Multi-Purpose Auditorium
Sound Reinforcement System Design
ECE 40020 – Spring 2013

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Outline

• Primary System Design Constraints
• Venue Illustration
• System Design Constraints
• Loudspeaker Selection, Placement, and Rigging
• EASE Simulation Results
• Power Amplifier Requirements and Selection
• Signal Processing Requirements and Selection
• Mixing Console Requirements and Selection
• Microphone Requirements and Selection
• Signal Path Wiring Diagram
• Rack Requirements and Design
• Cabling and Wiring Requirements
• System Component List and Street Price Estimate
• Summary and Recommendations
Primary System Design Constraints

- generic fan-shaped high school auditorium with seating for 3000 (approx. 2200 main floor, 800 balcony)
- minimum **SPL of 105 dB** at back row of seating
- no more than ±5 dB variation in SPL over the entire seating space for the 1 KHz, 2 KHz, 4 KHz, and 8 KHz frequency bands
- frequency response of 40 – 16,000 Hz ± 5 dB
- %ALCONS no greater than 10% over entire seating space
- minimum 48-channel mixing console
- minimum of 4 separate monitor mixes (and corresponding monitor loudspeaker systems)
- support for 20 compatible wireless microphone channels
- good assortment of general-purpose wired and wireless microphone systems
- digital media recording/playback capability
- all equipment mounted in rack cabinet(s)
- budget of $500,000
Venue Design

• Four seating areas per level with isles between
• Seating total: 3050 seats
  • Area per seat: 0.49 meters squared
  • Main level: 2100 seats
  • Balcony level: 950 seats
• Sound Reinforcement
  • Side walls: carpeting - reduce mid/high frequency reflections
  • Back wall: curtains – acoustic dampening/style
  • Ceiling: acoustic drop ceiling – acoustic dampening
Venue Design

- Performance space designed at ground level
  - Option to elevate based on performance demands
- Ethernet and Neutrik Powercon built into theater
  - Simplifies speaker connections and routings
- Sound booth located at center under balcony, recessed down
- Electrical requirements
  - 3-phase, 208V 200A service installed to stage
Venue Illustration
System Design Constraints

- Reliable, safe, easy to implement/troubleshoot and economic
- Digital Audio Networking
  - Setup and system monitoring through PC interface
    - Long distance signal propagation is digital
      - Ethernet and AES/EBU
      - Mixing console and IO connected via Ethernet
  - All Speakers Active with built-in DSP
  - Auto-sensing of array configuration
  - Built in Cardioid Presets for Subwoofers
- All Channels and mixing can be wirelessly adjusted via iPad
Reliability and No Down Time

- Remote monitoring w/ error reporting via PC interface
  - Soft-limiting protection
    - Excursion
    - RMS output
    - Voice coil temperature
- Power Conditioning with PF correction with sequencer to prevent in-rush current
- Extra Speakers spares on hand
  - 2- Array Elements
  - 1- Subwoofer
Safety

- Array has built in rigging hardware integrated into enclosure
- JBL SAFE – Secure Array Flying Ergonomics
  - Quick-Release Pins
    - Won’t load if the pin isn’t fully inserted
  - Heat Treated chromoly, cadmium plated pin
- Angle Stop Mechanism
Aesthetics and Accommodation

- Large Multipurpose Venue
- Line of sight interference
  - Sound Booth recessed into the floor in middle under balcony
  - Speakers suspended 18 meters above ground and 24m apart
- Center aisle wide enough for wheelchairs accessibility, front row and under balcony parking
- Univox DLS-50 Induction Loop for Hearing Impaired
Loudspeaker Selection, Placement, and Rigging

- **Loudspeaker Criteria:**
  - J-Arrayable
  - Integrated amplifier
  - DSP
  - 80Hz – 16kHz min.

- **Placement**
  - Pair of arrays, front, mid-height
  - Pair high in front of balcony
  - Splayed out slightly
    - Minimize overlap
  - Can reach far under balcony without fills
Loudspeaker Selection, Placement, and Rigging

- **Final Selection**
  - JBL Vertec 4888DP-DA
    - High SPL
    - Easy to fly
    - Adjustable splay- SAFE
    - DSP Controlled
    - Ethernet, AES w/ daisy chain capability

- **Other Products considered:**
  - Renkus-Heinz IC squared
    - SPL too low
    - Too complex to EASE model
    - Straight line array only
  - Renkus-Heinz STX9/94
    - Low power
    - Not arrayable
EASE Simulation Results

1 kHz SPL

2 kHz SPL
EASE Simulation Results

4 kHz SPL

8 kHz SPL
EASE Simulation Results

THEATRE TYP
Used:
A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17

Warning: Rough Approximation Only
Energy: 3.969
103 (dB re 1 W)

%ALCONS
Power Amplifier Requirements and Selection

- **Required SPL at 1 meter = 105dB + 20*log(60m)= 140.5dB**
  - JBL Vertec 4888DP-DA – 140dB at 1 meter
  - 3000 watts RMS Class-I amplifier
  - Individual element nearly capable, arrayed for full coverage
  - Simulation results
    - 109db minimum +3dB peak = 112dB = 7dB headroom

- **Integrated amplifiers**
  - Increased damping
  - Fully digital signal path
  - DSP on a per-speaker basis
  - Speaker diagnostics onboard

- **Considered passive subwoofers and VERTEC arrays**
  - Amplifiers more expensive, significantly more difficult to setup
Low Frequency Extension

- RCF TTS56-A subwoofers
  - 145dB
  - Cardioid array presets
  - 6800 watts RMS
  - Digital inputs
  - 32bit DSP
  - Dual 21” drivers
Signal Processing Requirements and Selection

- All speakers feature internal digital signal processing capabilities
  - Allow for essential calibrations (e.g. equalization, delay, etc.)
  - Accessed by PC utilizing HiQnet technology
- External signal processing for extra/group control
  - Post mix effects (digital reverb)
  - Group equalization
Signal Processing Options

- Products considered:
  - PreSonus Studio Live
    - Pros:
      - combined mixing / signal processing
      - “small” footprint
    - Cons:
      - only two signal processors
      - maximum 24 channels per single console
      - cost
Signal Processing Options

- Products considered:
  - Eventide H8000FW
    - Pros:
      - superb user customizable algorithms
      - i/o quality of 24 bits at 96kHz
    - Cons:
      - cost
      - overkill
Signal Processing Options

- Product selected:
  - DBX DriveRack PA+
    - Pros:
      - user customizable algorithms
      - automated feedback elimination
      - cost
    - Cons:
      - small edit menu
Mixing Console Requirements and Selection

- TASCAM DM-4800
  - 48 Channels
  - 16 Returns
- 24 Analog Inputs
- 4 Add-on slots
- 2 Effects Processors
- Can cascade two more
- Only 2 AES/EBU connections
- Found at a very discounted price
Mixing Console Requirements and Selection

• Yamaha CL5
  – 72 Mono
  – 8 Stereo
• Rio3224-D for I/O
  – 32 Analog Inputs
  – 16 Analog Outputs
  – 4 AES/EBU
• 3 Add-on slots
• Built in Wireless-N
• iPad mount
• Ethernet port
Microphone Requirements and Selection

- Shure KSM9/KSM9HS
  - Cardioid/Supercardioid
  - Hypercardioid/Subcardioid
  - Condenser
  - 50Hz-20kHz response
  - High gain before feedback
  - Mylar diaphragm
  - Transformerless preamp
  - Gold layered connections
Microphone Requirements and Selection

- Heil HDK-8
  - 8 piece drum kit
  - Dynamic microphones
  - Kick mic has 10dB boost “where it is needed”
  - Can mic snare on top and bottom
  - Tolerate up to 148dB-SPL
  - Tight cardioid patterns
Microphone Requirements and Selection

• Shure BETA 54
  – Supercardioid
  – Condenser
  – 50Hz-20kHz response
  – Handles high SPL
  – High gain before feedback
  – Extra protection against RF and cellular interference
Microphone Requirements and Selection

- Shure WA-304 cable
  - Convert to Wireless Guitar System
- WB98H/C
  - Instrument Microphone
  - Swivel joint allows for flexibility in placement
  - Transformer-less preamp
  - Can handle SPL of brass, woodwind and percussion
Monitoring

- JBL PRX612M and PRX618 Subwoofer on each side of the stage
- Shure P2TR215CL Wireless Monitors
- Beyerdynamic DT-770 for console monitoring
- Recording via HiQnet on PC and Protools
Rack Requirements and Design

- **26U required**
  - Rack needs locking doors
  - Should be well ventilated

- **Power Sequencing**
  - 4x Fuhrman 3-phase 120A power sequencers
  - 18 stages, 1 second per stage
  - First 2 are accessories
  - The rest are speakers/amplifiers, 2 at a time

- **Power Conditioning**
  - Supplied for non-amplifier equipment
  - Amplifiers are SMPS, 90-135VAC, active PFC
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Rack Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD-120 Sequenced power distribution, 120A</td>
<td>-2U</td>
</tr>
<tr>
<td>Furman PL-Plus C</td>
<td>-1U</td>
</tr>
<tr>
<td>Sony PS3 for CD playback w/ Rack Mount</td>
<td>-2U</td>
</tr>
<tr>
<td>Yamaha Rio3224-D 32 mic/line 16 analog outputs</td>
<td>-5U</td>
</tr>
<tr>
<td>D-Link DGS 1016D Switch - 16 ports</td>
<td>-1U</td>
</tr>
<tr>
<td>DBX PA+ Signal Processor ($500)</td>
<td>-1U</td>
</tr>
<tr>
<td>Shure UA844 Antenna Distribution System</td>
<td>-1U</td>
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<tr>
<td>($500) – 1U</td>
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<tr>
<td>Shure ULXD4Q Quad Wireless Mic Reciever ($5000)</td>
<td>-1U</td>
</tr>
<tr>
<td>($5000) – 1U</td>
<td></td>
</tr>
</tbody>
</table>
Digital Network Control – Audio Architect
Digital Everything, Everywhere

- Yamaha CL5
  - Cobranet and Dante support through add-on cards
  - Connected via Ethernet to RIO3224-D
    - 16 Analog Outputs
    - 32 Analog Inputs
    - 4 AES/EBU Digital I/Os
  - All Speakers are plug and play with auto detection
Digital Lovin’

- JBL Vertec
  - JBL HiQnet through DPDA 24bit/96kHz
  - Ethernet and AES/EBU input with
  - Daisy chain capability
- RCF TTS56-A
  - Cobranet and Dante support through Ethernet
  - 32 bit/96kHz DSP with FIR/IIR filters
Signal Flow

• Digital Audio Networking
  • Mixer <-> Ethernet <-> Yamaha RIO
• Analog Inputs (32)
  • Microphones, wired and wireless, and other
• Analog Outputs (16)
  • DBX DSP units -> Stage monitors
  • In-ear Monitors
• Digital Output (4)
  • Connected to top element of each Array
  • Daisy Chainable
Cable Requirements — $10,000 Budget

- Delayed Mains
  - 4–250ft Neutrik Powercon
    - 1 per pair
  - 2–250ft XLR
    - 1 per array
- Front Mains
  - 6–150ft Neutrik Powercon
  - 2-150ft XLR

- Subwoofers
  - 9–150ft Neutrik Powercon
    - Building Ethernet
  - Wired Microphones, Other
    - 30- 50ft XLR
    - 10- 10ft XLR
    - 20- 5ft XLR
    - 20- 3ft XLR
## System Component List and Street Price Cost Estimate

<table>
<thead>
<tr>
<th>Rack Equipment</th>
<th>Price</th>
<th>Quantity</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Tripp Lite 42U Rack</td>
<td>$2,000</td>
<td>1</td>
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<tr>
<td>4x ASD-120 AC SEQUENCED POWER DISTRIBUTION, 120 AMP</td>
<td>$700</td>
<td>4</td>
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<tr>
<td>Furman PL-Plus C</td>
<td>$230</td>
<td>2</td>
<td>$460</td>
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<tr>
<td>Sony PS3 for CD playback w/ Rack Mount</td>
<td>$400</td>
<td>1</td>
<td>$400</td>
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<tr>
<td>Yamaha Rio3224-D 32 mic/line 16 analog outputs - 5U</td>
<td>$8,500</td>
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<tr>
<td>D-Link DGS 1016D Switch - 16 ports</td>
<td>$146</td>
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<tr>
<td>2x DBX PA+ Signal Processor ($500)</td>
<td>$500</td>
<td>2</td>
<td>$1,000</td>
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<tr>
<td>Shure UA844 Antenna Distribution System ($500)</td>
<td>$500</td>
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<td>$500</td>
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<tr>
<td>Shure ULXD4Q Quad Wireless Mic Receiver ($5000)</td>
<td>$5,000</td>
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<td>$25,000</td>
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## Mixing and Distribution

<table>
<thead>
<tr>
<th>Mixing and Distribution</th>
<th>Price</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamaha CL5</td>
<td>$25,000</td>
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<td>$25,000</td>
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<tr>
<td>iPad with 4G</td>
<td>$700</td>
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<td>$700</td>
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<tr>
<td>JBL VT4888DPDA x22</td>
<td>$8,500</td>
<td>22</td>
<td>$187,000</td>
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<tr>
<td>RCF TTS 56-A new sub x10 (3x cardioid arrays on the floor)</td>
<td>$7,000</td>
<td>10</td>
<td>$70,000</td>
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<tr>
<td>SHURE D2/KSM9-J50 Handheld Wireless Microphone and Transmitter QTY:8</td>
<td>$1,050</td>
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<td>$8,400</td>
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<td>ULXD1 QTY:12</td>
<td>$445</td>
<td>12</td>
<td>$5,340</td>
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<tr>
<td>Shure BETA 54 Headworn Vocal Microphone QTY: 12</td>
<td>$350</td>
<td>12</td>
<td>$4,200</td>
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<tr>
<td>HEIL SOUND HDK-8 Drum Microphone Kit</td>
<td>$1,652</td>
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<td>$3,304</td>
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<tr>
<td>Optical to AES converter for PS3 - Hosa ODL312</td>
<td>$150</td>
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<tr>
<td>Cables</td>
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<tr>
<td>Dell XPS 15 Laptop</td>
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# System Component List and Street Price Cost Estimate

<table>
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<tr>
<th>Monitor Equipment</th>
<th>QTY</th>
<th>Price</th>
<th>Total</th>
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<tr>
<td>Shure P2TR215CL System QTY:2</td>
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<tr>
<td>Shure SE215 In Ear Monitors QTY:4</td>
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<tr>
<td>Beyerdynamic AMS-DT-770-M-80 QTY:4</td>
<td>4</td>
<td>$200</td>
<td>$800</td>
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<tr>
<td>JBL PRX612M PA Speakers (stage monitors) (qty 4)</td>
<td>4</td>
<td>$700</td>
<td>$2,800</td>
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<tr>
<td>JBL PRX618S-XLF High Performance 18&quot; Subwoofer QTY:2</td>
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<td>$1,150</td>
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<tr>
<td>Univox SLS-100 XF</td>
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<tr>
<td>Univox DLS-50</td>
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<td>$45</td>
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<td>Protocols Recording</td>
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<th>Installation and Extra</th>
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<tr>
<td>Ethernet Networking</td>
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<td>Neutrik Powercon Plugs</td>
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<td>3 Phase 208V 200A Service installation</td>
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<td>Rigging for Array</td>
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<td>Cables</td>
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<td>Acoustic Treatments</td>
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<td>Popcorn Machine</td>
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<td><strong>GRAND TOTAL</strong></td>
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<td>$465,175</td>
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Summary and Recommendations

- Summary of work completed
- Results obtained from design and simulation
- How extra funds would be utilized if available
Questions / Discussion