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UAV Landing Aid - Design Report

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Abstract

Integration of the SightLine Landing Aid for end users is problematic. Often drone operators want to just "plug in" a component and fly their mission. Installing software components is acceptable, but any requirement for programming is a barrier to entry or a complete show stopper. Various cables, power, and other electrical connectivity issues are also difficult for vehicle integrator. Rugged or at least robust mechanical enclosures, easy mounting, and environmental reliability are equally important. Lastly, choice of optical system (camera) for the greatest range has cause adoption delays in that it has been a decision left to the integrator. Recognizing the needs from the end-users, SightLine wants to develop a plug and play precision landing aid for UAVs and expect that this new project will be highly valuable to a wide range of multi-copter integrator.

Our solution to the problem involves: I. Selecting, and building a consumer level quad-copter that will be easily customizable for testing II. Designing a camera that will connect directly to the SightLine hardware, distribute power, and facilitate communication III. Research and development of documentation and software to meet plug and play expectations.

The selection, build, and testing of a custom quad-copter is a complicated task with many variables. GPS signal degradation made indoor flight tests impossible, and safe outdoor testing locations were hard to find. We did successfully build, and autonomously fly the Pixhawk4 controlled quad-copter using QGroundControl mission planning software. In the meantime, a camera for the SightLine hardware was designed utilizing an AR0134CS optical sensor. The camera board was also designed to provide power distribution, and facilitate communication between the Pixhawk 4 flight controller and the SightLine hardware.

Insert SLA1500CAM Test Results summary Here

Based on our project, the QGroundControl has demonstrated a great ability to control our quad-copter autonomously. The QGroundControl provides the ability to fully control all quad-copter parameters and as well as setting up a mission. We have successfully flied the drone autonomously using QGroundControl includes takeoff, land, fly the mission, and return to land. The precision landing feature on QGroundControl is not very promising. For the simple function like takeoff and landing, the position between takeoff and land was about 1 meter. For the flying to a destination and return, the difference in position was 2 meter. Additionally, before doing the flight test, we also use Mission Planner to simulate the flight and learn how to control the quad-copter's parameters.

*What are the limitations? The limitation comes from both QGroundControl and SightLine hardware. Since SightLine hardware, or 1500-SLA-kit, is unable to talk with QGroundControl and as well as, we don't know if QGroundControl is capable of talking to SightLine hardware. There will be some works that SightLine need to be done with their hardware so it will be able to talk with QGroundControl.

What are the Future implications of the project? The project is now divided into two parts. The first part is understand the Ground Control State software (QGroundControl) and hardware such as Pixhawk 4, and SLA1500CAM. The second part will emphasize in software and communication development. SightLine and our team has determined to leave the second part of the project for the future capstone team. With our achievements on this project, we have a strong belief that the future team will be successful in this project and future function development.

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1 Project Overview

1.1 Background

SightLine Applications has developed a precision visual landing algorithm that provides an excellent set of benefits:

- Works in degraded and denied GPS environments – Safety and reliability
- Reduces operator training and landing phase complexity.
- Provides detection functions for landing zone safety - detect people, animals, or objects from entering the landing zone
- Provides a rich set of telemetry for flight controllers. 30 Hz data with range, XY offsets, relative azimuth, etc.
- Supports landing on moving platforms - ground vehicles, marine.
- Is not impacted by bright sun or low light conditions.
- Can be used with Thermal (IR) cameras as well as visible (EO) cameras
- Effective range of operation (distance to target) only limited by the size of the landing pattern used

1.2 Problem Definition

Integration of the SightLine Landing Aid for end users is problematic for two main reasons:

1. Connectivity issues with a wide range of cameras.
2. Communication issues with a wide range of flight controller hardware and software.

Currently the end user selects a camera to be used with the SightLine processing hardware. A wide range of cameras must be supported, and custom AB boards must be designed for each one to interface with the SightLine hardware. Each of these AB boards can have cable, power, and electrical connectivity issues that are problematic for the end user. There is also a wide range of flight controller hardware and software, each with a myriad of different communication protocols. Installing software components to facilitate this communication is fine for the end user, but if any programming needs to be done this is usually a complete show stopper.

1.3 Solution

The proposed solution to these problems is to develop an all in one unit (SightLine Hardware w/Camera) with plug and play capabilities that can be directly connected to a consumer level flight controller. By doing so camera connectivity and selection problems are eliminated, and communication and software deployment are made much easier for the end user. We will build an off the shelf quad-copter with autonomous flight capabilities to test communication between current SightLine hardware, and our newly designed camera interface.

1.4 Project Management

The project is divided into three sections:

1. Choosing and building an "off the shelf" quad-copter that uses a Pixhawk 4 flight controller that can be used for testing
2. Designing a camera based on the On-Semi AR0134CS optical sensor that connects directly to the SightLine hardware, distributes power, and facilitates communication between the flight controller and SightLine hardware
3. Research and development of documentation and software installers to meet plug and play expectations using QGroundControl flight control and mission planning software

Insert Project Roles and Responsibilities here

1.4.1 Project Timeline

Insert Project Timeline here

2 Results(Technical Detail)

2.1 Quadcopter

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2.2 Hardware

The 1x1.5” SLA1500CAM utilizes the On-Semi AR0134CS, a monochrome 1/3-inch 1.2 Mp CMOS digital sensor with a 74MHz output. It connects seamlessly with the SightLine SLA1500OEM image processing hardware via a 50-pin Hirose DF12 connector. With a 5V input the SLA1500CAM converts and distributes the 3.3V, 2.8V, and 1.8V required for operation.

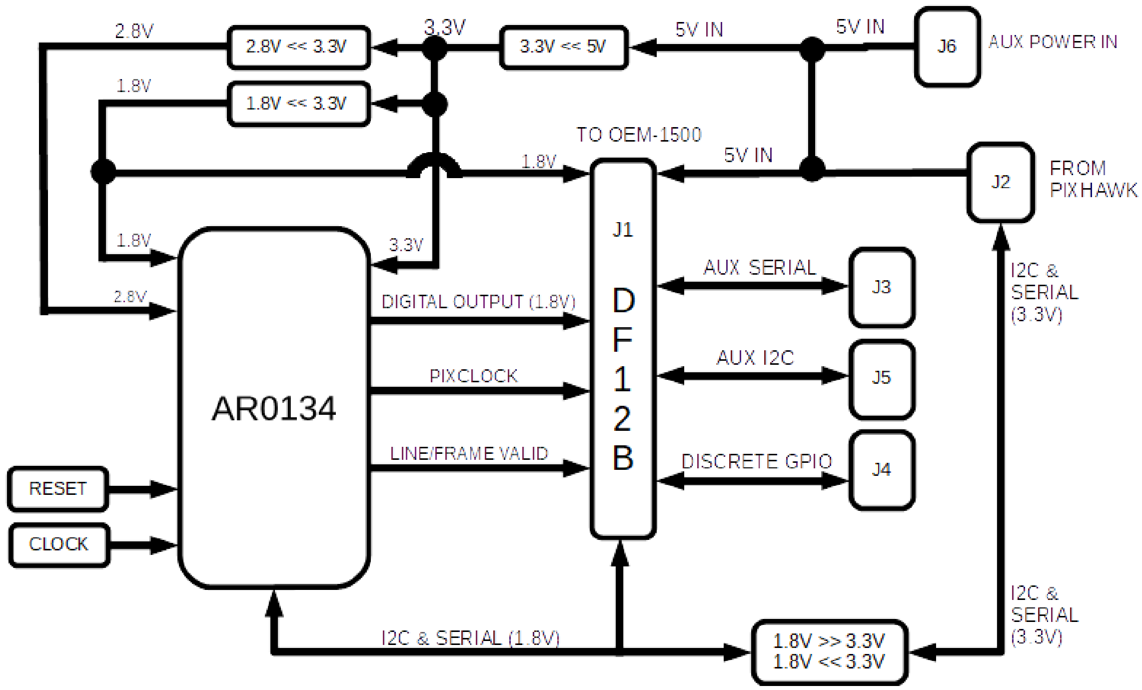

Figure 1: *Level 1 block diagram of SLA1500CAM REV 8.0*

The SLA1500CAM also provides bi-directional level translation for serial and I2C communication between the SightLine hardware, the flight controller, and the optical sensor. There are five I/O ports using standard Molex and JST connectors:

- Power and serial communication for the flight controller
- Auxiliary I2C bus
- Auxiliary serial communication
- Auxiliary power in

2.3 Connector Summary

LABEL	MFG PART NUMBER	FUNCTION	MATES WITH
J1	HIROSE DF12B-50DS-0.5V(86)	50-Pin Digital Connector, Connects Directly to OEM-1500 J4	HIROSE 1500-OEM J4 [DF12B(5.0)-50DP-0.5V(86)]
J2	JST SM06B-GH	5VDC Power, Serial and *I2C Communication With Pixhawk	JST GHR-06V-S
J3	MOLEX 53261-0371	Auxiliary Serial Communications for Sightline Debugging	MOLEX 51021-0300 / CAB-0302
J4	MOLEX 53261-0471	Discrete GPIO Lines from 1500-OEM	MOLEX 51021-0400 / CAB-0401
J5	MOLEX 53261-0471	Auxiliary I2C Bus to Sightline	MOLEX 51021-0400 / CAB-0401
J6	MOLEX 53261-0471	Auxiliary 5VDC Power In	MOLEX 51021-0400 / CAB-0401

Figure 2: *Connector summary for SLA1500CAM REV 8.0*

2.3.1 Connector J1

Digital camera, serial, power for SLA1500OEM
This connector is designed to mate with the SLA1500OEM J4 connector.

PIN	DESCRIPTION	SINGAL LEVEL	PIN	DESCRIPTION	SIGNAL LEVEL
1	UART RX CAM	VIOSEL	2	UART TX CAM	VIOSEL
3	LINE VALID	VIOSEL	4	FRAME VALID	VIOSEL
5	DGND		6	DGND	
7	12C SDA	VIOSEL	8	I2C SCL	VIOSEL
9	CAMGPIO 175	VIOSEL	10	NO CONNECT	
11	NO CONNECT		12	NO CONNECT	
13	CAMGPIO 174	VIOSEL	14	CAMGPIO 173	VIOSEL
15	RXC	VIOSEL	16	TXC	VIOSEL
17	DGND		18	NO CONNECT	
19	CAMGPIO 178	VIOSEL	20	NO CONNECT	
21	NO CONNECT		22	NO CONNECT	
23	CAM D11	VIOSEL	24	CAM D10	VIOSEL
25	CAM D9	VIOSEL	26	CAM D8	VIOSEL
27	DGND		28	DGND	
29	CAM D7	VIOSEL	30	CAM D6	VIOSEL
31	CAM D5	VIOSEL	32	CAM D4	VIOSEL
33	CAM D3	VIOSEL	34	CAM D2	VIOSEL
35	CAM D1	VIOSEL	36	CAM D0	VIOSEL
37	DGND		38	DGND	
39	CAM PCLK	VIOSEL	40	CAMGPIO 172	VIOSEL
41	DGND		42	AGND	
43	NO CONNECT		44	AGND	
45	DGND		46	VIOSEL	1.8V
47	DGND		48	POWER IN	5V
49	DGND		50	POWER IN	5V

Figure 3: *Connector summary for J1*

The GPIO connections for J1 are as follows:

- CAMGPIO 172 is connected to DNP Resistor R7 to AR0134 TRIGGER
- CAMGPIO 173 is connected to DNP Resistor R8 to AR0134 FLASH
- CAMGPIO 174 is connected to AR0134 RESET
- CAMGPIO 175 is connected to AR0134 STANDBY
- CAMGPIO 178 is connected to DNP resistor R26 to AR0134 OEBAR

AR0134 OEBAR is tied to ground with 0 OHM resistor R27.
***R27 MUST BE REMOVED BEFORE R26 IS INSTALLED AND CAMGPIO 178 CAN BE USED.**

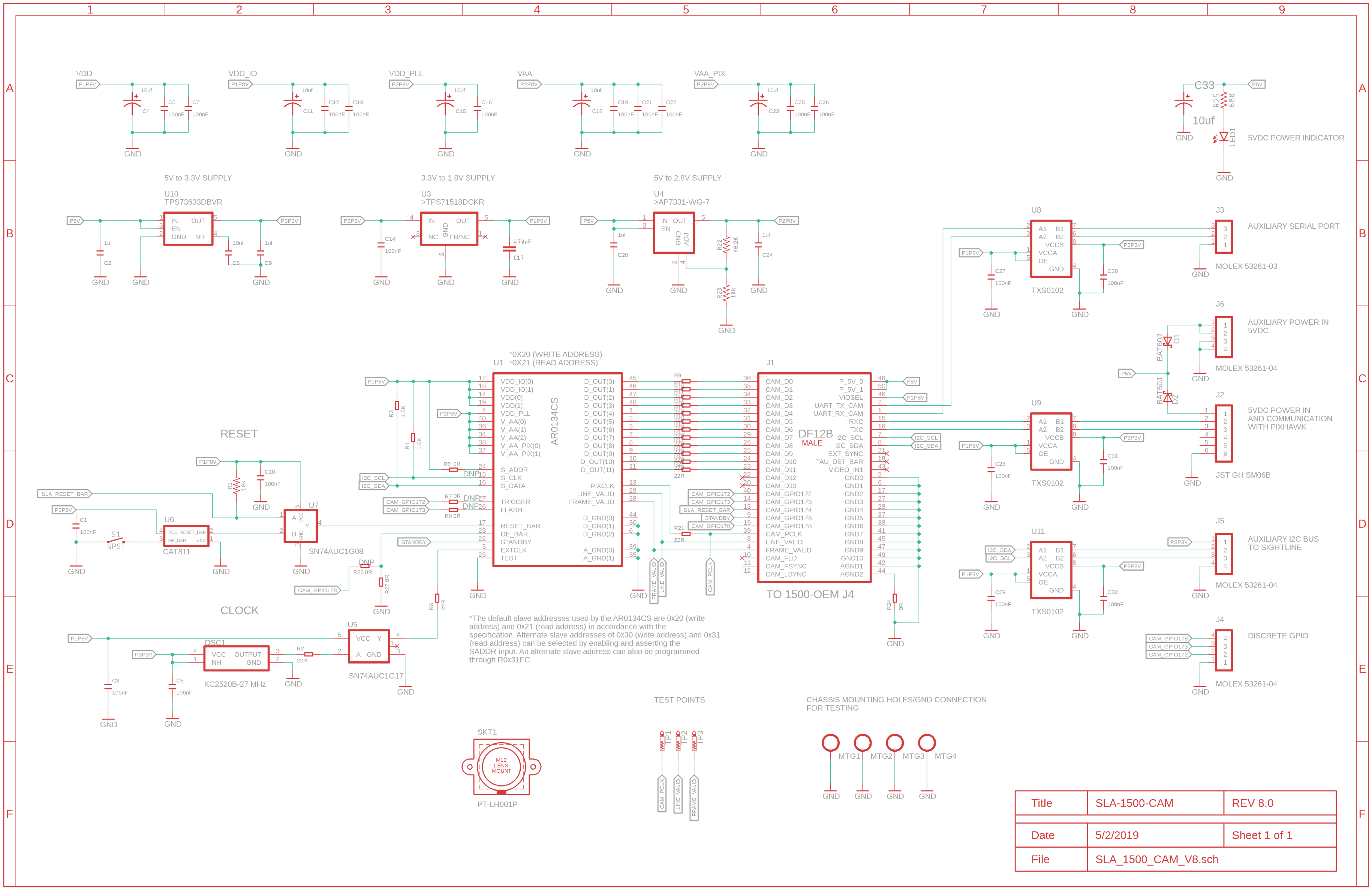

Figure 4: *SLA 1500 CAM REV 8.0 Schematic*

PROJECT		SLA1500CAM			SIGHTLINE APPLICATIONS	
HARDWARE REVISION		REV 8.0				
DATE		5/2/2019				
Qty	Reference	DNP	DESCRIPTION	MANF	MPN	SLPN
1	U4		300mA, LOW QUIESCENT CURRENT, FAST TRANSIENT LOW DROPOUT LINEAR REGULATOR, ADJUSTABLE OUTPUT, 5V to 2.8V, 3.1 x 1.7mm	Diodes Incorporated	AP7331-WG-7	SL00740
1	U1		1/3-inch 1.2 Mp CMOS digital image sensor with an active-pixel array of 1280 (H) — 960 (V) ILCC48 package	On Semiconductor	AR0134CSSM00SPCA0-DPBR	
1	U6		IC, SUPERVISOR, MICROPROCESSOR POWER SUPPLY, 2.93V, ACTIVE LOW RESET, SOT143-4	On Semiconductor	CAT811STBI-GT3	
1	J1		DF12B-50DS-0.5V(86)SMT Hirose Male 50-pin connector	Hirose	537-0309-6 86	SL00297
1	OSC1		KC2520B-27MHZ OSC, CRYSTAL CLOCK, SMD, CMOS, 2.25V TO 3.63V, 4mA, 27.0000MHz, 2.5MM x 2.0MM	Kyocera	KC2520B27.0000C2GE00	
1	LED1		LED BLUE DIFFUSED 0603 SMD	OSRAM Opto Semiconductors Inc.	LB Q39E-N1OO-35-1	
1	U7		IC, AND GATE, SINGLE, 2 INPUT POSITIVE, SGL, SOT23-5	Texas Instruments	SN74AUC1G08DBVR	
1	U5		IC, BUFFER, SINGLE SCHMITT-TRIGGER, 9mA, 0.8V TO 2.7V, SOT23-5	Texas Instruments	SN74AUC1G17DBV	
1	U3		50-mA, 24-V, 3.2-I¼A Supply Current Low-Dropout Linear Regulator in SC70 5-Pin Package, 3.3 to 1.8V, 2.15 x 1.4mm	Texas Instruments	TPS71518DCKR	SL00260
6	R6, R7, R8, R24, R26, R27	R6,R7,R8,R26	SMD-RES-0R-5%-1/16W(0402)	Yageo	RC0402JR-070RL	
2	R3, R4		SMD-RES-1.5K-5%-1/16W(0402)	Yageo	RC0402JR-071K5L	
21	C1, C3, C5, C6, C7, C10, C12, C13, C14, C16, C19, C21, C22, C25, C26, C27, C28, C29, C30, C31, C32		CERAMIC 100NF-10V-10%-X5R(0402)	Yageo	CC0402KRX5R6BB104	
2	R1, R23		SMD-RES-10KOHM-1%-1/10W(0603)	Yageo	RC0603FR-0710KL	
1	C8		CERAMIC-10NF-50V-10%-X7R(0402)	Yageo	CC0402KRX7R9BB103	
6	C4, C11, C15, C18, C23, C33		Tantalum Capacitors - Solid SMD 10uF 6.3V 20% 0402, 1.1x0.6x0.35mm	AVX	F980J106MUALZT	
4	C2, C9, C20, C24		CERAMIC-1UF-10V-10%-X5R(0402)	Yageo	CC0402KRX5R6BB105	
15	R2, R5, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21		SMD-RES-22R-1%-1/16W(0402)	Yageo	RC0402FR-0722RL	
1	C17		CERAMIC 470NF-6.3V-10%-X5R(0402)	Yageo	CC0402KRX5R5BB474	
1	R22		SMD-RES-62K-1%-1/10W(0603)	Yageo	RC0603FR-0762KL	
1	R25		SMD-RES-680R-1%-1/10W(0603)	Yageo	RC0603FR-07680RL	
2	D1, D2		DIODE SCHOTTKY 10V 3A SOD323	STMicroelectronics	BAT60JFILM	
1	J2		1.25 MM SIDE-ENTRY 6-PIN SMT CONNECTOR	JST	SM06B-GHS-TB	
1	J3		1.25mm Pitch PicoBlade Header, Surface Mount, Right-Angle, 3 Circuits, Tin (Sn) Plating	MOLEX	532610371	
3	J4, J5, J6		1.25mm Pitch PicoBlade Header, Surface Mount, Right-Angle, 4 Circuits, Tin (Sn) Plating	MOLEX	532610471	
1	SKT1		PT-LH001P Plastic M12 Lens Holder, 20mm Hole Spacing	M12 LENSES	PT-LH001P	
1	S1		Momentary Switch (Pushbutton) - SPST - SMD - 4.6X2.8MM	C&K	KMR221GLFS	
1	U10		Cap-Free, NMOS, 400-mA Low-Dropout Regulator with Reverse Current Protection 5.5 to 3.3V, SOT-23 5-pin, 2.9 x 1.6 mm	Texas Instruments	TPS73633DBVR	
3	U8, U9, U11		TXS0102 2-Bit Bidirectional Voltage-Level Translator for Open-Drain and Push-Pull Applications	Texas Instruments	TXS0102DQM	

Figure 5: *SLA1500CAM BOM REV 8.0*

The schematic and PCB were designed using EAGLE CAD 9.2.1. Many of the component footprints and devices were unavailable and were designed specifically for the project. This involved designing the device, footprint, schematic symbol, and linking material data to each device. The entire EAGLE library for the SLA1500CAM can be found in the GitHub repository.

Eagle Library for SLA1500CAM

2.4 Software

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3 Conclusion/What's Left to do

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4 Appendix

4.1 I

4.2 II

4.3 II

4.4 IV

4.5 V

5 References

1. Mali, P. (1960). *Magnetic Amplifiers*. New York, NY: John F. Rider.

2. Figure 1. Simple saturable reactor. Reprinted from *Magnetic Amplifiers*(pg. 27), by Paul Mali, 1960, New York, NY, John F. Rider Publisher, Inc.

3. Figure 2. Full-wave self-saturating magnetic amplifier. Reprinted from *Magnetic Amplifiers*(pg. 35), by Paul Mali, 1960, New York, NY, John F. Rider Publisher, Inc.