failure to meet the requirements within one year will result in removal from the major.

Only the Administrative Committee of the Hajim School of Engineering and Applied Sciences can make exceptions from the general degree requirements published in the Official Bulletin of the University. Petition forms for Administrative Committee consideration may be obtained from the AME Program Coordinator.

BS AME PROGRAM REQUIREMENTS

The BS AME program is built on a foundation of basic math, science, programming and music and includes advanced course work in fundamental engineering science, audio content production, audio hardware and audio software. The credit hour requirements for the BS AME degree are given in the following table.

Core Area	Credits
Basic Science and Mathematics	32
Engineering	60
Writing (WRT105, 273)	6
Hum & Soc Sci	20
Free electives	12
Total	**130**

Core Requirements

Mathematics (Complete one calculus sequence)
MATH161,162,164,165 or MATH171,172, 173, 174
MATH141,142,143 may be substituted for MTH161,162
ECE 270 or STAT 212 or STAT 213 or STAT 262
Physics (2 courses) PHYS 121, PHYS 122; PHYS 113, 114 or PHYS141, PHYS 142
Acoustics (1course) AME 233/PHYS 283

Other Natural Science (1 course)
The remaining course may be in astronomy, biology, brain and cognitive sciences (depends on the course and if used in a cluster - check with Dept.), chemistry, earth and environmental sciences, physics, or statistics. (PHY 123 or higher, AST 111 or higher, CHE 103 or higher, BIO 110 or higher, EES, 101 or higher, BCS 110 or higher)

Basic Music Competency All AME students must take **a minimum of 10 credits of music courses**, either from the River Campus Music Department or at the Eastman School of Music. **This includes 8 credits of music theory and 2 credits of musicianship.** The minimum requirement is completion of MUR101 and MUR111, however students with appropriate background and demonstrated proficiency in music theory may begin in a higher level course such as MUR110 followed by MUR111. The appropriate starting course is determined by placement exam administered by the River Campus Music Department, or for Eastman students placement in Music Theory is determined by the ESM faculty. To meet the musicianship requirement, students normally would complete two one-credit courses MUR109 and MUR113, 114, 115 or one 2 credit course MUR 201 or 202. Courses taken to fulfill the AME music requirement also may be counted toward a Music Cluster to meet the general AME Humanities or Social Science cluster requirement.

The BS AME major requires completion of courses and Portfolio projects in 5 subject areas: Recording Arts and Sound Design, Acoustics, Audio Electronics, Signal Processing and Software Design. The required and elective courses for the BS AME degree are listed below. All courses are 4 credits unless indicated otherwise. Optional elective courses are shown in red.

PROGRAM REQUIREMENTS CONTINUED

Foundations of Audio and Music Engineering
- AME 140 – Intro to Audio and Music Engineering
- AME 141 – Fundamentals of Digital Audio

Recording Arts and Sound Design – The focus is on audio and music recording and production, audio content creation and sound design:
- AME 191 – Art and Technology of Recording
- AME 192 – Critical Listening for Audio Prod
- AME 193 – Sound Design
- AME 194 – Audio for Visual Media
- AME 240 – Revolutions in Sound: Artistic and Technical Evolution of Sound Recording
- AME 391 – Applied Recording Arts
- AME 393 – Applied Sound Design

Acoustics – Studies in acoustics range from fundamental acoustics, architectural acoustics, acoustic design, the acoustics of musical instruments, hearing and auditory perception:
- AME 233 (PHY 283) – Musical Acoustics
- AME 292 – Acoustics Portfolio (2)
- ECE 439 – Electroacoustics and Spatial Audio

Audio Electronics – Analog and digital electronics for audio - from vacuum tubes to custom integrated circuits:
- AME 140 – Intro to Audio and Music Engineering
- ECE 113 – Circuits and Signals
- AME 223 – Audio Electronics
- AME 295 – Audio Electronics Portfolio (2)
- ECE 216 – Mechatronics and Embedded Systemd
- ECE 222 – Integrated Circuits: Design and Analysis
- ECE 261/461 – Introduction to VLSI

Signal Processing – Digital signal processing is the core of digital audio. The following courses are offered:
- ECE 240 – Signals
- AME 272 – Audio Signal Processing
- AME 294 – Audio DSP Portfolio (2)
- AME 277/477 - Computer Audition
- ECE 246/446 – Digital Signal Processing

Software Design – The principles and practice of programming and software development for audio:
- ECE 114 – Intro to C/C++ Programming
- AME 262 – Audio Software Design I
- AME 264 – Audio Software Design II
- AME 196 - Interactive Music Programming
- CSC 172 – The Science of Data Structures
- CSC 210 – Web Programming

Senior Design – All AME BS students must complete a one-year senior design project
- AME 386– Senior Design Project I (2)
- AME 387 – Senior Design Project II

PROGRAM REQUIREMENTS CONTINUED

Humanities/Social Science Requirement – All AME majors must take a minimum of 5 humanities and/or social science (H&SS) courses. This includes the three courses taken to satisfy the University Cluster requirement. These five courses can be chosen from any recognized Humanities and/or Social Science field listed below. Students also are expected to take some of these courses beyond the introductory level. Ordinarily, H&SS Clusters will count for three of the five required courses, but if questions arise, students should consult their advisors. Language courses at the 101 level are only accepted when followed by another, more advanced course in the same language. A minor of 5 or more courses in one area will satisfy the H/SS requirement. If pursuing a music cluster, some required music courses may count toward the 12 credit cluster requirement. In this case, additional electives in H /SS are needed to reach the 20 credit requirement.

Acceptable Humanities Courses: Any English course except for ENG101 or the course taken to satisfy the university primary writing requirement (usually WRT 105); any 4 - credit course in American sign language, art or art history, digital media studies, dance, English, foreign or comparative literature**,** a foreign language sequence above 101 level, music theory or music history, philosophy, religion & classics, or film studies courses cross-listed in a humanities department.

Acceptable Social Sciences Courses: Any course in anthropology, brain and cognitive sciences (depends on the course and if used in a cluster - check with Dept.), economics, entrepreneurship, health and society, history, linguistics, political science, psychology, sociology, or women's studies.

Business courses from the Simon School may not be used to satisfy the H/SS distribution requirement. Also, no computer courses offered in the humanities or social sciences may be used as a H&SS distribution course.

Ordinarily, courses taken at the University of Rochester to meet the requirements in H&SS are 4 credit hour courses. Consult your advisor concerning 2 or 3 credit courses (including transfer courses). You may need to petition the Undergraduate Committee to use such courses for the H&SS distribution requirement.

The following restriction applies to all courses used to satisfy the distribution requirement: **Two 2-credit courses may be combined to fulfill one 4-credit distribution requirement only if both courses are from the same discipline. No more than two courses may be combined to count toward a distribution requirement.** However, any number of two, 2-credit courses from different disciplines may be substituted for other 4-credit free electives.

Upper Level Writing – The University's Upper-level Writing Requirement applies to all majors. Within the BS Audio and Music Engineering major the requirement is met through work in **AME192, AME193, AME233, AME262 and AME386**. Students who transfer credit for any one or more of these courses from another institution to the UR must consult with the AME Program Coordinator to determine if their program satisfies the writing requirement. **WRT 273** – Professional writing is also required of all AME majors.

BS AME CURRICULUM AND SAMPLE COURSE SCHEDULES

MATH 160 SERIES:

Core Curriculum				FRESHMAN YEAR						
Math and Physics				**FALL**				**SPRING**		
MATH 161	Calc I	4		MATH 161	Calculus 1a	4		MATH 162	Calculus IIa	4
MATH 162	Calc II	4		AME 140	Intro to Audio Music Engineering	4		AME 191	Art & Tech of Recording	4
MATH 165	Linear Algebra	4		WRTG 105	Primary Writing	4		PHYS 121	Physics I	4
MATH 164	Multivariable Calc	4		MUSC 111	Music Theory I	4		AME 141	Fundamentals of Digital Audio	4
PHYS 121	Physics I	4		MUSC 109	Musicianship I	1		MUSC 113	Musicianship II	1
PHYS 122	Physics II	4								
AME 233	Musical Acoustics	4		**TOTAL**		**17**		**TOTAL**		**17**
ECE 270	Probability	4								
		32		**SOPHOMORE YEAR**						
Engineering				**FALL**				**SPRING**		
ECE 114	Intro to C/C++	4		MATH 165	Differential Equations and Lin Algebra	4		MATH 164	Multidimentional Calculus	4
ECE 113	Systems	4		PHYS 122	Physics II	4		AME 233	Musical Acoustics	4
ECE 240	Signals	4		AME 193	Sound Design (alt ECE 114 C/C++)	4		ECE 113	Circuits and Systems	4
AME 140	Intro to Audio and Music Engineering	4		WRTG 273	Professional Writing	2			Elective	4
AME 141	Fundamentals of Digital Audio	4		AME 192	Critical Listening for Audio Production	4				
AME 191	The Art and Technology of Recording	4								
AME 192	Critical Listening for Audio Production	4		**TOTAL**		**18**		**TOTAL**		**16**
AME 193	Sound Design	4								
AME 223	Audio Electronics	4		**JUNIOR YEAR**						
AME 262	Audio Software Design I	4		**FALL**				**SPRING**		
AME 264	Audio Software Design II	4		AME 223	Audio Electronics	4		AME 272	Audio Signal Processing	4
AME 272	Audio Signal Processing	4		ECE 240	Signals	4		AME 295	Audio Electronics Portfolio	2
AME 292	Acoustics Portfoio	2		**ECE 114**	**C/C++ Programming (alt: AME 193 sound design)**	**4**		AME 262	Audio Software Design I	4
AME 294	Audio DSP Portfolio	2		ECE 270	Probability for Engineers	4		AME 292	Acoustics Portfolio	2
AME 295	Audio Electronics Portfolio	2						MUSC 112	Music Theory II	4
AME 386	Senior Design Project I	2								
AME 387	Senior Design Project II	4		**TOTAL**		**16**		**TOTAL**		**16**
		60								
Writing Requirement				**SENIOR YEAR**						
WRTG 105	Primary Writing	4		**FALL**				**SPRING**		
WRTG 273	Professional Writing	2		AME 294	Audio DSP Portfolio	2		AME 387	Senior Design Project II	4
		6		AME 264	Audio Software Design II	4		Elective		4
Humanities and Social Sciences				AME 386	Senior Design Project I	2		Elective		4
	Music	10		Elective		4		Elective		2
	Cluster	12		Elective		4				
	H/SS Electives	up to 8*								
		20		**TOTAL**		**16**		**TOTAL**		**14**
Free Electives										
	Free Electives	**12**							**Total Credits**	**130**
Total Credits		**130**								

*** If pursuing a music cluster, some required music courses may count toward the 12 credit cluster requirement. In this case, additional electives in H /SS are needed to reach the 20 credit requirement**

BS AME CURRICULUM AND SAMPLE COURSE SCHEDULE

MATH 140 SERIES:

FRESHMAN YEAR						
FALL				**SPRING**		
MATH 141	Calculus I	4		MATH 142	Calculs II	4
AME 140	Intro to Audio Music Engineering	4		AME 191	Art & Tech of Recording	4
WRTG 105	Primary Writing	4		PHYS 113	General Physics I	4
MUSC 111	Music Theory I	4		AME 141	Fundamentals of Digital Audio	4
MUSC 109	Musicianship I	1		MUSC 113	Musicianship II	1
TOTAL		**17**		**TOTAL**		**17**
SUMMER						
MATH 143	Calculus III	4				
TOTAL		**4**				
SOPHOMORE YEAR						
FALL				**SPRING**		
MATH 165	Differential Equations and Lin Algebra	4		MATH 164	Multidimentional Calculus	4
PHYS 114 or 122	General Physics II	4		AME 233	Musical Acoustics	4
AME 193	Sound Design (alt ECE 114 C/C++)	4		ECE 113	Circuits and Systems	4
WRTG 273	Professional Writing	2			Elective	4
AME 192	Critical Listening for Audio Production	4				
TOTAL		**18**		**TOTAL**		**16**
JUNIOR YEAR						
FALL				**SPRING**		
AME 223	Audio Electronics	4		AME 272	Audio Signal Processing	4
ECE 240	Signals	4		AME 295	Audio Electronics Portfolio	2
ECE 114	C/C++ Programming (alt: AME 193 sound design)	4		AME 262	Audio Software Design I	4
ECE 270	Probability for Engineers	4		AME 292	Acoustics Portfolio	2
				MUSC 112	Music Theory II	4
TOTAL		**16**		**TOTAL**		**16**
SENIOR YEAR						
FALL				**SPRING**		
AME 294	Audio DSP Portfolio	2		AME 387	Senior Design Project II	4
AME 264	Audio Software Design II	4		Elective		4
AME 386	Senior Design Project I	2		Elective		4
Elective		4		Elective		2
TOTAL		**12**		**TOTAL**		**14**
					Total Credits	**130**

To meet graduation requirements, BS-AME majors must achieve a minimum cumulative grade-point average of 2.0 in the required AME courses. In addition, 130 total credits are required for graduation with an overall cumulative grade point average of 2.0. By placement exam of RC Music Department - students may need to substitute MUR101 or MUR110 for MUR111. **Notes – Students cannot take BOTH MUR 101 and MUR 110 for the music requirement.**

OTHER PROGRAM CONSIDERATIONS

TRANSFER CREDITS

If a student wishes to take a course at another institution to satisfy an AME degree requirement, **PRIOR APPROVAL** is strongly recommended. Proper supporting documentation about the course should be submitted to the AME Undergraduate Program Coordinator before taking any courses for transfer. An electronic approval from will need to be submitted with approvals from the instructor and the ECE department. Students are strongly advised to seek the guidance and feedback from their advisor before registering for a course at another institution. Completed forms will be forwarded to the Undergraduate Committee for action. Seeking approval after the fact may result in delays, and refusal to allow a student to take advanced courses for lack of prerequisites.

INTERNSHIPS AND PRACTICUM

AME majors are strongly encouraged to participate in internships with local or nationally based engineering firms for professional development. Only in a few cases can internship experiences be used for academic credit. Students who wish to obtain such credit for an internship must obtain prior approval from the ECE Undergraduate Committee.

The Engineering Practicum program, supervised jointly by the Hajim School of Engineering and Applied Sciences and the Gwen M. Greene Career and Internship Center, is a way to gain valuable work experience. A student in this program takes one semester and the preceding or following summer to work for a company. Academic credit is not granted, but the work experience and references obtained are valuable in students' career development. Usually graduation will be delayed by one semester but students with Advanced Placement credit or summer classes may still graduate in four years. Additional information, including example programs, is available from the Hajim School of Engineering and Applied Sciences office in Lattimore Hall, or from the Gwen M. Greene Career and Internship Center.

TRANSITIONING TO THE MSEE PROGRAM

AME Seniors contemplating earning their Master's degree may wish to consider the Master's program offered by the department. This program provides the advantage of a smooth transition between undergraduate and graduate study. Program enrollment is competitive and students are encouraged to apply for admission in their Senior year. Applicants may begin to take graduate level courses in their Senior year with the intent to transfer up to 10-credits of graduate level credits. These credits cannot be used toward the BS degree. (Transfer Credit Policy) Successful applicants will be granted a tuition scholarship for the Master's year of study. Conferral of the BS degree is required in order to matriculate into the Master's program. Please visit the Master's Program webpage for up-to-date information: http://www.hajim.rochester.edu/ece/graduate/ms.html

AME MINORS

The AME Minor consists of 18-20 credit hours of study in AME or closely related fields. Note that the AME Minor Tracks specified below that require only 18 credit hours each include a design/portfolio component. The other AME Minor Tracks require 20 credit hours of regular courses.

Students must choose one of the following AME Minor Tracks and corresponding course sequences:

Recording and Sound Design (20 Credits Total)
- AME 140: Introduction to Audio and Music Engineering
- AME 191: The Art and Technology of Recording
- AME 192: Critical Listening for Audio Production
- AME 193: Sound Design
- One additional track course ; AME 141 is recommended

Audio Signal Processing (18 Credits Total)
- AME 140: Introduction to Audio and Music Engineering
- AME 141: Fundamentals of Digital Audio
- ECE 240: Signals
- AME 272: Audio Signal Processing
- AME 294: Audio DSP Portfolio (2 credits)

Audio Electronics (18 Credits Total)
- AME 140: Introduction to Audio and Music Engineering
- AME 141: Fundamentals of Digital Audio
- ECE 113: Circuits and Signals
- AME 223: Audio Electronics
- AME 295: Audio Electronics Portfolio (2 credits)

Audio Computing and Software Design (20 Credits Total)
- AME 140: Introduction to Audio and Music Engineering
- AME 141: Fundamentals of Digital Audio
- ECE 114: Introduction to Computers and Programming (or CSC 171)
- AME 262: Audio Software Design
- AME 264: Audio Software Design II

Musical Acoustics (18 Credits Total)
- AME 140: Introduction to Audio and Music Engineering
- AME 191: The Art and Technology of Recording
- AME 233: Musical Acoustics
- AME 292: Acoustics Portfolio (2 credits)
- One additional track course

Acceptable MUR Classes: MUR 101, MUR 110, MUR 111, MUR 112, MUR 201, MUR 202, MUR 211, MUR 212, MUR 234, or equivalent courses offered at the Eastman School of Music.

If a student wishes to make course substitutions in any of the above tracks they should contact the AME Program Coordinator to seek approval prior to taking any alternative classes

COURSE DESCRIPTIONS

AME 140 Introduction to Audio and Music Engineering The course provides an introduction to the science and technology of audio. Students will learn about the vibration of strings, musical tuning systems, overtones and timbre, modes of oscillation through the concept of a guitar. Fourier analysis, transducers and passive electrical components and circuits will be introduced when discussing amps and audio components. The class will utilize hands on projects to introduce the fundamental concepts of electronics, including voltage, current, resistance and impedance, basic circuit analysis, ac circuits, impedance matching, and analog signals. The course then moves on to introduce basic digital signal processing concepts, where they will use Arduinos and Pure Data to learn about conversion of sound to digital format, frequency analysis, digital filtering and signal processing and musical sound synthesis. Lectures and weekly lab sessions. High School Algebra and Trigonometry AME140 is recommended as an introduction to the Audio and Music Engineering major but it is accessible to students of music or other non-technical disciplines who wish to learn the fundamentals of music technology and enjoy building projects. **F**

AME 141 Fundamentals of Digital Audio This course covers the fundamentals of manipulating and encoding sound in a digital format. Mathematical representations of digital signals are introduced and the effects of simple filters are analyzed in the context of audio. This course further provides students with an introduction to programming in Matlab through a series of assignments exploring sound synthesis algorithms and audio effects processing. **S**

AME 191 The Art and Technology of Recording This course covers the acoustical and psychoacoustic fundamentals of audio recording including the nature of sound, sound pressure level, frequency and pitch, hearing and sound perception, reflection, absorption and diffusion of sound, sound diffraction, room acoustics, reverberation, and studio design principles. The course also provides practical experience in audio recording including an introduction to recording studio equipment, microphones and microphone placement techniques, signal flow, amplification, analog and digital recording, analog to digital conversion, digital processing of sound, multi-track recording and an introduction to mixing and mastering. Each student is required to complete a substantive recording project at the end of the course. **INSTRUCTOR PERMISSION ONLY. F & S**

AME 192 Critical Listening for Audio Production This course is a continuation of AME 191. Emphasis is on the development of critical listening skills and proficiency in audio mixing and mastering. Fundamental topics covered include the human auditory system, theories of hearing and audio perception, perception of loudness and pitch, critical bands and auditory masking, beats and roughness, temporal and pitch acuity, binaural hearing. Listening skills development include hearing "width" and "depth" in audio, mixing techniques in various musical genres, recognition of various effects including reverb, delay, compression, phasing and distortion. Production skills development includes equalization and achieving spectral balance, the use of compression and dynamic range control, achieving depth and dimension in recordings, panning and auditory scene control. Students will complete an extensive mixing and mastering project at the end of the course. Prerequisite: AME 191 **INSTRUCTOR PERMISSION ONLY. F**

AME 193 Sound Design The course is intended to provide students a basic understanding of sound design, and working with sound for picture. The emphasis is on demonstrations and hands-on experience to enable students to gain a practical knowledge of sound and music production using computers. Topics include synthesizers & samplers; recording and editing with Pro Tools; sound effect creation; foley & automatic dialog replacement; basic soundtrack composition; and working to picture. Many techniques are explored employing software and hardware based sound creation tools throughout the course. Students will complete a major project at the conclusion of the course. **Only AME and MUR Majors. Instructor permission required**. **F/S**

AME 194 Audio for Visual Media This course is intended to provide students with a basic understanding of the process and the skills for creating music for picture. The course emphasizes hands-on experience where students gain practical skills in scoring to picture using computers and it features guest lectures by industry leading professionals, who will share their insights on creating music for TV Shows, Advertising, Movies, Gaming, Animation, and Industrial Work. Topics also include soft synthesizers, samplers and virtual instruments; recording and editing with Pro Tools and Logic; and sound design on audio workstations. Students will complete a number of projects throughout the course. Strong musical ability, basic piano keyboard proficiency, AME 193 or familiarity with either Pro Tools, Logic Pro or Ableton are highly recommended for this course. **INSTRUCTOR PERMISSION ONLY**. **F/S**

AME 196 Interactive Music Programming In this course, students will explore digital audio synthesis and real-time interactive technologies by studying two audio programming languages, ChucK and Pure Data. They will be able to manipulate sound with MIDI controllers, laptops, mobile devices, joysticks, mice, and Wiimotes. Students will have a midterm presentation to demonstrate their programs in ChucK and at the end of the semester, we will have an interactive performance showcase. This interdisciplinary course does not require any programming experience. All students, including music and technology majors, are welcomed to take this course. **S**

AME 197 Audio for Gaming The course is intended to provide students a basic understanding of audio for gaming. The emphasis is on demonstrations and hands-on experience to enable students to gain a practical knowledge of the integration of sound and music into video games using middleware. Students will primarily work with Wwise, Unity, Reaper, Pro Tools and Logic Pro X; Topics will include basic soundtrack composition for interactive; Advanced sound effect creation; foley; Dialog recording and editing; Working directly within a game environment; and audio for virtual reality. Supplementary software discussed will include FMod, Unreal, Fabric, Nuendo, and Elias. The course will also feature guest lectures by industry leading professionals, who will share their experience and insights. **Instructor permission required. F/S**

AME 223 Audio Electronics The devices, circuits, and techniques of audio electronics are covered in this course. Included is a survey of small signal amplifier designs and small-signal analysis and characterization, operational amplifiers and audio applications of opamps, large-signal design and analysis methods including an overview of linear and switching power amplifiers. ¬†The course also covers the design of vacuum tube circuits, nonlinearity and distortion. Other important audio devices are also covered including microphones, loudspeakers, analog to digital and digital to analog converters, and low-noise audio equipment design principles. Prerequisites: ECE 221 or Permission of Instructor. **S**

AME 227 PODCASTING HISTORY: HEAR UR This team-taught class will explore the life and works of the father of modern taxidermy, Carl Akeley, who trained in Rochester. Akeley rose to fame in the early 20th century as the designer of the taxidermy animals in New York's American Museum of Natural History. In lieu of writing a final research paper, students will team up to create a podcast series. Based in part on documents at the University's department of Rare Books, Special Collections, and Preservation. **S**

AME 233 Musical Acoustics Aspects of acoustics. Review of oscillators, vibratory motion, the acoustic wave equation, reflection, transmission and absorption of sound, radiation and diffraction of acoustic waves. Resonators, hearing and speech, architectural and environmental acoustics. , Prerequisites: Linear algebra and Differential Equations (MTH 165), Multivariable Calculus (MTH 164), and Physics (PHY 121) or equivalents. **S**

AME 240 Revolutions in Sound: Artistic and Technical Evolution of Sound Recording This course provides a multifaceted account of the evolution of sound technologies, starting with Edison,Äôs invention of the phonograph in 1877 through the development of microphones, radio, magnetic tape recording, vinyl records, multi-track recording, digital audio, compact discs, the MP3 format, surround sound, online music streaming, and 3D audio. We will discuss how technology has shaped the musical experience, and, conversely, how the performance of various genres of music, including classical, rock, jazz, hip-hop, and country, has influenced the development of audio technologies. We will also investigate, drawing from a variety of primary and secondary sources, how certain legendary recordings were produced, including those of Enrico Caruso, Bessie Smith, Les Paul, Louis Armstrong, Elvis Presley, The Beatles, Michael Jackson, and Madonna. A special topic focuses on spatial audio for virtual reality (VR) and augmented reality (AR), binaural recording, and ambisonics All students, including technology and music majors, are welcome. **F**

AME 262 Audio Software Design I In this course, students will develop skills for designing audio/music applications and creating computer music in C and Max. We will begin with the history of computer music, a survey of audio programming languages, and a review of C. Libsndfile, a C library for reading and writing sound files, will be used to explore topics in sound synthesis, analysis, and digital signal processing. Students will use PortAudio, a C library for realtime audio input/output, to design DSP applications. Max is a visual programming language for interactive audio/music and multimedia. Students are required to watch pre-recorded lectures to learn Max and attend recitations for reviews. They will also practice their programming techniques through a series of programming assignments, a midterm drum machine project in Max, and a final research/design project. Prerequisites: ECE 114 or instructor permission. **F**

AME 264 Audio Software Design 2 This course is a sequel to Audio Software Design I. Students will learn how to create audio applications and plug-ins with Faust and C++. Faust is a high-level functional programming language designed for real-time digital signal processing (DSP), sound synthesis, and sound analysis. The Faust compiler can translate the same source code into other programming languages and export to audio applications or plug-ins running on various platforms, including Windows, MacOS, and Linux, iOS, and Android. JUCE is a cross-platform C++ application framework used to design audio applications, audio plug-ins, animated applications, and OpenGL applications. Many professional audio applications and plug-ins have been built with JUCE, mainly used for its GUI, plug-in, and DSP libraries. At the end of the semester, we will have an Audio Software Show demonstrating the audio applications or plug-ins designed by the students. Prerequisites: AME 262 or ECE 475 or Instructor Permission. **S**

AME 272 Audio Signal Processing This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, digital filters, audio effects, music audio analysis and synthesis, and other advanced topics in audio signal processing. Implementation of algorithms using Matlab and on dedicated DSP platforms is emphasized. Prerequisites: ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses. **S**

AME 277 Computer Audition Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required. **F**

AME 292 Acoustics Portfolio This is a follow on course to AME233, Musical Acoustics. In this course students will complete a major project in acoustics, such as the acoustical characterization of an architectural space, design or re-design of an architectural or studio space, development of acoustical computer simulation tools, design or characterization of acoustic musical instruments, design and fabrication of loudspeakers, design and implementation of a live sound or sound reinforcement system, or any other project in acoustics with the agreement of the instructor. Weekly meetings and progress reports are required. Prerequisite: AME 233 **F**

AME 294 Audio DSP (Digital Signal Processing) Portfolio This is a follow on course to AME 272, Audio Digital Signal Processing. Students will complete a major design/build project in the area of audio digital signal processing in this course. Examples include a real-time audio effects processor, music synthesizer or sound analyzer or other projects of student interest. Weekly meetings and progress reports are required. ECE 241; strong MATLAB expertise, and C/C++ programming familiarity (ECE 210 recommended) The course is intended for junior/senior undergraduate level students in Audio and Music Engineering. Prerequisite: AME 272 **F**

AME 295 Audio Electronics Portfolio This is a follow on course to AME 223, Audio Electronics. In this course students will complete a major design/build project in the area of audio electronics. Examples include a solid state or tube-based instrument amplifier, audio power amplifier, audio effects processor, audio analog/digital interface or any other audio electronic project with the agreement of the instructor. Weekly meetings and progress reports are required. Prerequisite AME 223. **F**

AME 386 Senior Design Project 1 Senior Design Project in Audio and Music Engineering. In this first semester of the year-long AME Senior Project course students will define their product, possibly in collaboration with an outside customer, and then develop product concept documentation, detailed requirements specifications, system level designs, detailed sub-system designs and hopefully build demonstration prototypes. **F**

AME 387 Senior Design Project II Senior Design Project in Audio and Music Engineering. In the second semester of the year-long AME Senior Project course students will complete their projects including final system level designs, detailed sub-system designs, prototype building, testing, evaluation and final presentation to the customer. **S**

AME 433 Musical Acoustics Aspects of acoustics. Review of oscillators, vibratory motion, the acoustic wave equation, reflection, transmission and absorption of sound, radiation and diffraction of acoustic waves. Resonators, hearing and speech, architectural and environmental acoustics. Prerequisites: MTH 165, MTH 164 and PHY 121 or equivalent. **S**

AME 460 Digital Programs and Programing I The course is intended to provide students a basic understanding of sound design, and working with sound for picture. The emphasis is on demonstrations and hands-on experience to enable students to gain a practical knowledge of sound and music production using computers. Topics include MIDI; synthesizers & samplers; recording and editing with Pro Tools and Logic Pro X; sound effect creation; foley & automatic dialog replacement; basic soundtrack composition; and working to picture. Many techniques are explored employing software and hardware based sound creation tools throughout the course. Students will complete a major project at the conclusion of the course. **ESM students only. F/S**

AME 461 Digital Programs and Programming II The course emphasizes hands-on experience where students gain practical skills in scoring to picture using digital audio workstations. It features guest lectures by industry leading professionals, who will share their insights on creating music for TV Shows, Advertising, Movies, Gaming, Animation, and Industrial Work. Topics also include soft synthesizers, samplers and virtual instruments; recording and editing with Pro Tools and Logic; and sound design on audio workstations. Students will complete a number of projects throughout the course. **AME 460 - ESM students only. F & S**

AME 472 Audio Signal Processing This course is a survey of audio digital signal processing fundamentals and applications. Topics include sampling and quantization, analog to digital converters, time and frequency domains, spectral analysis, vocoding, analysis and synthesis of digital filters, audio effects processing, musical sound synthesis, and other advanced topics in audio signal processing. Implementation of algorithms on dedicated DSP platforms is emphasized. ECE 114 and basic Matlab programming, ECE 241 or other equivalent signals and systems courses. **S**

AME 473 Music and Sound for Gaming The course is intended to provide students a basic understanding of music and audio for gaming. With demonstrations and hands-on experience, students will gain a practical knowledge in the integration of sound and musical elements into a video game environment using middleware. Students will primarily work with Wwise, Unity, Reaper, Pro Tools and Logic Pro X; Topics will include basic soundtrack composition for interactive; Advanced sound effect creation; foley; Dialog recording and editing; Working directly within a game environment; and audio for virtual reality. **ESM students only Instructor permission required. F**

AME 477 Computer Audition Computer audition is the study of how to design a computational system that can analyze and process auditory scenes. Problems in this field include source separation (splitting audio mixtures into individual source tracks), pitch estimation (estimating the pitches played by each instrument), streaming (finding which sounds belong to a single event/source), source localization (finding where the sound comes from) and source identification (labeling a sound source). Prerequisites: ECE 246/446 or ECE 272/472 or other equivalent signal processing courses, and Matlab programming. Knowledge of machine learning techniques such as Markov models, support vector machines is also helpful, but not required. **F**

MUR 101 Elements of Music - A course for the student with no previous musical experience. Topics covered include notation, intervals, chords, and other basic concepts of tonal harmony, with application to the study of a wide range of styles including popular idioms. Students should not be able to read music. **(F/S)**

MUR 109 Musicianship I: Literacy Skills - Introduces students to basic musicianship skills. Begins with exercises in pitch matching and basic interval recognition and progresses toward other skills, such as singing simple melodies at sight, sight-reading various rhythmic patterns, and dictating simple melodies and chord progressions. Prospective music majors, especially those with prior singing experience, typically skip this course and begin with MUR 113. **F/S**

MUR 110 Introduction to Music Theory - Basic concepts addressing students with previous experience in an instrument or voice and little music theory. Scales, keys, intervals, chords, basic part-writing, and other fundamental aspects of musical structure. Some ear training and aural skills. **Prerequisites: Ability to read music, preferably in both treble and bass clefs. Students completing MUR 101 should NOT register for MUR 110. F**

MUR 111 Theory I - The first in a four-course sequence. Deals with basic elements of harmony, voice-leading, and analysis. Part-writing in chorale style teaches elementary aspects of tonal theory. Prospective music majors should begin their theory requirement with this course. **Prerequisites: MUR 101, 110 or permission of instructor (placement test) F**

MUR 112 Theory II - Continuation of MUR 111. This course continues with chorale and keyboard-style harmony exercises, but also introduces chromaticism, modulation, and analysis of form and phrase structure. **Prerequisite: MUR 111. S**

MUR 113 Musicianship II: This course develops basic musicianship skills with an emphasis of diatonic sight-singing, rhythmic sight-reading, and dictation of diatonic melodies and chord progressions. The exercises and in-class activities are similar to MUR 109 but at a more advanced level. **F/S**

ECE 113 Circuits and Signals: The principal focus of ECE113 is frequency domain representation of time signals, starting with phasors and ending with elements of Fourier series and Fourier transforms. Mathematics is introduced as needed for the specific material being covered, including: complex numbers, initial value problems, Laplace transform pairs, matrices, Fourier series, and Fourier transforms, including convolution. In addition, some effort is devoted to non-linear circuit analysis using loadlines. Workshop experience is an integral part of this course, students will be expected to attend a Workshop section (up to 2 hours each) almost every week of the semester. Days and times for these sections are arranged during the first week of classes, working with the Workshop Leaders and students. Prerequisites: ECE111, MTH165; concurrent with MTH164. **S**

ECE 114 Introduction to C/C++ Programming - This course provides an introduction to the C and C++ programming languages and the key techniques of software programming in general. Students will learn C/C++ syntax and semantics, program design, debugging, and software engineering fundamentals, including object-oriented programming. In addition, they will develop skills in problem solving with algorithms and data structures. Programming assignments will be used as the primary means of strengthening and evaluating these skills. **F/S**

ECE 240 Signals – Introduction to continuous and discrete time signal theory and analysis of linear time-invariant systems. Signal representations, systems and their properties, LTI systems, convolution, linear constant coefficient differential and difference equations. Fourier analysis, continuous and discrete-time Fourier series and transforms, properties, inter-relations, and duality. Filtering of continuous and discrete time signals. Sampling of continuous time signals, signal reconstruction, discrete time processing of continuous time signals. Laplace transforms. Laboratory. **F**

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