REFERENCES

[1] B. Peter M: Flowerdew, "Method and apparatus for tracing conductors using an alternating signal having two components related in frequency and phase.". US Patent 5,260,659, 09 Nov 1993.

[2] Dong-soo kima,*,Jin-Sun Leel, "Propergation and attenuation Characteristics of various ground vibration," 27 December1999 .

[3] M. S.Hons, "Seismic sensing:Comparison of geophones and accelerometers using laboratory and field data," July,2008.

[4] O. Hunaidi, A. Wang, M. Bracken, T. Gambino and C. Fricke, " Acoustic methods for locating leaks in municipal water pipe networks,," pp. pp. 1-1, May 30-June 3,2004.

[5] J. R. D. &. D. M. J. W.D. O'Brien, "Acoustic Characterization of Soil" 28th March 1996.

[6] Y. Chen, "Vibration Motor ,Application Note," April 4th, 2013.

[7] J. W. Waite, "center line and depth locating method for non -metallic buried utility lines"". L05 Gates, CA (Us) Patent US 7,113,124 B2, 26 Sep 2006.

[8] J. H. Bradford, " Frequency dependent attenuation analysis of ground penetrating radar data".

[9] G. Leucci, "Ground Penetrating Radar: The Electromagnetic Signal Attenuation and Maximum Penetration Depth," 27 November 2008.

[10] K. f. a. P. W.Maxwell, "Geophone spurious frequency : What is it and how does it affect seismic data quality," December 1997.

[11] J. I. H. P. a. S. K. Kazunori Takahashi1, "Basics and Application of Ground-Penetrating Radar as a Tool for Monitoring Irrigation Process"9 March 2012.

[12] S. P. b. o. M. P. Coursolle, "Bruce D. Rovner, Eden Prairie; Thomas Magnetic Flow meter with empty pipe detector"27 June 1995.

[13] "Theory of buried cable and pipe location," Radio detection Ltd, 2017.

[14] P. J. J. M. a. Y. G. M.J. Brennan*, " Some Recent Research Results on the use of Acoustic Methods to Detect Water Leaks in Buried Plastic water Pipes".

[15] J. F. a. G. Steczko, "Seismic Vibration Sensor with Acoustic Surface Wave"2013

[16] O. H. a. P. Giamou, "Ground -Penetrating radar for Detection of Leaks in Buried plastic Water distribution pipes" 30 May 1998.

[17] J. Joseph L. Kelly, T. Mig A. Howard both of Houston, S. Paul A. Nysen and p. A. b. o. C. Colin A_ Hacking, "Surface Acoustic wave pipe identification system" 6 October 1987.

[18] J. S. Lamancusa, " Outdoor sound propagation," Penn State, July 20th 2009.

[19] R. E.Bland, "Acoustic and seismic signal processing for foot step detection," June 2006.

[20] "https://www.lincenergysystems.com/linc-energy-blog/entry/ground-penetrating-radar-disadvantages-in-clay-soil-and-shale#.WRQhFFWGPIU," [Online].

APPENDIX A: SPECIFICATIONS AND CODING

A1.1 Precision Instrumentation Amplifier AD524

FEATURES

Low noise	: 0.3 μV p-p at 0.1 Hz to 10 Hz
Low nonlinearity	: 0.003% (G = 1)
High CMRR	: 120 dB (G = 1000)
Low offset voltage	: 50 μV Low offset
Voltage drift	: 0.5 μV/°C
Gain bandwidth product	: 25 MHz

- Pin programmable gains of 1, 10, 100, 1000
- Input protection, power-on/power-off
- No external components required
- Internally compensated
- MIL-STD-883B and chips available
- 16-lead ceramic DIP and SOIC packages and 20-terminal leadless chip carrier available
- Available in tape and reel in accordance with EIA-481A standard
- Standard military drawing also available

GENERAL DESCRIPTION

The AD524 is a precision monolithic instrumentation amplifier designed for data acquisition applications requiring high accuracy under worst-case operating conditions. An outstanding combination of high linearity, high common-mode rejection, low offset voltage drift, and low noise makes the AD524 suitable for use in many data acquisition systems.

The AD524 has an output offset voltage drift of less than 25 μV/°C, input offset voltage drift of less than 0.5 μV/°C, CMR above 90 dB at unity gain (120 dB at G = 1000), and maximum nonlinearity of 0.003% at G = 1. In addition to the outstanding dc specifications, the AD524 also has a 25 kHz bandwidth (G = 1000). To make it suitable for high speed data acquisition systems, the AD524 has an output slew rate of 5 V/μs and settles in 15 μs to 0.01% for gains of 1 to 100.

As a complete amplifier, the AD524 does not require any external components for fixed gains of 1, 10, 100 and 1000. For other gain settings between 1 and 1000, only a single resistor is required. The AD524 input is fully protected for both powers-on and power-off fault conditions.

The AD524 IC instrumentation amplifier is available in four different versions of accuracy and operating temperature range. The economical A grade, the low drift B grade, and lower drift, higher linearity C grade are specified from −25°C to +85°C. The S grade guarantees performance to specification over the extended temperature range −55°C to +125°C. The AD524 is available in a 16-lead ceramic DIP, 16-lead SBDIP, 16-lead SOIC wide packages, and 20-terminal leadless chip carrier.

PRODUCT HIGHLIGHTS

1. The AD524 has guaranteed low offset voltage, offset voltage drift, and low noise for precision high gain applications.
2. The AD524 is functionally complete with pin programmable gains of 1, 10, 100, and 1000, and single resistor programmable for any gain.
3. Input and output offset nulling terminals are provided for very high precision applications and to minimize offset voltage changes in gain ranging applications.
4. The AD524 is input protected for both power-on and power-off fault conditions.
5. The AD524 offers superior dynamic performance with a gain bandwidth product of 25 MHz, full power response of 75 kHz and a settling time of 15 μs to 0.01% of a 20 V step (G = 100)

A1.2 Microprocessor Programmable Universal Active Filters (MAX260/MAX261/MAX262)

The MAX260/MAX261/MAX262 CMOS dual second order universal switched-capacitor active filters allow microprocessor control of precise filter functions. No external components are required for a variety of band pass, low pass, high pass, notch, and all pass configurations. Each device contains two second-order filter sections that place center frequency, Q, and filter operating mode under programmed control. An input clock, along with a 6-bit f0 program input, determine the filter's center or corner frequency without affecting other filter parameters. The filter Q is also programmed independently. Separate clock inputs for each filter section operate with a crystal, RC network, or external clock generator. The MAX260 has offset and DC specifications superior to the MAX261 and MAX262 and a center frequency (f0) range of 7.5 kHz. The MAX261 handles center frequencies to 57 kHz, while the MAX262 extends the center frequency range to 140 kHz by employing lower clock-to-f0 ratios. All devices are available in 24-pin DIP and small outline packages in commercial, extended, and military temperature ranges.

FEATURES

- Filter Design Software Available
- Microprocessor Interface
- 64-Step Center Frequency Control
- 128-Step Q Control
- Independent Q and f0 Programming
- Guaranteed Clock to f0 Ratio-1% (A grade)
- 75kHz f0 Range (MAX262)
- Single +5V and ±5V Operation

A1.3 Arduino DUE Technical Specification

Microcontroller	AT91SAM3X8E
Operating Voltage	3.3V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54(of Which 16 Provide PWM output)
Analog Input Pins	12
Analog Output Pins	2(DAC)
Total DC Output Current on all I/O lines	130mA
DC Current for 3.3V Pin	800mA
DC Current for 5V Pin	theoretical 1A, realistic 800mA
Flash Memory	512KB all available for the user applications
SRAM	96KB (64+32KB)
Data Flash	2 Mbit (250KB)
Clock Speed	84MHz

A1.4 Instantel Micromate Specification

Tri axial geophone

Table 5-1 Tri axial geophone Specification

Range	Up to 254 mm/s (10 in/s)
Response Standard	ISEE Seismograph Specification or DIN 45669-1
Resolution	0.00788 mm/s (0.00031 in/s)
Frequency Range (ISEE/DIN)	2 to 250 Hz, within zero to -3 dB of an ideal flat response / 1 to 315 Hz
Accuracy (ISEE/DIN)	+/- 5% or 0.5 mm/s (0.02 in/s), whichever is larger, between 4 and 125 Hz / DIN 45669-1 Standard
Transducer Density	2.2 g/cc (137 lbs/ft^3)
Maximum Cable Length (ISEE/DIN)	1,000 m (3,250 ft.)