



USE CASE



PROJECT OBJECTIVE

- GENERATE VISIBLE PLASMA ARCS CORRESPONDING TO REAL-TIME MUSICAL INPUT
- CONVERT HIGH-FREQUENCY ELECTRICAL RESONANCE INTO AUDIBLE SOUND THROUGH PLASMA MODULATION
- SERVE AS A DEMONSTRATIVE PLATFORM FOR ADVANCED ELECTRICAL ENGINEERING PRINCIPLES

EDUCATIONAL AND DEMONSTRATION VALUE

- VISUALIZES ELECTROMAGNETIC RESONANCE AND ENERGY TRANSFER
- DEMONSTRATES REAL-TIME CONTROL OF HIGH-POWER ELECTRONICS
- PROVIDES INTUITIVE UNDERSTANDING OF FREQUENCY, MODULATION, AND FEEDBACK SYSTEMS



ECE AREAS INVOLVED

- ELECTRONIC DEVICES AND ANALOG CIRCUITS
- SIGNALS AND SYSTEMS



USE CASE REQUIREMENTS (PERFORMANCE METRICS)



REQUIREMENTS

20HZ - 15KHZ AUDIBLE FREQUENCY RANGE

≥ 0.75 INCH ARC LENGTH

< 20 MS MAX INPUT-TO-OUTPUT LATENCY

≥ 10 MINUTES CONTINUOUS OPERATION TIME

DISTINGUISHABLE OUTPUT TONES



CLASS-E SWITCHING BEHAVIOR WITH ZVS

STABLE ARCS AND UNDISTORTED SOUND

CONTROL CIRCUITRY UNAFFECTED BY
ELECTROMAGNETIC AND RF INTERFERENCE

NO ARCS REACH BEYOND BREAKOUT REGION

COMPONENT LIMITS NEVER VIOLATED

MUST BE SUITABLY SIZED FOR TABLETOP
OPERATION



DESIGN REQUIREMENTS AND SOLUTION APPROACH



USE CASE REQUIREMENTS

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≥ 0.75 INCH ARC LENGTH

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< 20 MS MAX INPUT-TO-OUTPUT LATENCY

DESIGN REQUIREMENTS

MUST UTILIZE A CONSTANT SUPERSONIC
(> 20 KHZ) CARRIER FREQUENCY FOR
AMPLITUDE MODULATION

VOLTAGE SUPPLIED TO PRIMARY COIL MUST
BE HIGH ENOUGH (> 12 V) TO DRIVE
SUFFICIENTLY LONG ARCS BUT LOW ENOUGH
(< 120 V) TO KEEP ARCS CONTAINED

MAKE USE ONLY OF ANALOG COMPONENTS, AS
DIGITAL CONVERSION ADDS LARGE LATENCY



DESIGN REQUIREMENTS AND SOLUTION APPROACH



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$\geq$ 10 MINUTES CONTINUOUS OPERATION TIME

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CLASS-E SWITCHING BEHAVIOR WITH ZVS

MUST BE SUITABLY SIZED FOR TABLETOP
OPERATION

DESIGN REQUIREMENTS

LOW INTERRUPTER DUTY CYCLE ($<40\%$) TO
REDUCE HEAT GENERATION. SHUNT TVS
DIODES OF 18V ON CONTROL SIDE AND 400V
ON PRIMARY SIDE. HIGH VOLTAGE
COMPONENTS SUCH AS 1000V MOSFET AND
CAPACITORS. CONTROL CIRCUITRY IN
SHIELDED CONTAINER.

USE PRIMARY COIL AS A CHOKE INDUCTOR,
WITH SINK CAPACITOR ACTING AS MOSFET
SHUNT. LOW COUPLING FACTOR

SIZED LESS THAN 3FT*3FT*3FT
TAKES 120VAC 60HZ INPUT POWER



BROADER SOLUTION APPROACH



A SMALL SSTC

- A SMALL TESLA COIL POWERED AT RELATIVELY LOW VOLTAGE PRODUCES RELATIVELY MANAGEABLE ARCS. THUS DANGER IS MINIMIZED.
- SOLID STATE TESLA COILS ARE SIMPLER, EASIER TO POWER, AND EASIER TO ENSURE RELIABILITY OF
- SINGLE COIL MAKES CLASS-E OPERATION MUCH MORE ATTAINABLE AS OPPOSED TO DUAL RESONANT COILS, WHICH WOULD REQUIRE A SECOND CIRCUIT TO GUARANTEE CLASS-E OPERATION OF

PRE ASSEMBLED POWER SUPPLIES

- ENSURES OPERABILITY IN ANY LOCATION NEAR ENOUGH TO A WALL OUTLET
 - PREASSEMBLED SUPPLIES ARE SAFER (FOR US TO USE THAN DEVELOPING 120VAC TRANSFORMERS), PROVIDE VERIFIED, RELIABLE POWER WITH OVERCURRENT PROTECTION, AND ARE CHEAPER CONSIDERING THE NEED FOR SEPARATE POWER FOR CONTROL AND COIL CIRCUITRY
 - 12VDC AND 5VDC SUPPLIED BY AN ATX POWER SUPPLY FOR CONTROL, 48VDC SUPPLIED BY AN LED POWER SUPPLY
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SCHMITT TRIGGER OSCILLATOR AM

- USE A 555 TIMER OPERATING AT SUPERSONIC FREQUENCY TO CREATE AMPLITUDE MODULATED BURST ENABLE SIGNAL FROM AUDIO INPUT
- USE TIMER OUTPUT AS AN ENABLE FOR SCHMITT TRIGGER OSCILLATOR TUNED TO COIL RESONANT FREQUENCIES, WHICH DRIVES MOSFET GATE
- PLASMA ARCS WILL ENGAGE/DISENGAGE FOLLOWING THE ENVELOPE CREATED IN THE ENABLE SIGNAL

INSULATED BOX FOR CONTROL CIRCUITRY, POSSIBLE ACTIVE COOLING

HIGH VOLTAGE CIRCUIT COMPONENTS TO ENSURE RELIABILITY, MOST COMPONENTS RATED FOR $\geq 1000V$

SYSTEM SPECIFICATION/BLOCK DIAGRAM

8 MAJOR COMPONENTS

ATX POWER SUPPLY TO SUPPLY 12V AND 5V
TO CONTROL CIRCUITS

48V LED POWER SUPPLY TO POWER
PRIMARY COIL

INTERRUPTER

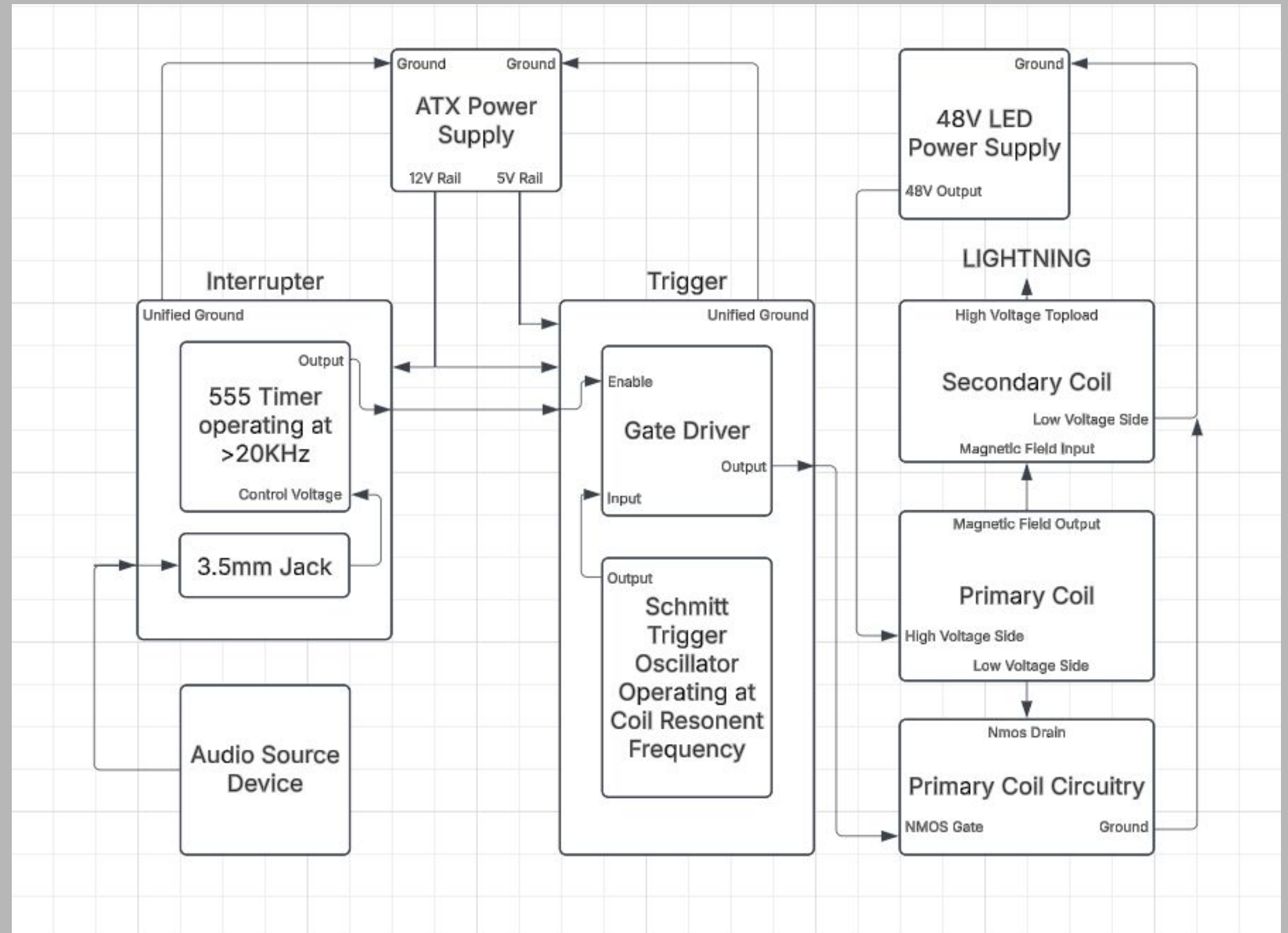
TRIGGER

PRIMARY COIL CONTROL CIRCUIT

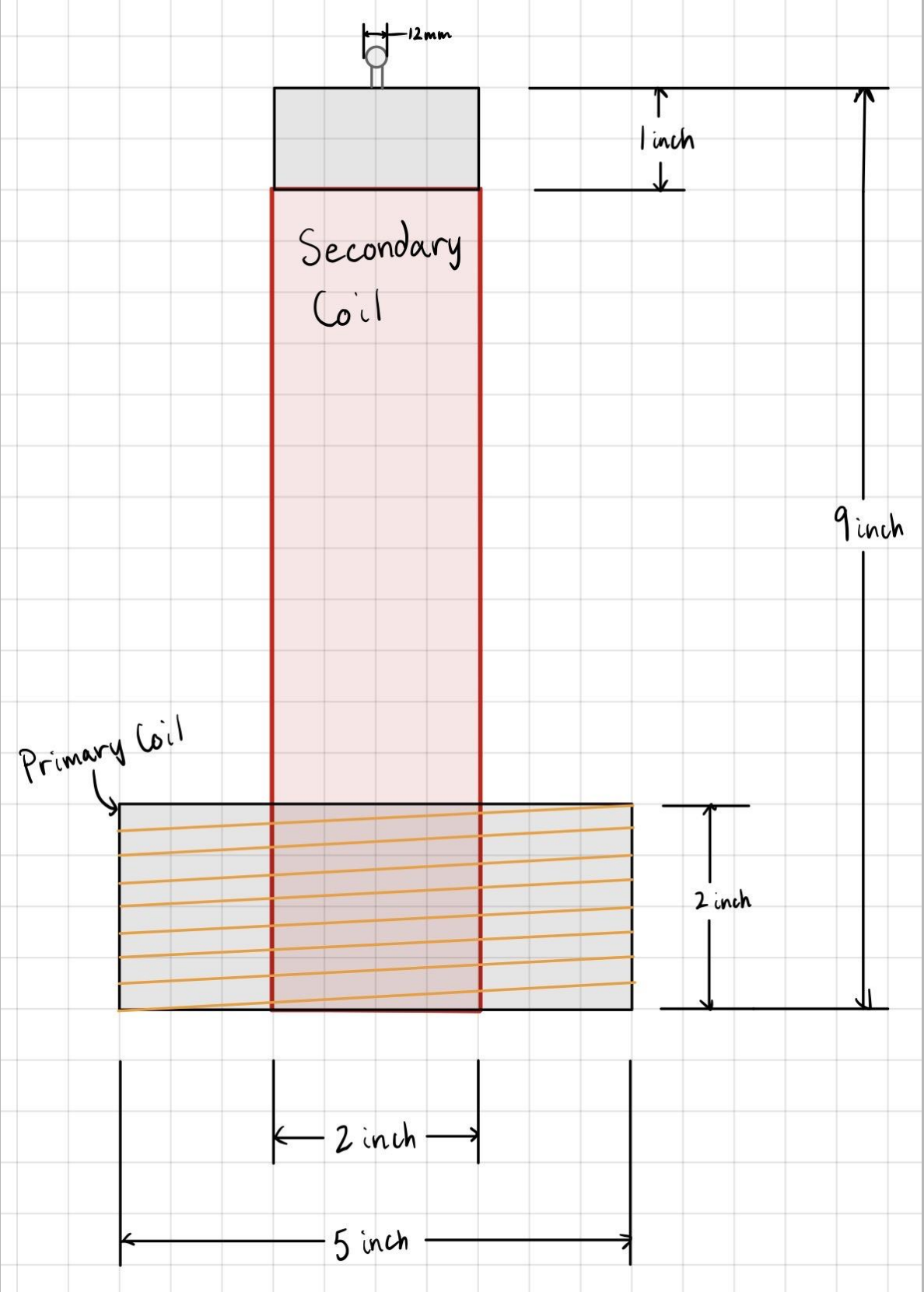
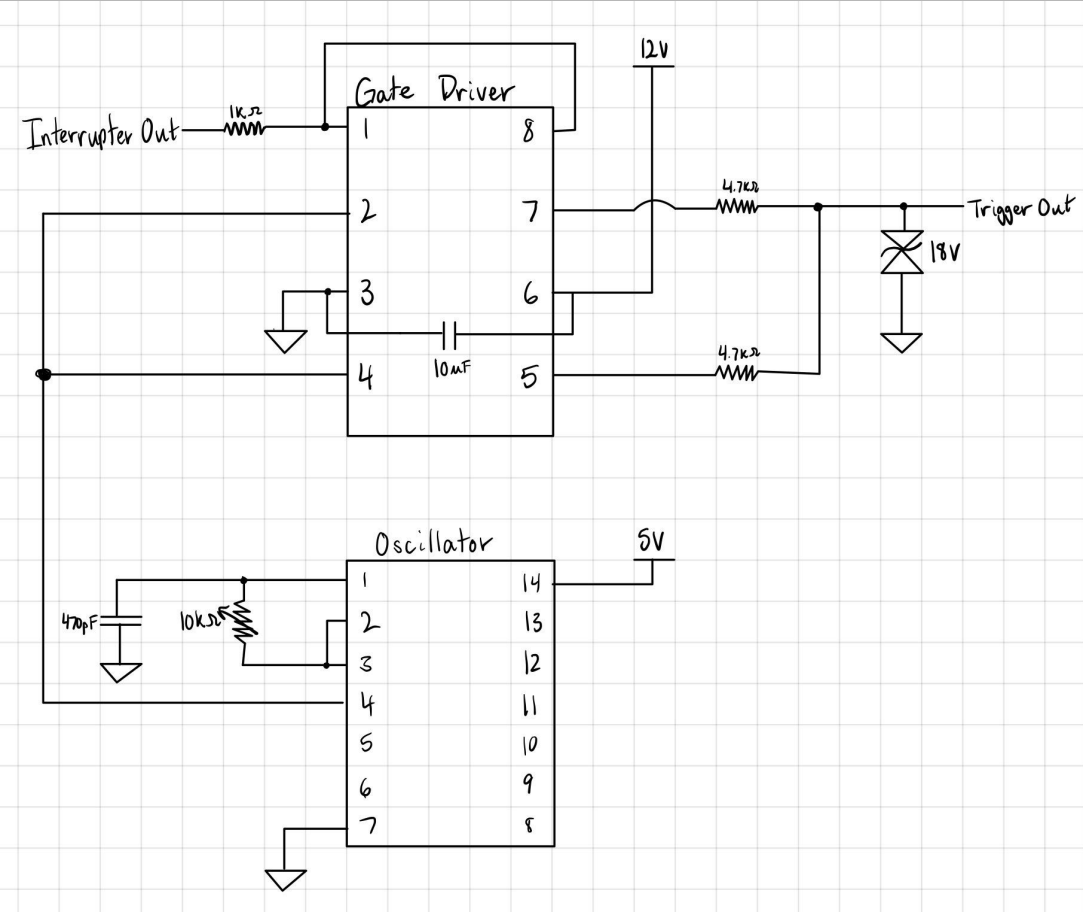
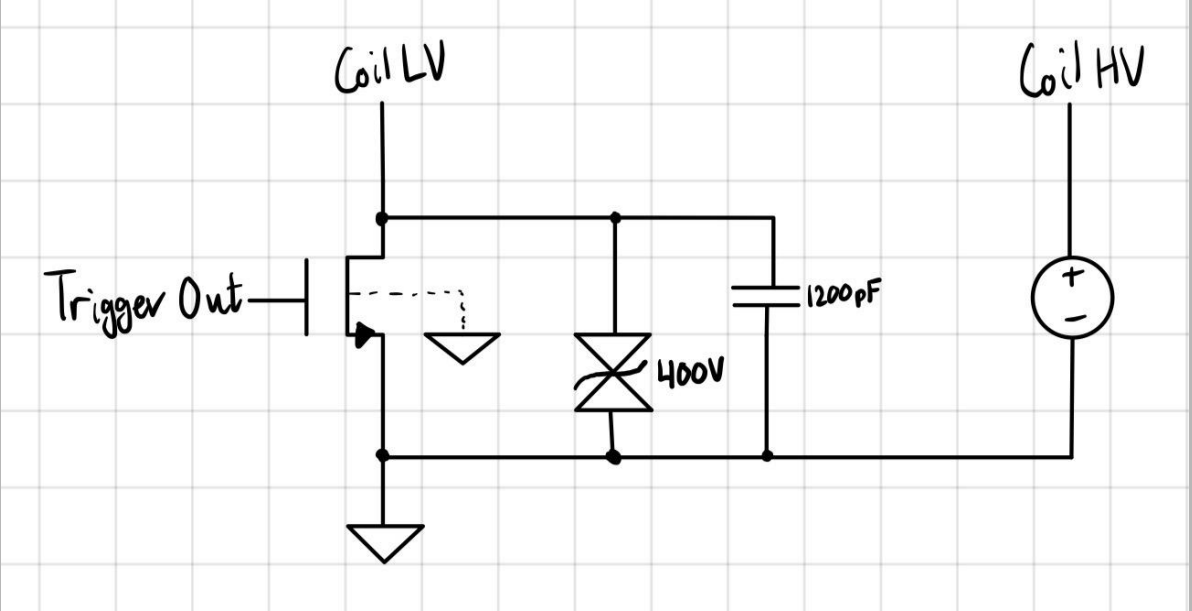
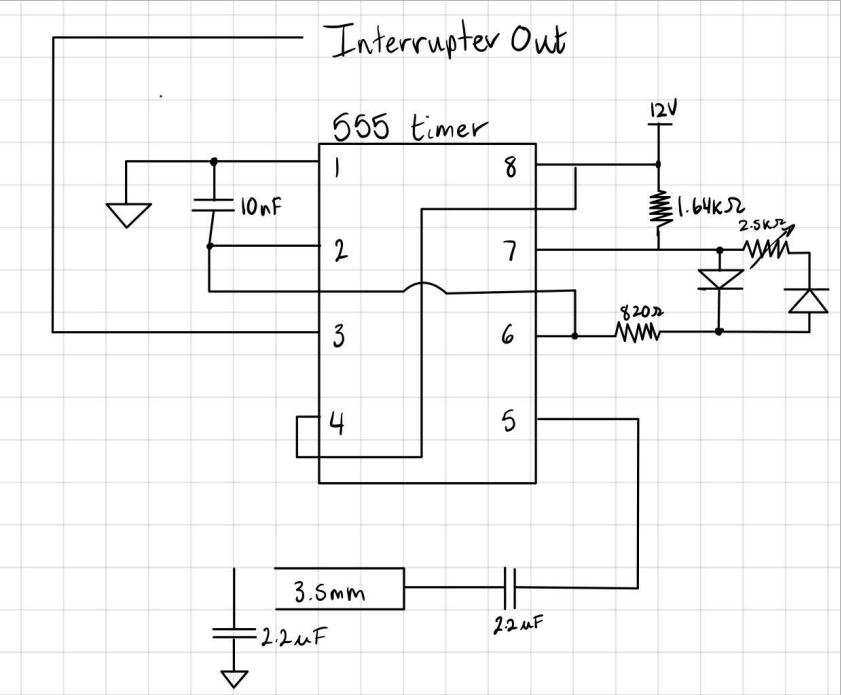
PRIMARY COIL

SECONDARY COIL

AUDIO PLAYBACK DEVICE



SYSTEM SPECIFICATION/BLOCK DIAGRAM





IMPLEMENTATION PLAN

THINGS TO BUY	THINGS TO ASSEMBLE	THINGS THAT HAVE BEEN DESIGNED	THINGS TO DESIGN
ATX POWER SUPPLY	INTERRUPTER	INTERRUPTER CIRCUIT	CIRCUITRY ENCLOSURE
LED POWER SUPPLY	TRIGGER	TRIGGER CIRCUIT	COIL MOUNTING SYSTEM
CIRCUIT COMPONENTS	COIL CIRCUIT	COIL CIRCUIT	
555 TIMER IC	PRIMARY COIL	PRIMARY COIL	
OSCILLATOR IC	SECONDARY COIL	SECONDARY COIL	
GATE DRIVER IC	CIRCUITRY ENCLOSURE	COOLING SYSTEM (IF NECESSARY)	
BREADBOARD FOR CONTROL	COIL MOUNTING SYSTEM		
PERFBOARD FOR COIL			
COIL COMPONENTS			
120MM FANS AND HEATSINKS			
K-TYPE THERMISTORS (TESTING)			



TESTING VERIFICATION

THERMAL TESTING



TEST METHOD

- A K-TYPE THERMISTOR IS ATTACHED TO ALL MAJOR HEAT LIMITED COMPONENTS.
- THE CIRCUIT IS OPERATED IN STANDARD OPERATION, PLAYING MUSICAL INPUT THROUGH THE COIL.
- TEMPERATURES ARE MONITORED OVER A MINIMUM TESTING PERIOD OF 10 MINUTES

SUCCESS METRIC

- NO THERMALLY LIMITED COMPONENTS REACH WITHIN 10% OF MANUFACTURER SPECIFIED THERMAL MAXIMUMS
- COMPONENT TEMPERATURE LEVELS OUT AND HOLDS STABLE FOR AT LEAST THE LAST TWO MINUTES OF TESTING

FAILURE RESPONSE

- REDUCE DUTY CYCLE OF INTERRUPTER TO REDUCE POWER DRAW
 - ATTACH HEATSINKS AND IMPLEMENT ACTIVE COOLING USING 12V FAN
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INTERFERENCE TESTING

TEST METHOD

- THE CIRCUIT AND COIL ARE OPERATED IN STANDARD OPERATION, WITH AN OSCILLOSCOPE MEASURING VOLTAGES ACROSS THE INTERRUPTER OUTPUT AND TRIGGER OUTPUT. • ASSUMED ASSEMBLY CONDITIONS ARE UTILIZED, CONSISTING OF THE COIL SUSPENDED 1 FT. ABOVE THE CIRCUIT, BOTH WITH AND WITHOUT INTERFERENCE SHIELDING.
- OSCILLOSCOPE OUTPUT IS MONITORED OVER A TESTING PERIOD OF AT LEAST 10 MINUTES

SUCCESS METRIC

- NO SIGNIFICANT INTERFERENCE IS DETECTED THROUGH OSCILLOSCOPE OUTPUT
- NO UNINTENDED TRIGGERING OR ARCING IS DETECTED

FAILURE RESPONSE

- MORE EFFECTIVE EMI/RFI SHIELDING IS IMPLEMENTED



TESTING VERIFICATION

SPECIFICATION TESTING

TEST METHOD

- THE COIL IS RUN IN STANDARD OPERATION OVER A 10 MINUTE TESTING PERIOD
- MEASURE CURRENT DRAW AND VOLTAGE DIFFERENCE THROUGH ALL LIMITED COMPONENTS USING AN OSCILLOSCOPE
- MEASURE MOSFET DRAIN AND GATE VOLTAGES AND MOSFET DRAIN CURRENT USING OSCILLOSCOPE

SUCCESS METRIC

- CURRENT REMAINS WITHIN SPECIFIED COMPONENT RANGE
- VOLTAGE TRANSIENTS ARE PROPERLY SHUNTED THROUGH SHUNT RESISTORS
- MOSFET EXHIBITS ZERO VOLT SWITCHING PATTERN

FAILURE RESPONSE

- TEST TO ENSURE ALL COMPONENTS ARE PROPERLY FUNCTIONING
- REDESIGN SUPPLY POINTS OF FAILED CIRCUIT
- PERFORM EVALUATION OF THEORETICAL DESIGN

RELIABILITY TESTING

TEST METHOD

- THE COIL IS RUN IN NORMAL OPERATION FOR ACROSS MULTIPLE 10 MINUTE TESTING INTERVALS, WITH 5 MINUTE IDLE PERIODS IN BETWEEN

SUCCESS METRIC

- ALL TESTS SUCCEED AT CONTINUOUS OPERATION FOR 10 MINUTES

ACOUSTIC TESTING

TEST METHOD

- A MUSICALLY SIMPLE, WELL KNOWN TUNE (MARY HAD A LITTLE LAMB) IS PLAYED THROUGH THE COIL
- A FREQUENCY SCAN FROM 20HZ-20KHZ IS PLAYED THROUGH THE COIL

SUCCESS METRIC

- THE TUNE IS RECOGNIZABLE BOTH TO US AND OTHERS
 - A FREQUENCY ANALYSIS APP SHOWS AT LEAST 20HZ-15KHZ PRESENT
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REMAINING TASKS & DIVISION OF LABOR

CALEB’S REMAINING TASKS	JACK’S REMAINING TASKS	JAYSON’S REMAINING TASKS
ORDER CIRCUITRY COMPONENTS	ORDER PRIMARY COIL COMPONENTS	ORDER SECONDARY COIL COMPONENT
ASSEMBLE CIRCUITRY	ASSEMBLE PRIMARY COIL	ASSEMBLE SECONDARY COIL
PERFORM THERMAL TESTING	PERFORM CURRENT TESTING	PERFORM INTERFERENCE TESTING
PERFORM ACOUSTIC TESTING	PERFORM SAFETY TESTING	DESIGN PRODUCT ENCLOSURE
ASSEMBLE PRODUCT ENCLOSURE	PERFORM RELIABILITY TESTING	DESIGN ENCLOSURE SHIELDING



SCHEDULE



CALEB’S TASKS

JACK’S TASKS

JAYSON’S TASKS

