	day	weekday	time	room	type	topic	notes and details	GL	RN	LP, MDP, AF
2	16/09/2024	mon	08:30-10:30	2.1.1	L	**L01 Introduction to the course**	Course organization, classes, exams, material, program. Status of the MEMS and CMOS market. Key applications and course overview.	2		
4	18/09/2024	wed	14:30-16:00	7.0.1	L	**L02 Technologies for MEMS sensors**	Overview of a sample MEMS process. Main steps: epitaxial growth, DRIE, bonding, packaging.	2		
6	19/09/2024	thu	14:30-16:00	T02	L	**L03 The spring-mass-damper system**	Inertial and non-inertial references. Spring-mass-damper system in the time and frequency domains. Quality factor (underdamped and overdamped systems). Role of electrostatic forces in the system.	2		
8	20/09/2024	fri	08:30-10:30	9.0.3	L	**L04 MEMS accelerometers: part 1**	General architecture: capacitance variation vs displacement. Charge amplifier differential readout. Pull-in effects. Electrostatic softening and overall sensitivity. Linearity of a parallel-plate configuration.	2		
10	23/09/2024	mon	08:30-10:30	2.1.1	L	**L05 MEMS accelerometers: part 2**	Accelerometer bandwidth and choice of the quality factor. Thermomechanical noise in MEMS. Trade-offs vs applications. Comb finger readout.	2		
12	25/09/2024	wed	14:30-16:00	7.0.1	L	**L06 MEMS accelerometers: part 3**	Sample configurations of springs: in-plane translation, out-of-plane translation and rotation. Series and parallel of springs. Sample acceleroemters architectures. Effects of process nonuniformities on springs. Folded springs.	2		
14	26/09/2024	thu	14:30-16:00	T02	E	**E01 MEMS accelerometer design**	Design of an in-plane MEMS accelerometer to satisfy a specific application with a specific process.		2	
16	27/09/2024	fri	08:30-10:30	9.0.3	L	**L07 MEMS accelerometers: part 4**	The problems of scaling and pull-in. Charge control vs voltage control: effects of parasitics. Switched capacitor circuits. Force feedback.	2		
18	30/09/2024	mon	08:30-10:30	2.1.1	L	**L28 UN-related goals**	Autonomous driving and its impact on the society for cities of the future. Associated sensor needs. Sensors in biomedical applications. Sensors for sustainable infrastructures	2		
20	02/10/2024	wed	14:30-16:00	7.0.1	E	**E02 MEMS accelerometers electronic readout**	Circuits for MEMS accelerometers: description and exercise, noise limitations (MEMS and electronics), dynamics considerations.		2	
22	03/10/2024	thu	14:30-16:00	T02	E	**E03 Torsional MEMS accelerometer design**	Torionsal springs. Calculation of the srffness and of the moment of inertia for simple configurations. Numerical exercise.		2	
24	04/10/2024	fri	08:30-10:30	9.0.3	L	**L08 MEMS resonators: part 1**	Comb-finger actuation and sensing. Transduction coefficient and calculation of the admittance. Equivalent electrical model in the frequency domain.	2		
26	07/10/2024	mon	08:30-10:30	2.1.1	C	**E04 CAD simulation of MEMS capacitances**	Review of capacitive sensing configurations in MEMS. Ideal laws and deviations due to fringe effects. Case study for vertical parallel plates.			2
28	09/10/2024	wed	14:30-16:00	7.0.1	L	**L09 MEMS resonators: part 2**	Oscillator circuits: Barkhausen criteria. Sample TIA plus nonlinearity example. Issues of linearity. Example of resonant accelerometer.	2		
	10/10/2024	thu				**M.S. Graduation day**	No classes			
30	11/10/2024	fri	08:30-10:30	9.0.3	L	**E05 Resonator design**	Dimensioning of a Tang resonator to be used in a 32 kHz clock, with process spread and tunability.		2	
32	14/10/2024	mon	08:30-10:30	2.1.1	L	**L11 MEMS gyroscopes: part 1**	Generalities and the Coriolis force. Sample architecture. Resonant operation. Drive displacement. Sensitivity.	2		
34	16/10/2024	wed	14:30-16:00	7.0.1	E	**E06 Oscillator circuit**	Dimensioning of an oscillator based on a CA configuration. Comparative discussion with respect to the TIA case.		2	
36	17/10/2024	thu	14:30-16:00	T02	L	**L12 MEMS gyroscopes: part 2**	Issues from accelerations and advanced architectures. Single and double decoupling. In-plane and out-of-plane architectures. Tuning fork. Capacitive PP sense detection. Overall sensitivity.	2		
38	18/10/2024	fri	08:30-10:30	9.0.3	V	**L10 MEMS resonators: part 3**	Effects of the feedthrough capacitance on the electrical model of the resonator, and on the Gloop of the oscillator. Common resonator configurations.	2		
40	21/10/2024	mon	08:30-10:30	2.1.1	V	**L13 MEMS gyroscopes: part 3**	Gyroscope bandwidth. Sensitivity and gain-bandwidth trade-off. Electronics and thermomechanical noise.	2		
42	23/10/2024	wed	14:30-16:00	7.0.1	C	**E07 CAD simulation of MEMS accelerometers**	Introduction to CAD FEM simulations for MEMS. Examples on an accelerometer.			2
44	24/10/2024	thu	14:30-16:00	T02	C	**E08 CAD simulation of torsional accelerometers**	Autonomous design of an out-of-plane MEMS accelerometer with capacitive readout for consumer applications.			2
	25/10/2024	fri				**Backup slot**	No classes			
46	28/10/2024	mon	08:30-10:30	2.1.1	L	**L14 MEMS gyroscopes: part 4**	Issues in resonance operation (temperature dependence). Off-resonance operation. Gyroscope bandwidth. Sensitivity and gain-bandwidth trade-off.	2		
48	30/10/2024	wed	14:30-16:00	7.0.1	E	**E09 Gyroscopes electromechanical design**	Push pull actuation and sizing of relevant electromechanical parameters.		2	
50	31/10/2024	thu	14:30-16:00	T02	E	**E10 Drive circuits for gyroscopes**	Oscillators for gyroscopes. Relevance of AGC circuits and solutions. AGC stability.		2	
	01/11/2024	fri				**All saints holiday**	No classes			
52	04/11/2024	mon	08:30-10:30	2.1.1	L	**L15 MEMS gyroscopes: part 5**	Themormechanical noise in mode-split operation. Electronic noise in mode-split operation. Examples of real measurements.	2		
54	06/11/2024	wed	14:30-16:00	7.0.1	C	**E11 CAD simulation of MEMS yaw gyroscopes**	Design of a MEMS gyroscope. Parametric approach and finalisation of the geometry.			2
56	07/11/2024	thu	14:30-16:00	T02	C	**E12 CAD simulation of pitch MEMS gyroscopes**	Autonomous design of a MEMS gyroscope.			2
58	08/11/2024	fri	08:30-10:30	9.0.3	L	**L16 MEMS gyroscopes: part 6**	Quadrature error. Origin. Modelling. Coupling with phase noise. Quadrature error compensation. Tatar scheme.	2		
	11/11/2024	mon			F	**L17 MEMS magnetometers: part 1**	Lorentz force and resonant working principle. Simplified architecture. Sensitivity. Comparison with Coriolis and inertial forces. Noise, offset.	2		
	13/11/2024	wed			F	**L18 MEMS magnetometers: part 2**	Off-resonance operation and solutions of the trade offs. Design criteria. Integrated electronics. Comparison with other technologies (AMR, Hall).	2		
60	14/11/2024	thu	14:30-16:00	T02	E	**E13 Sense circuits for gyroscopes**	Sensing and demodulation electronics for capacitive gyroscopes. Noise considerations.		2	
	15/11/2024	fri			F	**L19 MEMS magnetometers: part 3**	Monolithic 3-axis architectures and basic knoledgwe of Q factor prediction	2		
62	18/11/2024	mon	08:30-10:30	2.1.1	L	**L20 MEMS characterization and the Allan Variance**	The next killer application: the IMUs. Stability issues. Offset drift and the Allan variance. Definition, relation with white noise, and use.	2		
64	20/11/2024	wed	14:30-16:00	7.0.1	E	**E14 MEMS microphone**	Exercise on a sensor not treated in the course, to stimulate the students approach towards other sensors developed in the same technology.		2	
66	21/11/2024	thu	14:30-16:00	T02	S	**Seminar from industry n. 1**	Job profiles in the MEMS industry: the system architect and case studies on digital processing for MEMS			
68	22/11/2024	fri	08:30-10:30	9.0.3	L	**L21 Light sensors basics: part 1**	Human vision. Description of the eye, photoreceptors, concept of a color space, stimuli to the brain. Basics of light sources.	2		
70	25/11/2024	mon	08:30-10:30	2.1.1	L	**L22 Light sensors basics: part 2**	CMOS image sensors. System architecture. Basics of optics and diffraction. Number of photons on a pixel.	2		
72	27/11/2024	wed	14:30-16:00	7.0.1	S	**Seminar from industry n. 2**	Job profiles in the MEMS industry: the MEMS designer and case studies on gyroscope and process design			
74	28/11/2024	thu	14:30-16:00	T02	L	**L23 CMOS 3T APS: part 1**	Interaction of light in semiconductors. Absorption law. Simple photodiode and typical dimensions. Signal generation and noise overview.	2		
76	29/11/2024	fri	08:30-10:30	9.0.3	C	**E15 CAD light absorption in Silicon**	Preliminaty CAD to imaging sensors			2
78	02/12/2024	mon	08:30-10:30	2.1.1	L	**L24 CMOS APS: part 2**	3-transistor APS topology. Transistor-level architecture. Operation. Phases. Linearity. Signal to Noise ratio.	2		
80	04/12/2024	wed	14:30-16:00	7.0.1	E	**E16 photons on a pixel**	Calculation of the number of photons generated per second on a pixel of a mobile phone camera from a generic scene.		2	
82	05/12/2024	thu	14:30-16:00	T02	S	**Seminar from industry n. 3**	Job profiles in the MEMS industry: the test and qualification engineer and case studies on MEMS testing			
84	06/12/2024	fri	08:30-10:30	9.0.3	L	**L25 CMOS APS: part 3**	Dynamic range of a 3T image sensor. Other limitations: fixed pattern noise. Photon transfer curve.	2		
86	09/12/2024	mon	08:30-10:30	2.1.1	L	**L26 CMOS APS: part 4**	Limits of a 3T topology and introduction of 4T topologies. Correlated Double Sampling. Backside illumination and advantages.	2		
88	12/12/2024	thu	14:30-16:00	T02	E	**E17 SNR in a 3T topology**	Calculating the Signal to Noise Ratio for a 3T CMOS pixel topology. Numerical examples.		2	
90	13/12/2024	fri	08:30-10:30	9.0.3	E	**E18 DR and maximum SNR in 3T APS**	Maximum SNR and dynamic range of a 3T CMOS pixel. Choice of the ADC number of bit.		2	
92	16/12/2024	mon	08:30-10:30	2.1.1	E	**E19 photon transfer curve**	Example of a circuit for correlated double sampling in CMOS APS 4T topologies with calculation of DR. PTC and its analysis.		2	
94	18/12/2024	wed	14:30-16:00	7.0.1	L	**L27 CMOS APS: part 5 + Q&A n. 4**	CFA for CMOS image sensors. Demosaicking. Layered junction sensors (working principle). General pros and cons of the two approaches. Color conversion and color spaces. White balance.	2		
96	19/12/2024	thu	14:30-16:00	T02	C	**E20 CAD simulations of advanced imaging pixels**	Autonomous design of a Pinned photodiode			2
99	20/12/2024	fri	8.30-11.30	Alpha, Beta, 9.0.3	EXM	**Anticipated exam session**		3		
								59	26	14