Common Impedance Coupling Effect on Video and Audio Circuitry

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Outline

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2. Objectives of grounding
3. Single- vs. multiple-point ground
4. Common-impedance coupling
5. Circuit board and schematic
6. Demo and discussion
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Signal Ground – Signal Return Path

A signal ground is normally defined as an equipotential point or plane that serves as a reference potential for a circuit or system.

This definition, however, does not emphasize the importance of the actual path taken by the current in returning to the source.

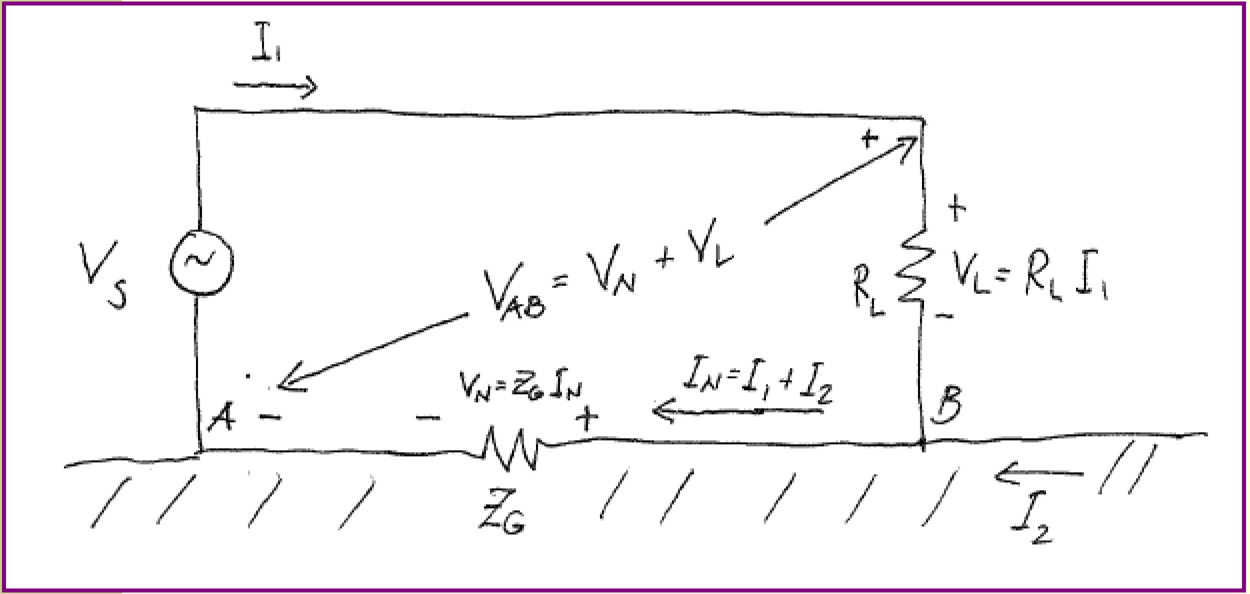
An alternative definition for a single ground is: A low impedance path for current to return to the source.

This current concept of a ground emphasizes the importance of current flow.

This definition implies that since current is flowing through some low, but finite, impedance there will be a difference of potential between two physically separated points in the ground system.

It is important for the designer to know the actual return current path to evaluate the radiated emissions or susceptibility of a circuit, or signal interference or coupling within the circuit.

Forward Conductor and a Return Conductor



Current I_1 flows down the conductor to the load R_L and returns to the source through the ground plane, or a return conductor (ground).

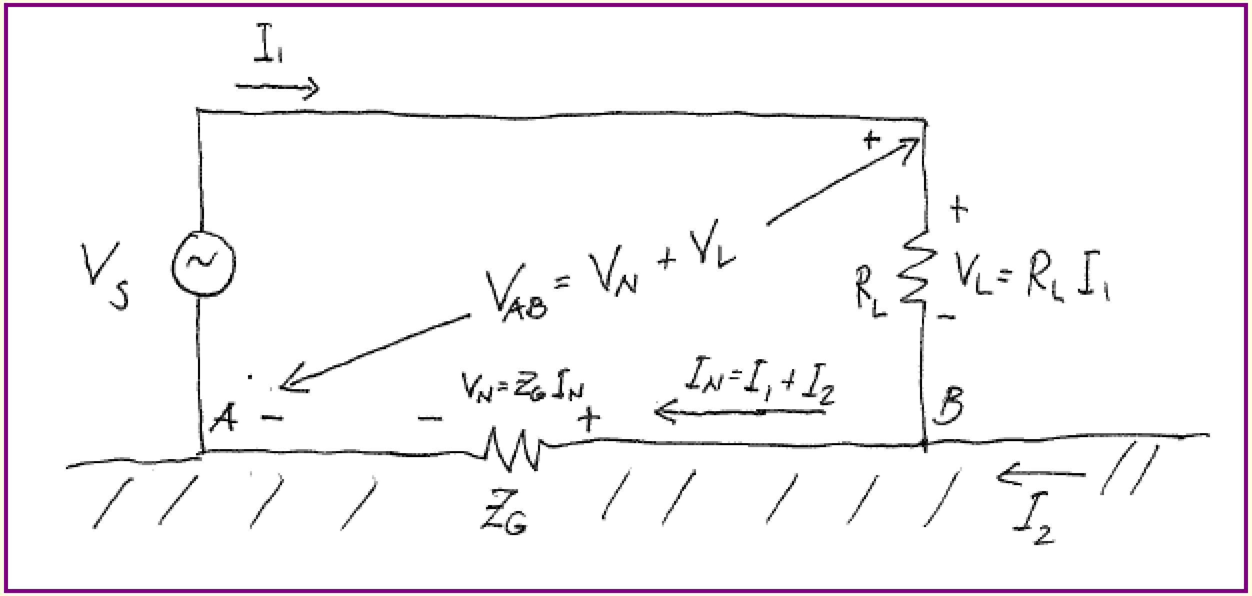
If additional circuits were connected to the ground plane, or were sharing the return conductor, another current I_2 may also be flowing in the ground, resulting in the total current of I_N .

Since the return path has a finite impedance Z_G, this current will produce a noise voltage between points A and B:

$$V_N = Z_G I_N$$

The voltage across at the load with respect to node A will then be $V_L + V_N$.

Forward Conductor and a Return Conductor



Due to the loop formed by the forward conductor and the return conductor, the return path impedance Z_G, will comprise of the resistance R_G as well as the inductance L_G :

$$Z_G = R_G + j\omega L_G$$

Voltage Drop across the Ground Conductor

Impedance of a ground conductor:

$$Z_G = R_G + j\omega L_G$$

resistance R_G - dominant factor at low frequency
inductance L_G - dominant factor at high frequency

Any ground conductor carrying a current I_N will exhibit a voltage drop

$$V_G = Z_G I_G$$

The effect of this voltage on all circuits connected to ground must be considered (minimized)!

Grouding Objectives (Demo)

$$V_G = Z_G I_G$$

To minimize ground voltage:
1. Minimize ground impedance Z_G
2. Decrease ground current I_G

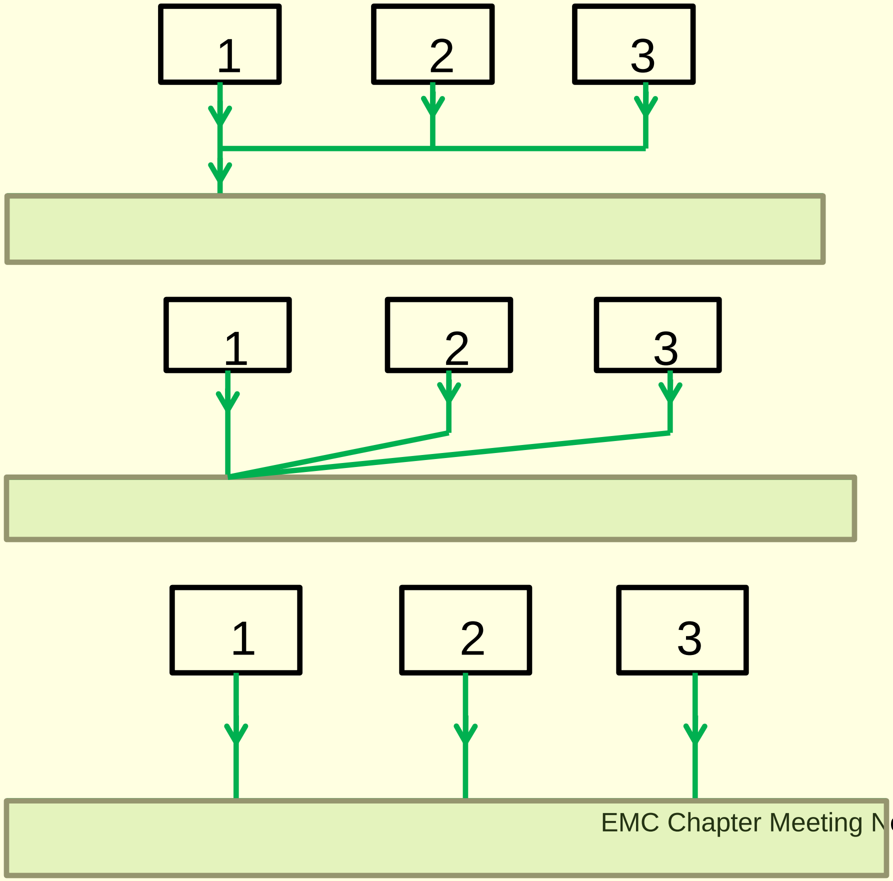
These two objectives are the main two objectives of grounding!

*The following demo will show the effects of both the **ground impedance changes and the ground current variations** on the audio and video signals sharing the return path with other PCB circuits.*

Ground Schemes

$$V_G = Z_G I_G$$

The existence and the magnitde of the ground voltage is influenced by the grounding scheme.

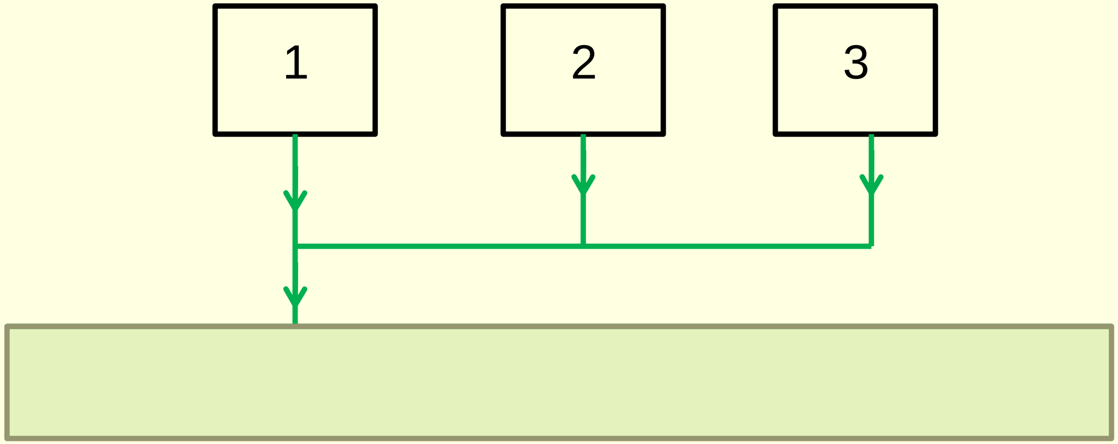


Single-Point Series

Single-Point Parallel

Multi-Point

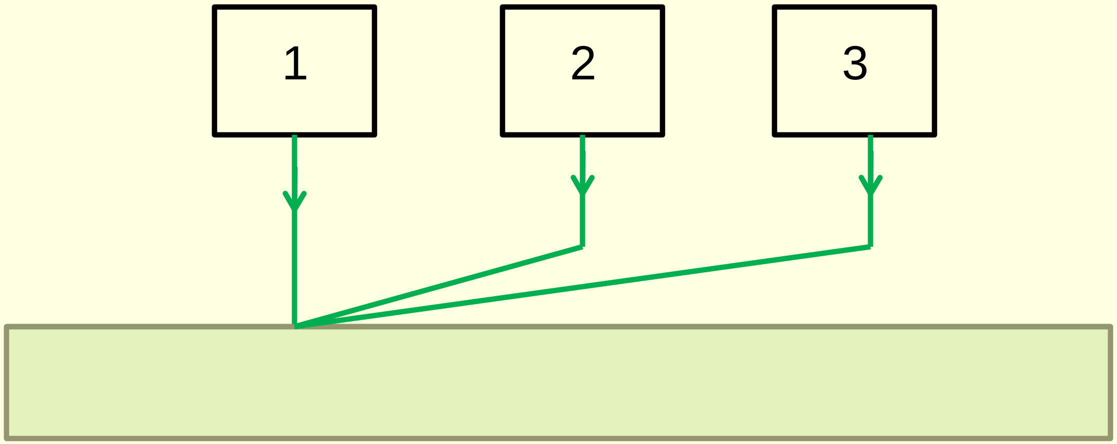
Single-Point Series Ground



Least-desirable grounding scheme, yet commonly used because of simplicity.

Should not be used between circuits that operate at widely different current levels because of common-impedance coupling.

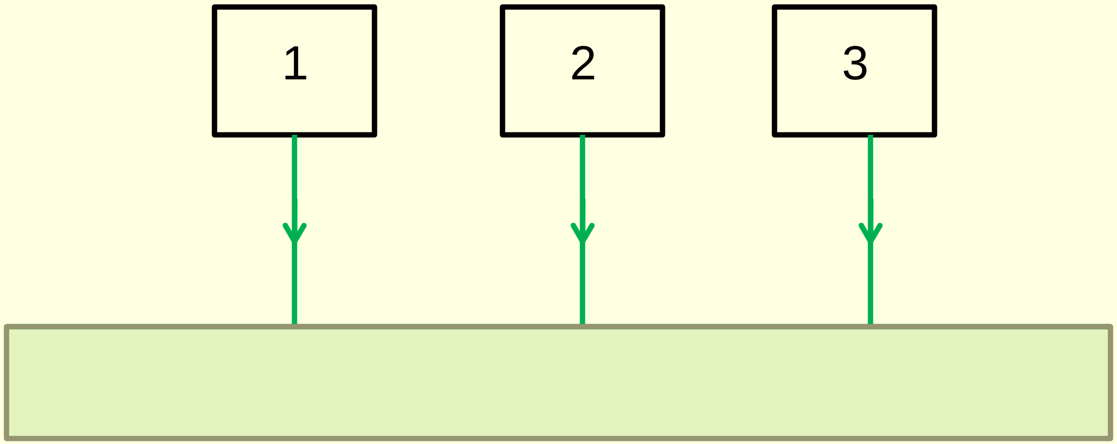
Single-Point Parallel Ground



No cross-coupling occurs between ground currents from different circuits.

Can be mechanically cumbersome, because in a large system an unreasonable number of ground conductors may be necessary.

Multi-Point Grounds



Used at high frequency (above 100kHz) and in digital circuitry.

Multipoint ground systems minimize the ground voltage by minimizing the ground impedance (inductance).

Single-Point Grounds

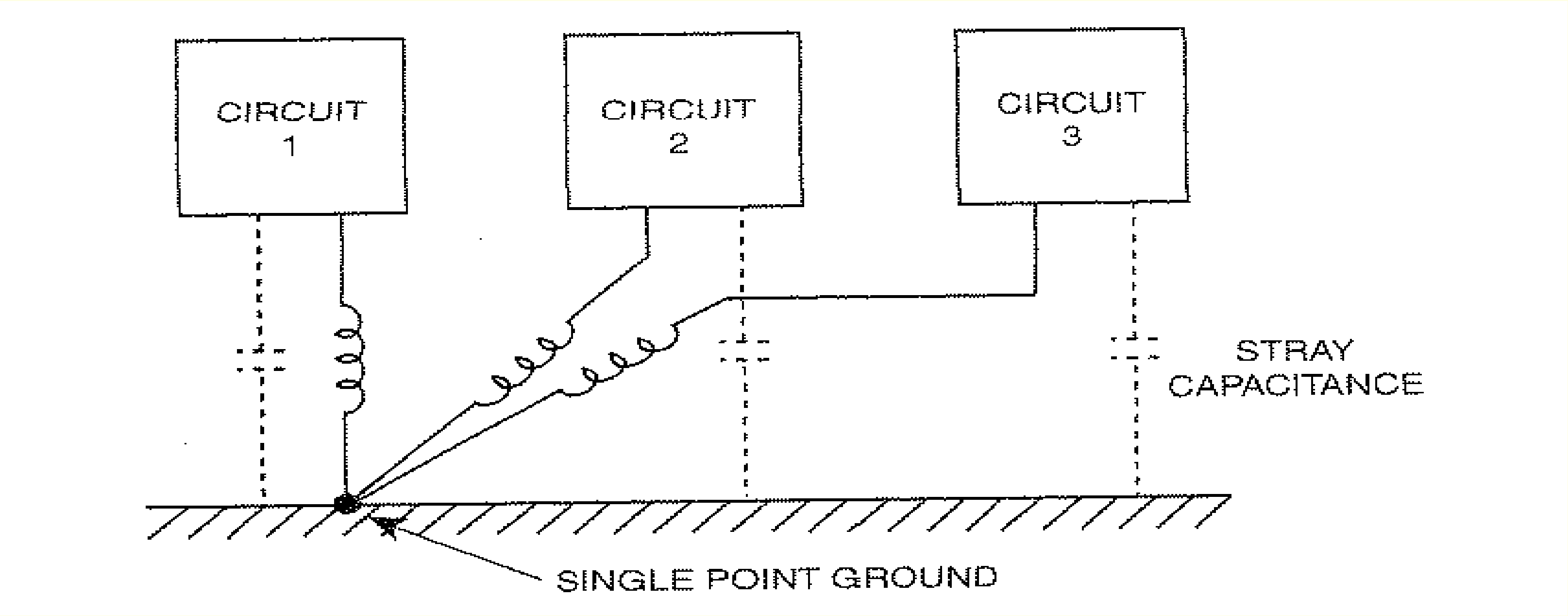
Most effective from dc to 20 kHz, should not be used above 100kHz. Benefits: control of the return current, simplicity. Drawbacks: common-mode impedance (series), number of ground conductors (parallel)

Most practical single-point ground systems are a combination of the series and parallel connections. Compromise between the noise level and wiring complexity.

To balance these factors, group ground leads selectively, so that the circuits of widely varying power and noise levels do not share the same ground return path.

This demo will show the effects of the ***single point grounds*** *on the audio and video signals sharing the return path with other PCB circuits.*

Single-Point Ground at High Frequency



At high frequency, the impedance of the stray capacitance between the circuits and ground is low. The ground current flows through the capacitance.

The result is a ***multipoint ground at high frequency****.*

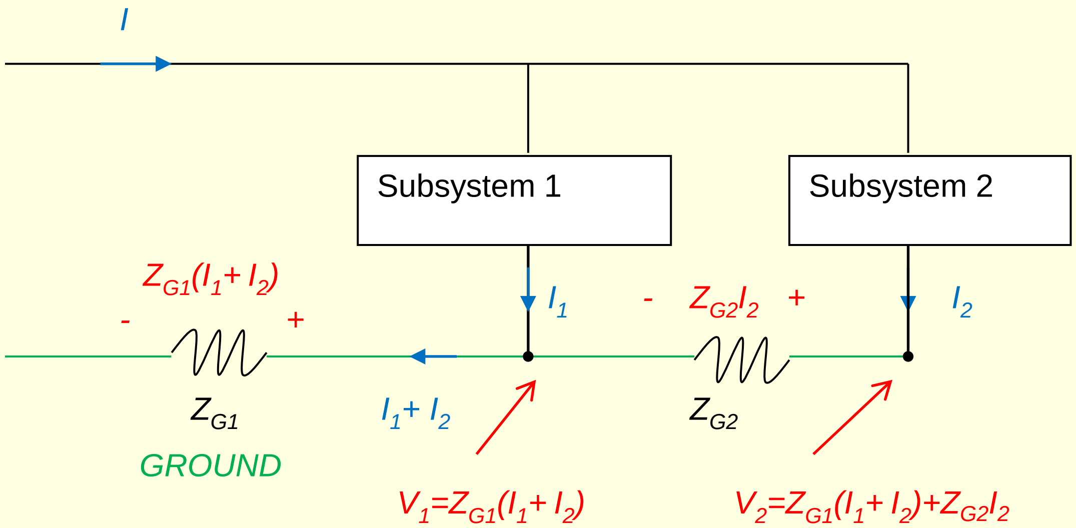
Factors Influencing Grounding Scheme

Proper signal grounding is determined by:

- *type of circuitry*
- *frequency of operation*
- *size of the system*
- *whether it is self-contained or distributed*
- *safety*
- *ESD protections*

No ground scheme proper for all applications

Common Impedance Coupling



At the ground point of subsystem 1, V_1 has the signals of subsystem 2, I_2 coupled to it by virtue of the nonzero impedance Z_{G1} shared by both signals.

At the ground point for subsystem 2, V_2 has the signals of subsystem 1, I_1 imposed on it through Z_{G1}.

This phenomenon is referred to as ***common-impedance coupling****.*

Common-Impedance Coupling Conditions

Common-impedance coupling becomes a problem when two or more circuits share a common ground and one or more of the following conditions exist:

- *A high-impedance ground (at high frequency: too much inductance; at low frequency: to much resistance)*

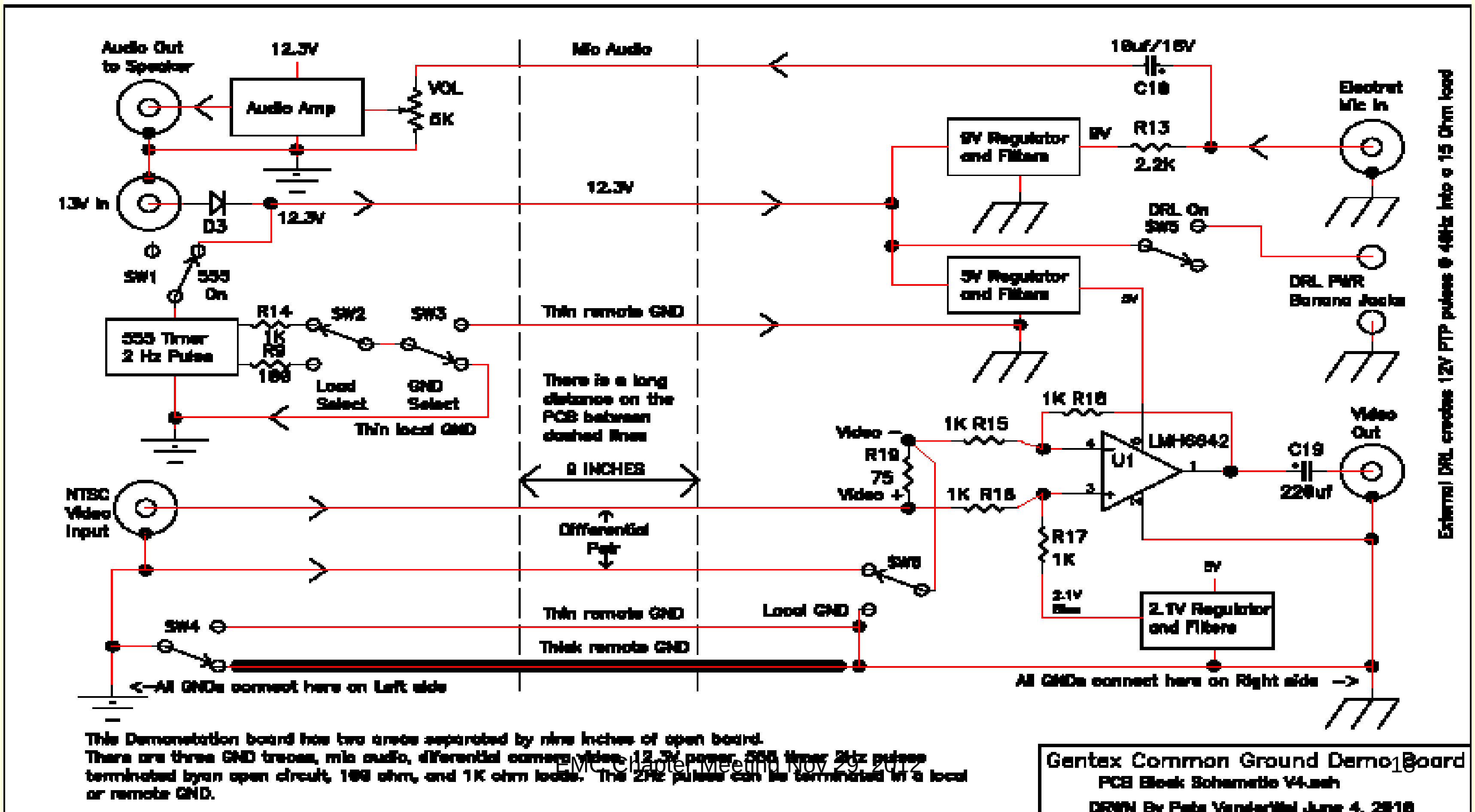
- *A large ground current*

- A very sensitive, low-noise margin circuit, connected to ground

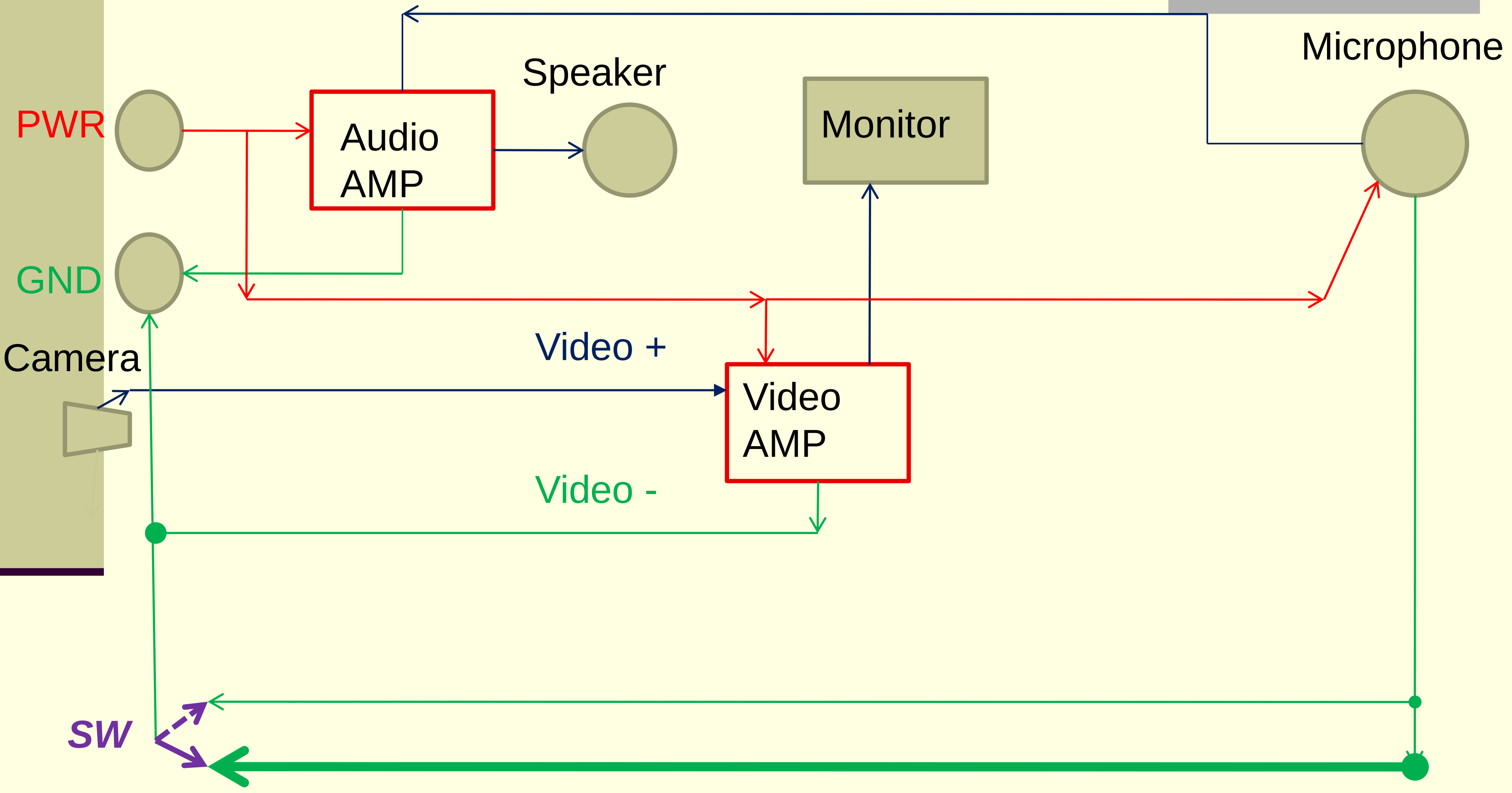
Demo Board


100
LOAD
GND
1K
LOAD
REMOTE
OFF
DRL
OFF
DIFFERENTIAL
VIDEO AMP INPUT
COMMON GND
THIN GND
THICK GND

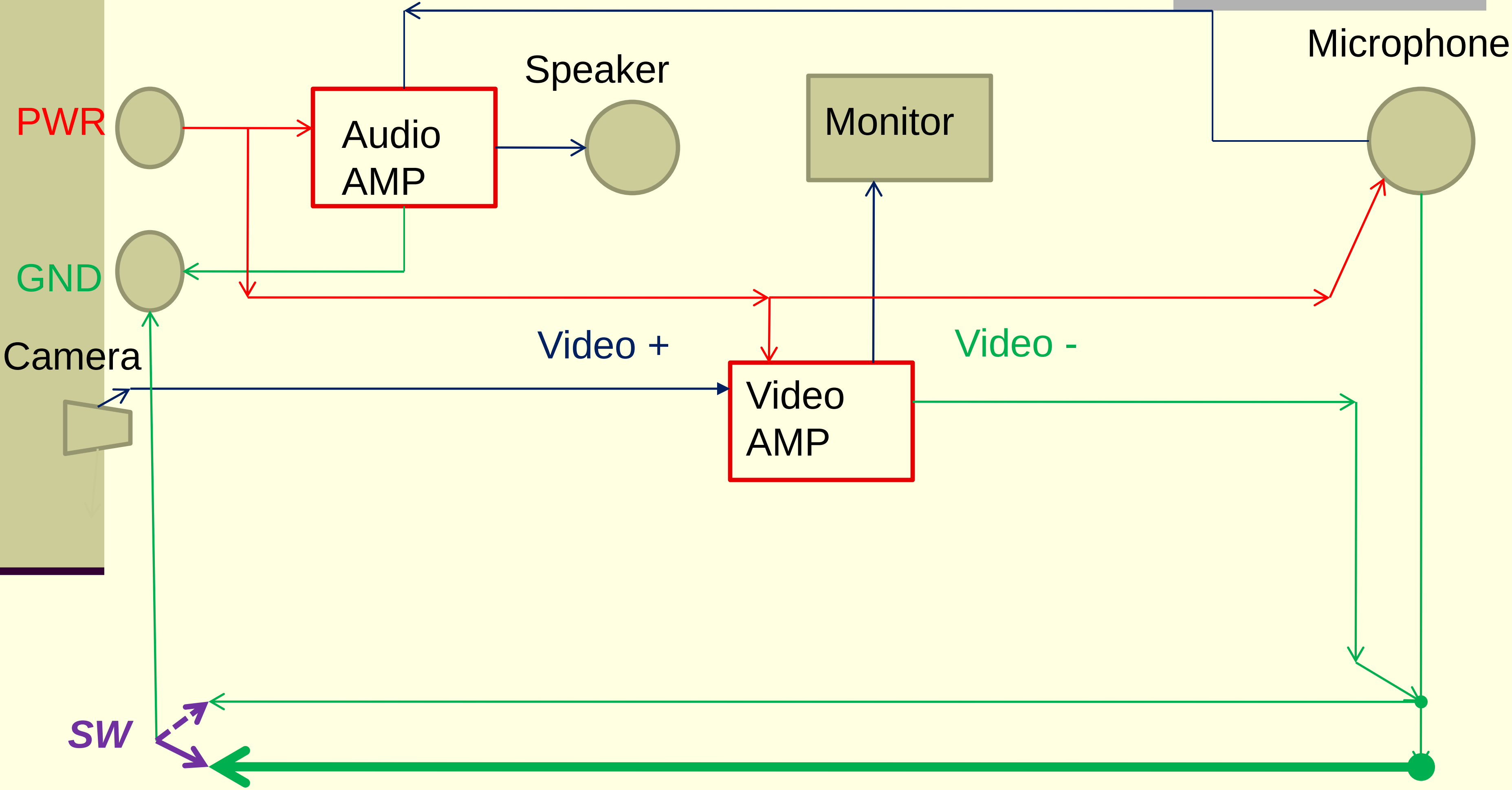
Circuit Schematics



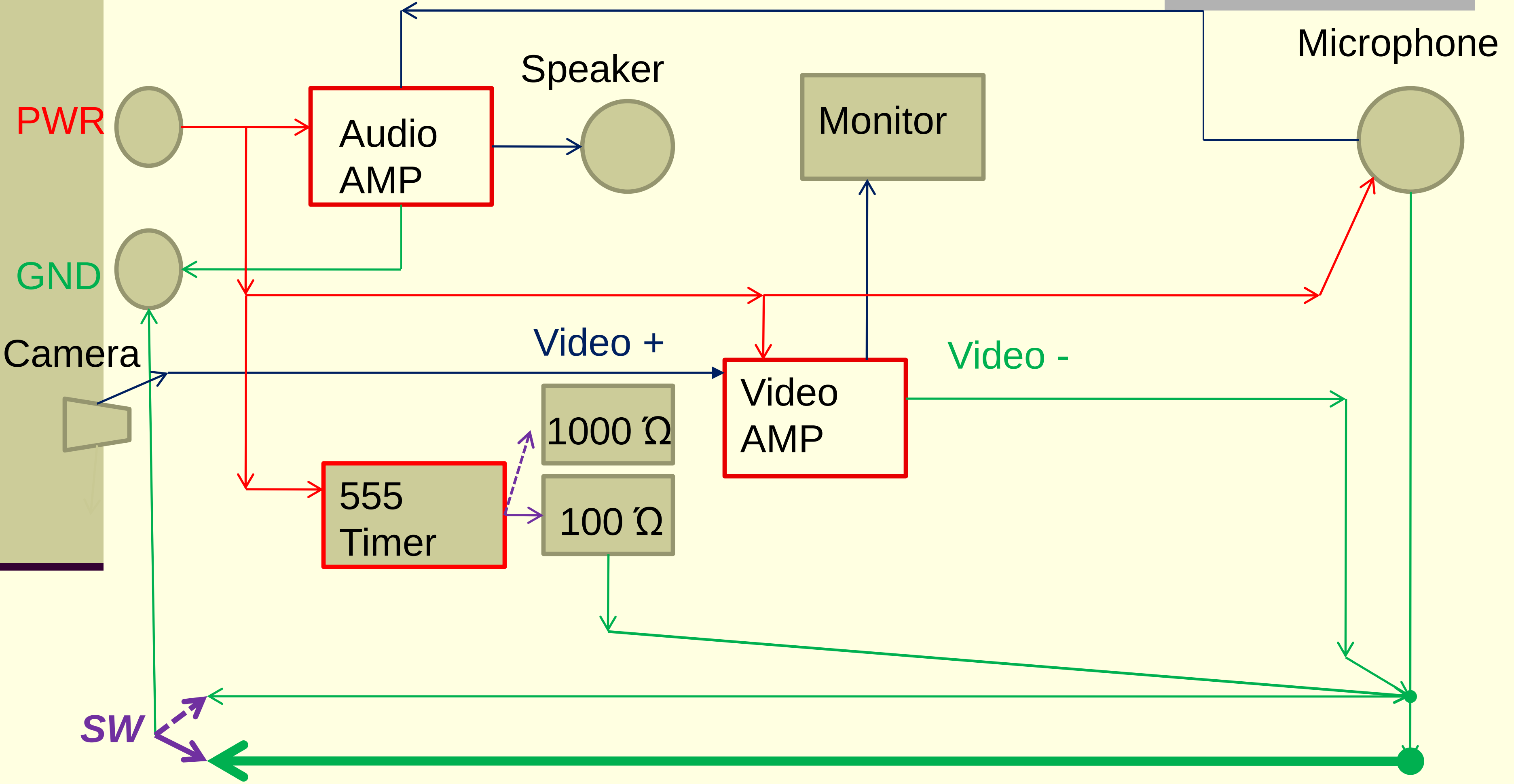
Differential Mode = Isolated Return (Video, Mic). Low/High GND Impedance



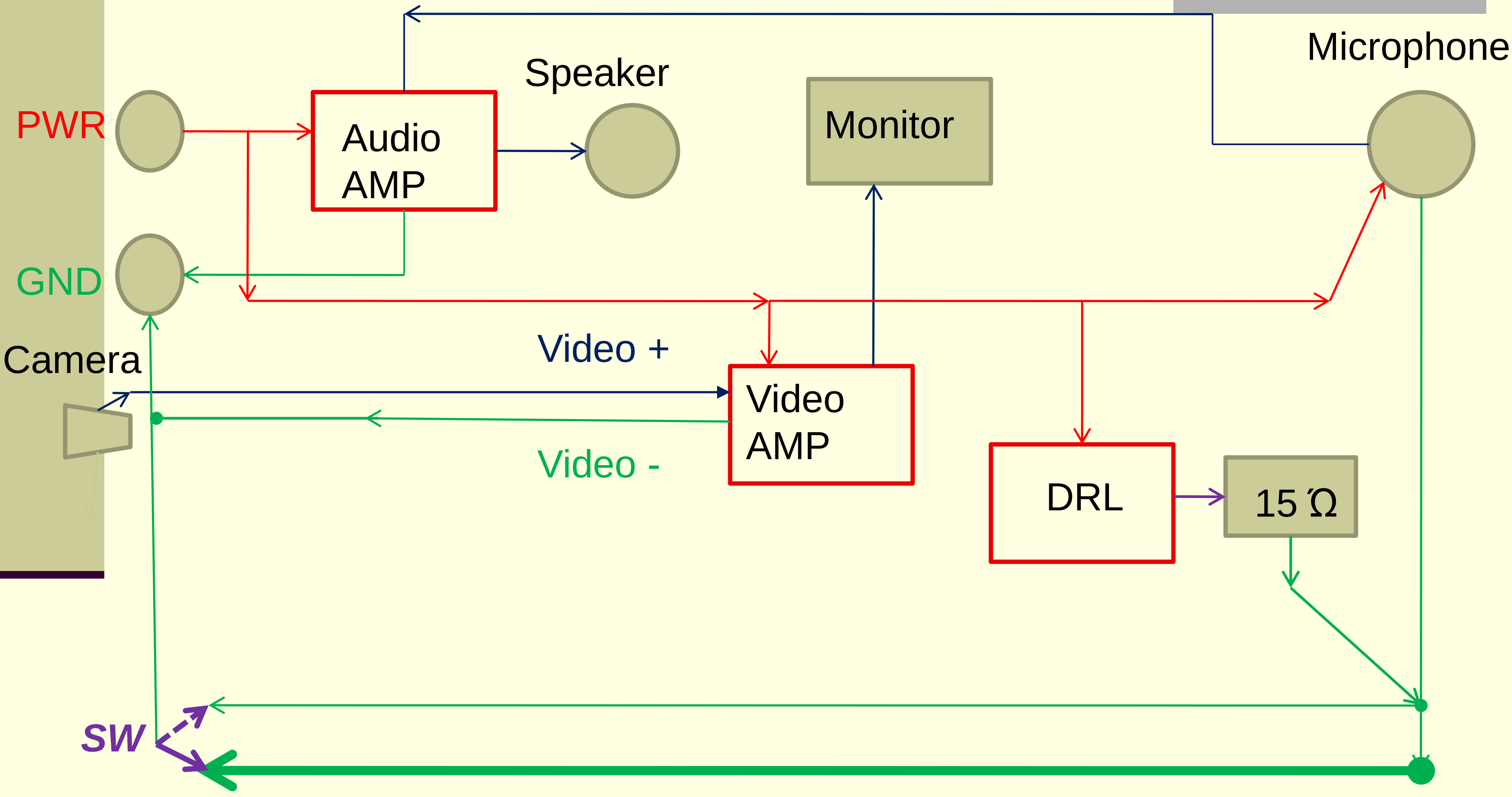
Common Mode = Shared Return (Video, Mic). Low/High GND Impedance



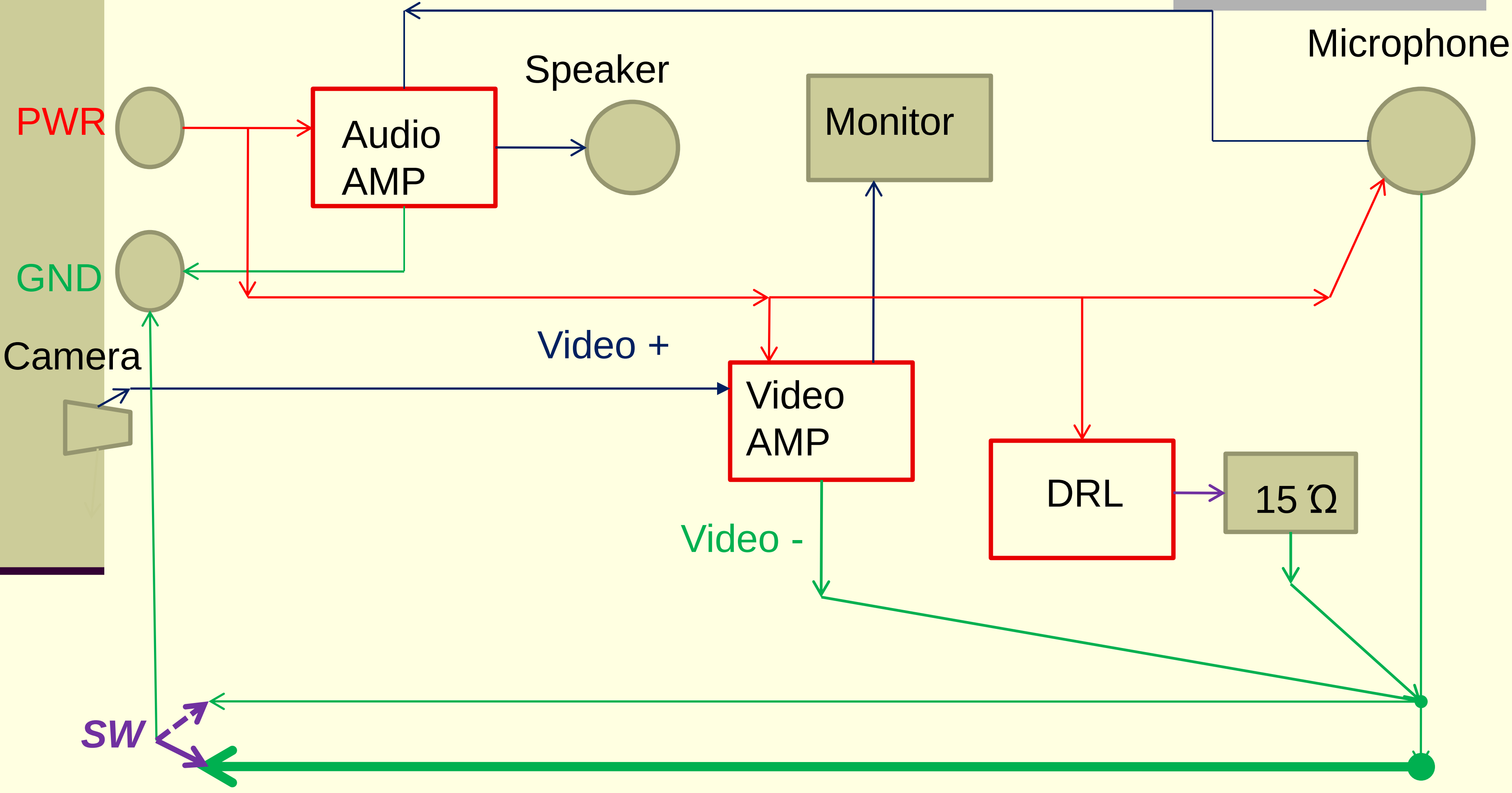
Common Mode. Shared w/555 Timer Low/High GND Impedance



Differential Mode. Shared w/DRL. Low/High GND Impedance



Common Mode. Shared w/DRL. Low/High GND Impedance



Conclusions

1. *Series single point ground is introduces common-impedance coupling. Do not use it for signals of widely varying levels.*

2. *Low-level circuits may share the same return path*

3. *High level signals should use different ground return path*

4. *No single grounding scheme is adequate for all circuits and more than one scheme may exist for a particular situation*

References and Acknowledgements

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C. R. Paul, Introduction to Electromagnetic Compatibility, 2nd Ed,, 2006

H. W. Ott, Electromagnetic Compatibility Engineering – 2009

EMC Chapter Meeting – January 31, 2013

Model, Simulate & Correlate electrical PCB designs using Mentor Graphics analysis tools:

1) Model digital signal integrity using Hyperlynx SI
a. Component modeling
b. PCB layout modeling (Pre-route analysis, Post-route analysis)

2) Model power integrity using Hyperlynx PI
a. PDN impedance calculation
b. IC Decoupling analysis
c. DC drop analysis

3) Perform design rule checks using Hyperlynx DRC

4) Perform electrical simulations using SystemVision
a. Mixed analog/digital circuits

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