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Theme:
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for Sustainable Societies

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PROCEEDINGS
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Theme: Technical and Vocational Education and Training for Sustainable Societies

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FOREWORD

Welcome for all respected scholars, researchers, post graduate students and especially Keynote Speakers to the 4 ICTVET. The theme of the conference focus on Technical and Vocational Education and Training for sustainable societies and consist of six subthemes. i.e Development of learning model on TVET, Workplace Learning and entrepreneurship, Innovation on applied engineering and information technology, Management and Leadership on TVET, Vocational and Technical Teachers education, and Assessment and Evaluation on TVET.

Sustainable society should be followed by the improvement of various factors that have impacts to the quality of vocational and technical education and training, particularly to overcome the competitiveness of the world business. As we have already known the rapid change of technology as well as the change of demography, having a great effects to the life of peoples in this world, The competitiveness need a collaborativeness to survive the life of millions peoples who lost their jobs. Young peoples as a productive generation have to be creative and innovative to face the competitiveness. So this proceeding contents consist of various findings of research in the field of vocational and technical education as well as applied technology and mainly based on the subthemes of the conference.

Finally, we would like to thank a million for all participants of this conference and all parties who support the success of this conference. Hopefully the seminars and scientific work of this seminar can be a reference material for basic education and elementary school teacher education in Indonesia.

Padang, July 2, 2018

Tim Editor
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>THE PROSPECT OF OFFSHORE IRON SAND IN TIRAM BEACH PADANG PARIAMAN REGENCY WEST SUMATERA</td>
<td>Adree Octova, Ansosry, Yoszi Mingsi Anaperta and Indah Elok Mukhlisah</td>
<td>1-7</td>
</tr>
<tr>
<td>2</td>
<td>OPTIMIZE OF LEAST-SQUARE INVERSE CONSTRAIN METHOD OF GEOELECTRICAL RESISTIVITY WENNER-SCHLUMBERGER FOR INVESTIGATION ROCK STRUCTURES IN MALALAK DISTRICTS OF AGAM WEST SUMATRA</td>
<td>Akmam, Amir Harman, Putra Amali</td>
<td>8-13</td>
</tr>
<tr>
<td>3</td>
<td>CLUSTER ANALYSIS DISTANCE INTER DISTRICT USING SINGLE LINKAGE METHOD FOR DETERMINATION OF MPLIK CAR OPERATION ZONE IN MEDAN CITY</td>
<td>Ali Ikhwan, Yasmin Mohd Yacob, Solly Aryza</td>
<td>14-16</td>
</tr>
<tr>
<td>4</td>
<td>EFFECT OF MIND MAPPING LEARNING METHODS ON LEARNING OUTCOMES</td>
<td>Almasri</td>
<td>17-21</td>
</tr>
<tr>
<td>5</td>
<td>DESIGN OF SKILL ASSESMENT IN COMPUTER NUMERICAL CONTROL PROGRAMMING SUBJECT</td>
<td>Ambiyar, Febri Prasetya, Yufrizal</td>
<td>22-26</td>
</tr>
<tr>
<td>6</td>
<td>MODIFICATION OF INPUT PUSHER ASSEMBLY OF LASER MARKING MACHINE</td>
<td>Arif Rahman Hakim</td>
<td>27-34</td>
</tr>
<tr>
<td>7</td>
<td>COLLABORATIVE PROJECT-BASED LEARNING: AN INSTRUCTIONAL DESIGN MODEL IN THERMODYNAMICS ON TECHNICAL VOCATIONAL EDUCATION AND TRAINING (TVET)</td>
<td>Arwizet K, Nizwardi Jalinus, Krismadinata</td>
<td>35-39</td>
</tr>
<tr>
<td>8</td>
<td>DEVELOPMENT OF EMPLOYEE INFORMATION SYSTEM-BASED WEB IN MAN 1 PADANG</td>
<td>Asrul Huda, Rendy Harisca</td>
<td>40-46</td>
</tr>
<tr>
<td>9</td>
<td>DECISION SUPPORT SYSTEM (DSS) WITH WP AND MFEP METHODS IN SELECTION OF BEST BABY CLOTHES</td>
<td>Asyahri Hadi Nasyuha, Rahmat Sulaiman Naibaho, Saniman</td>
<td>47-53</td>
</tr>
<tr>
<td>10</td>
<td>IMPROVING LEARNING MOTIVATION THROUGH IMPLEMENTATION PROBLEM SOLVING LEARNING STRATEGY</td>
<td>Budi Syahri, Primawati, Syahrial</td>
<td>54-58</td>
</tr>
<tr>
<td>11</td>
<td>THE MODELING OF MASSIVE LIMESTONE USING INDICATOR KRIGING METHOD (CASE STUDIES OF MASSIVE LIMESTONE IN PT SINAR ASIA FORTUNA)</td>
<td>Dedi Yulhendra, Yoszi Mingsi Anaperta</td>
<td>59-65</td>
</tr>
<tr>
<td>12</td>
<td>ELECTRONIC COMPONENT TESTER AS A LEARNING MEDIA FOR CLASS X STUDENTS AUDIO VIDEO ENGINEERING SMKN 1 SUMBAR</td>
<td>Delsina Faiza, Thamrin, Ahmaddul Hadi, Yongki Saputra</td>
<td>66-74</td>
</tr>
</tbody>
</table>
13. EFFECTIVENESS OF INTERACTIVE INSTRUCTIONAL MEDIA ON ELECTRICAL CIRCUITS COURSE: THE EFFECTS ON STUDENTS COGNITIVE ABILITIES
Doni Tri Putra Yanto, Sukardi, Deno Puyada .............................................................. 75-80

14. EVALUATION OF LEARNING PROCESS USING CIPP MODEL
Dwi Sudarono Putra, Misra Dandi Utama, Dedi Setiawan, Remon Lapisa, Ambiyar ........ 81-86

15. IMPLEMENTATION OF CONTEXTUAL TEACHING AND LEARNING ON ANALYZING ELECTRICAL CIRCUITS SUBJECT
Dwiprima Elvanny Myori, Citra Dewi, Erita Astrid, Ilham Juliwardi ............................... 87-91

16. DOMESTIC EMPLOYMENT PROCESSING SYSTEM ON WORKING PROTECTION AND TRANSMIGRATION USING GEOGRAPHIC INFORMATION SYSTEM (GIS)
Eddis Syahputra Pane, Kori Cahyono .......................................................... 92-98

17. CONDUCTING LABOR MARKET ASSESSMENT IN ENGINEERING CURRICULUM DEVELOPMENT
Edi Septe, Suryadimal, Wenny Marthiana, Nizwardi Jalinus, Ramli ............................. 99-105

18. DIFFERENCES IN LEARNING OUTCOMES IN THE PRACTICE OF MICROCONTROLLER SYSTEM USING MCS51 MICROCONTROLLER TRAINER KIT
Edidas, Dedy Irfan ........................................................................................................ 106-108

19. MICROCONTROLLER SKILL TRAINING FOR SMKN 2 PAYAKUMBUH AND SMKN 1 SUNGAI RUMBAI
Edidas, Legiman Slamet and Ilmiyati Rahmy Jasril .............................................. 109-113

20. THE EFFECT OF ISLAMIC WORK ETHICS AND SPiritual LEADERSHIP ON EMPLOYEE’S COMMITMEN IN PADANG SHARIA HOTELS
Eka Mariyanti, Rasidah Nasrah ............................................................................. 114-120

21. THE DESIGNING OF THE PROTOTYPE OF THE AIR QUALITY MEASURING HELMET
Eko Hariyanto, Solly Ariza Lubis, Zulham Sitorus, M. Iqbal ........................................ 121-124

22. REVIEW DEVELOPING OF PROJECT BASED AS INNOVATION INSTRUCTIONAL
Eko Indrawan .............................................................................................................. 125-130

23. IMPROVING THE ESP STUDENTS’ VOCABULARY BY USING PICTURES IN CIVIL ENGINEERING STUDY PROGRAM AT FIRST SEMESTER OF EKASAKTI UNIVERSITY PADANG
Elda Martha Suri ......................................................................................................... 131-133

24. INTEGRATED SERVICES SYSTEMS ELECTRONIC DEVELOPMENT FACULTY OF ENGINEERING PADANG STATE UNIVERSITY BASED ON JAVA DESKTOP
Elfi Tasrif, Asrul Huda .......................................................................................... 134-137

25. THE EFFECT OF STRATEGY OF TRAINING MODELS IN LEARNING ELECTRICAL INSTALLATION
Elfizon, Syamsuarnis, Oriza Candira ........................................................................ 138-141
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.</td>
<td>SOFTWARE DEVELOPMENT OF CONCENTRATION SELECTION WITH INTEREST TEST BASED ON INTELLIGENT SYSTEM</td>
<td>Elin Haerani</td>
<td>142-149</td>
</tr>
<tr>
<td>27.</td>
<td>NEEDS ANALYSIS ON INCREASING COMPETENCY TEST RESULTS STUDENTS IN S1 PROGRAM OF PUBLIC HEALTH SCIENCES STIKES HANG TUAH PEKANBARU</td>
<td>Emy Leonita, Nopriadi, Ahmad Satria Efendi, and Niswardi Jalinus</td>
<td>150-155</td>
</tr>
<tr>
<td>28.</td>
<td>THE READINESS OF STUDENT TO ENTREPRENEUR THROUGH INCORPORATION OF THE PILOT PROJECT PRACTICE</td>
<td>Ernawati</td>
<td>156-161</td>
</tr>
<tr>
<td>29.</td>
<td>EFFECT OF PROJECT BASED LEARNING MODEL IN IMPROVING STUDENT LEARNING RESULT</td>
<td>Erwinsyah Simanungkalit</td>
<td>162-166</td>
</tr>
<tr>
<td>30.</td>
<td>DESIGNING LEARNING TOOLS BY USING PROBLEM BASED INSTRUCTION (PBI) MODEL ON ENERGY RESOURCE MATERIAL INTEGRATED TO ENERGY SAVING CHARACTER</td>
<td>Estuhono</td>
<td>167-170</td>
</tr>
<tr>
<td>31.</td>
<td>THE DESIGN OF LECTURER PERFORMANCE EVALUATION MODEL BASED ON ANALYTIC NETWORK PROCESS (ANP)</td>
<td>Fenny Purwani, Nizwardi Jalinus, Ambiyar</td>
<td>171-175</td>
</tr>
<tr>
<td>32.</td>
<td>DEVELOPMENT OF ONLINE EXAMINATION SYSTEM USING WONDERSHARE QUIZCREATOR BASED ON WEB</td>
<td>FitriYanti, Rijal Abdullah, Krismadinata</td>
<td>176-180</td>
</tr>
<tr>
<td>33.</td>
<td>THE VALIDITY OF TRAINERON MATERIALS SCIENCE AND DEVICES SUBJECT AT DEPARTMENT OF ELECTRICAL ENGINEERING</td>
<td>Fivia Eliza, Dwiprima Elvanny Myor, Hastuti</td>
<td>181-185</td>
</tr>
<tr>
<td>34.</td>
<td>TRAINING MODEL-BASED KNOWLEDGE MANAGEMENT SYSTEM FOR VOCATIONAL HIGH SCHOOL TEACHERS SKILLS ENGINEERING COMPUTER NETWORK</td>
<td>Gunawan Ali, Kasman Rukun, Syahril</td>
<td>186-193</td>
</tr>
<tr>
<td>35.</td>
<td>FUZZY LOGIC BASED CONTROLLER FOR BUCK CONVERTER</td>
<td>Habibullah, Irma Husnaini, Asnil</td>
<td>194-200</td>
</tr>
<tr>
<td>36.</td>
<td>A NEW DESIGN OF HANDLELESS STIRRED DEVICE</td>
<td>Hanne Aulia, Riki Mukhaiyar</td>
<td>201-204</td>
</tr>
<tr>
<td>37.</td>
<td>ACADEMIC INFORMATION SYSTEM OF STIKES PERINTIS PADANG</td>
<td>Harleni, Marisa</td>
<td>205-209</td>
</tr>
<tr>
<td>38.</td>
<td>DESIGN OF ELECTROMAGNETIC REGENERATIVE SHOCK ABSORBER AS A TOOL OF HARVESTING VIBRATION ENERGY ON VEHICLE</td>
<td>Hasan Maksum, Aslimeri, Putra Jaya, Wanda Afnison</td>
<td>210-213</td>
</tr>
</tbody>
</table>
39. THE EFFECTIVENESS OF USING POSTER AND VIDEO MEDIA IN EDUCATION ABOUT DANGERS OF SMOKING ON KNOWLEDGE AND ATTITUDES OF SENIOR HIGH SCHOOL 12 PEKANBARU STUDENTS  
Hastuti Marlina, Reno Renaldi .......................................................... 214-217

40. A MODEL PREVENTIVE MAINTENANCE CONTROL IN THE MACHINE TURNING AT WORKSHOP THE FACULTY OF ENGINEERING OF THE STATE UNIVERSITY IN PADANG  
Hefri Hamid, Nizwardi Jalinus, Syahril, Ambiyar, Febri Prasetya .................... 218-224

41. INVESTIGATION OF CHEMICAL FEASIBILITY AND DISTRIBUTION OF IRON SAND RESERVE REGIONAL AREA OF AGAM DISTRICT FOR CEMENT RAW MATERIAL IN PT. SEMEN PADANG  
Heri Prabowo, Sumarya........................................................................... 225-227

42. THE DEVELOPMENT OF INTERACTIVE MULTIMEDIA-BASED LEARNING MEDIA USING ADOBE FLASH CS3 AND CAMTASIA IN PROBLEM-SOLVING LEARNING IN ELEMENTARY MATHEMATICS OF IN STUDENT PGSD STKIP ADZKIA IN PADANG  
Ika Parma Dewi, Lativa Mursida, Rizkayeni Marta........................................ 228-235

43. ART EDUCATION THROUGH FREE EXPRESSION APPRECIES, DISCIPLINE SCIENCE, AND MULTICULTURAL AS EFFORTS TO IMPROVE STUDENT CREATIVITY  
Indra Irawan ........................................................................................... 236-242

44. THE INFLUENCE OF USING ANIMATION MEDIA AND LEARNING MOTIVATION TOWARD LEARNING RESULT OF AUTOMOTIVE STUDENTS IN SMK N 2 PAYAKUMBUH  
Indra Wahyu, Fahmi Rizal, Rijal Abdullah.................................................. 243-248

45. INFORMATION SYSTEM AND REPORT VALUE PROCESSING BASED MICROSOFT VISUAL BASIC 6.0 ON SENIOR HIGH SCHOOL (CASE STUDY AT SMAN 12 PADANG)  
Indra Wijaya, Isra Mouludi, Fandy Neta, Yaslinda Lizar, Satria Ami Marta .............. 249-256

46. DESIGN OF SIMULATOR FOR REPLACEMENT OF TOOLSPRACTICE DIGITAL ENGINEERING IN THE VOCATIONAL SCHOOL  
Irwan Yusti, Ganefri, Ridwan ...................................................................... 257-259

47. CELL ROTATION TO RESOLVE THE WEAKEST CELL DAMAGE IN THE BATTERY PACK IN DISCHARGING PROCESS  
Irwanto Zarma Putra, Citra Dewi ................................................................ 260-263

48. IMPROVEMENT OF CONCRETE QUALITY WITH ADDITION OF SUNUA PASIR PADANG PARIAMAN WEST SUMATRA  
Iskandar G. Rani, Widya Salmita ............................................................... 264-268

49. SIMPLE WATER PURIFIER USING MULTILEVEL SYSTEM  
Jasman, Nelvi Erizon, Syahrul, Junil Adri, Bulkia Rahim ................................ 269-272
50. DESIGN OF LIBRARY INFORMATION SYSTEM USING BARCODE ON SMAN 1 SOLOK CITY  
Jeprimansyah .................................................................................................................. 273-280

51. THE DESIGN OF THE SIGNAL MEASUREMENT DEVICE OF BODY’S BIOELECTRICAL IMPEDANCE By USING THREE ELECTRODES  
Juli Sardi, Hastuti, Ali Basrah Pulungan ........................................................................ 281-286

52. PATIENT INFORMATION SYSTEM DESIGN ON MATERNITY HOSPITAL RESTU IBU PADANG  
Jusmita Weriza .............................................................................................................. 287-293

53. IDENTIFICATION THE IMPORTANCE OF LEARNING TOOLS DEVELOPMENT ON ENERGY-EFFICIENT BUILDING INNOVATIONS USING ROOT CAUSE ANALYSIS  
Kemala Jeumpa ............................................................................................................. 294-297

54. DECISION SUPPORT SYSTEM FOR RECOMENDATION CERTIFICATION TEACHER ON VOCATIONAL HIGH SCHOOL  
Khairul, Rahmad Budi Utomo ....................................................................................... 298-302

55. IMPACT OF THE TWI LEARNING MODEL IN LEARNING STONE AND CONCRETE CONSTRUCTIONS ON VOCATIONAL EDUCATION  
Kinanti Wijaya, Daniel IrvansiusTampubolon .................................................................. 303-307

56. THE EFFECT OF SOFTWARE MASTERCAME TOWARD MECHANICAL ENGINEERING STUDENTS PERFORMANCE IN MAKING PRODUCT WITH CNC MILLING MACHINE IN VOCATIONAL HIGH SCHOOL 1 PADANG  
Kms. Muhammad. Avrieldi, Suparno, Nofri Helmi ........................................................... 308-310

57. LEARNING BROADCAST VIDEO SYSTEM WITH H264 VIDEO ENCODING RASPBERRY PI  
Leni Marlina, Aswandi ..................................................................................................... 311-315

58. OPTIMIZATION OF EXTERNAL LIGHTNING PROTECTION SYSTEM DESIGN IN BUILDING CENTER FOR INFORMATION TECHNOLOGY AND DATA BASE (PTIPD) UIN SUSKA RIAU  
Liliana, Afriani, Anwardi ............................................................................................... 316-322

59. A NEW MODEL MOBILE LEARNING MANAGEMENT SYSTEM BASED ON MOODLE IN UNIVERSITY  
Lita Sari Muchlis, Kasman Rukun, Krismadinata, Yahfizham ......................................... 323-327

60. DEVELOPMENT OF MECHANICAL TECHNOLOGY LEARNING MODULE PROGRAM EXPERTISE OF SMK ENGINEERING  
M. Giatman, Waskito, Maruli Sihombing ........................................................................ 328-332

61. SECURITY OF MEDICAL RECORD WITH RIVEST SHAMIR ADLEMAN (RSA) METHOD  
M.Syaifuddin, Ahmad Fitri Boy, Ali Ilkwan ...................................................................... 333-336

62. RAHMATAN LIL ALAMIN, THE CONCEPT OF MULTICULTURAL EDUCATION  
Muh. Barid Nizarudin Wajdi, Achmad Fathoni Rodli ..................................................... 337-340
63. LESSON STUDY FOR IMPROVING A LEARNING QUALITY
Muh. Barid Nizarudin Wajdi, Andi Mursidi ................................................................. 341-345

64. THE ROLE OF INFORMATION TECHNOLOGY IN THE IMPROVEMENT OF TEACHER’S COMPETENCIES AND TEACHING LEARNING PROCESS EFFECTIVENESS IN ESA SEJAHTERA SCHOOL PEKANBARU
Muhammad Luthfi Hamzah, Hamzah, Astri Ayu Purwati ................................................. 346-350

65. IMPLEMENTATION OF PROJECT BASED LEARNING MODEL IN COURSE WEB DESIGN
Muhammad Sabir Ramadhan, Neni Mulyani, Muhammad Amin........................................ 351-357

66. MEASUREMENT MODEL OF CONTRIBUTED FACTOR AND INDICATOR TOWARDS VOCATIONAL EDUCATION PRODUCTIVITY
Mulianti, Ambiyar, Generousdi and Rodesri Mulyadi .......................................................... 358-364

67. ORNAMENTS ON THE TRADITIONAL ACEHNESE HOUSE IN CENTRAL ACEH, ACEH PROVINCE
N Novita, M Mukhirah, R Dewi, Fitriana, F Noer, F Fadillah, E Erni.................................... 365-368

68. DESIGNING STRATEGY MAPS FOR PRIVATE ENGINEERING COLLEGE
Nanang Alamsyah, Larisang, Muhammad Ansyar Bora ......................................................... 369-376

69. DESIGN OF INTERACTIVE MEDIA INTERACTIVE EYE LESSONS FOR CLASS III SD N 04 BARINGIN PADANG CULTURAL CULTURAL FLOOR BASED ON MULTIMEDIA
Nelda Azhar, Putra Jaya, Asrul Huda, Etika Fahmidyah ....................................................... 377-383

70. DEVELOPMENT OF MALAY FRUIT ORNAMENT
Netty Juliana ......................................................................................................................... 384-387

71. THE CONTRIBUTIONS OF DISCIPLINE AND ENVIRONMENTAL KNOWLEDGE ON CLEAN BEHAVIOR OF STUDENTS IN PUBLIC ELEMENTARY SCHOOL KAMPUNG BARU PARIAMAN, WEST SUMATERA
Nurhasan Syah, Sanny Edinov .............................................................................................. 388-393

72. ANALYSIS OF VOLUME AND STRONG CONCRETE IMPROVEMENT ON NON-SAND CONCRETE MIXED WITH ADDITION BAKING POWDER
Nurmaidah ......................................................................................................................... 394-398

73. BRACING CROSS SECTION EFFECT TO DISSIPATION ENERGY BY NUMERICAL ANALYSIS
Prima Zola, Rahmat, Fitra Rifwan ......................................................................................... 399-405

74. DEVELOPMENT OF MODEL OF PROPELLER-CROSS FLOW WATER TURBINE FOR PICO HYDRO POWER GENERATOR
Purwantono, Refdinal, Hendri, Syahrul ................................................................................. 406-408

75. THE POTENTIAL OF RENEWABLE ENERGY (STUDY CASE IN TOMUAN HOLBUNG VILLAGE, ASAHAN REGENCY OF SUMATERA UTARA PROVINCE)
Rahmaniar, Agus Junaidi ....................................................................................................... 409-413
76. VIRTUAL LAB IMPLEMENTATION QOS METAROUTER ON COMPUTER NETWORK LEARNING
Raimon Efendi ........................................................................................................ 414-418

77. BLASTING DESIGN DEVELOPMENT AREA DECLINE CIBITUNG AND CIKONENG UNDERGROUND MINE PT CIBALIUNG SUMBERDAYA BANTEN
Raimon Kopa, Afdhal Husnuzan, Bambang Heriya .............................................. 419-423

78. ANALYSIS OF LEARNING COMPETENCY ENGINEERING STUDENTS VOCATION D 3 FT UNP
Ramli, Febri Prasetya .................................................................................................. 424-429

79. FACTORS AFFECTING THE AUTOMOTIVE ENGINEERING STUDENTS’ INTEREST ON TEACHING PROFESSION
Rasinov Chandra, Anggi Aprianto, Mawardi, Reza Rahmadani ............................... 430-435

80. AN EXPERIMENTAL STUDY ON THE EFFECT OF CENTRIFUGAL CLUCTH COOLING GROOVE ON MOTORCYLCE PERFORMANCE
Remon Lapisa, Hendika Syahputra, Irma Yulia Basri, Rifidarmon, Hendra Dani Saputra 436-440

81. EXPERT MODEL SYSTEM ON ENTREPRENEURSHIP PERSONALITY
Resmi Darni, Z. Mawardi Efendi and Selamat Triono ............................................. 441-446

82. THE ANALYZED OF TAR AS WASTE MATERIAL OF BITUMINOUS COAL GASIFICATION BY USING GASCHROMATOGRAPHY
Rijal Abdullah and Hengki Ade Satria ...................................................................... 447-450

83. EMPLOYEE PRODUCTIVITY IN TWO CROSS CULTURES BASED ENTREPRENEURSHIP
Riki Adriadi, Ganefri and Fahmi Rizal ...................................................................... 451-455

84. DEVELOPMENT OF INTERACTIVE MULTIMEDIA CD OF INSTRUCTIONAL MEDIA ON BUILDING CONSTRUCTION
Rizky Indra Utama, Nurhasan Syah, Rijal Abdullah .................................................. 456-458

85. MULTIMEDIA INTERACTIVE IN WEB PROGRAMMING SUBJECTS
Rusli Saputra, Sophan Sophian, Delia Putri .............................................................. 459-464

86. PREDICTED VULNERABILITY ASSESSMENT OF NON ENGINEERED HOUSES BASED ON DAMAGE DATA OF THE 2009 PADANG EARTHQUAKE IN PADANG CITY, INDONESIA
Rusnardi Rahmat Putra, Junji Kiyono and Aiko Furukawa ........................................ 465-472

87. TWO SPECIES OF TERMITE DAMAGING TO BUILDING AND HOUSES AT BANDA ACEH (SUMATRA, INDONESIA)
S Syaukani, M Bahi, M Muslim, M Shabri Abd Majid, D Sutekad, Y Yasmin, N Novita 473-476

88. PERSONNAL MANAGEMENT IN INFORMATION SYSTEMS APPLICATIONS WITH TOGAF FRAMEWORK
Safrian Aswati, Saleh Malawat, Suhendra, Iskandar, Yessica Siagian, Arridha Zikra Syah 477-482
89. ANALYZING OF TECHNICAL CUTTING OF EMPTY PALM BUNCHES
Safril, Dedi Wardianto................................................................. 483-492

90. DESIGNING AND MANUFACTURE OF RADIUS PAJI HAIRERS (PAHAT RADIUS POST) ON LATHE MACHINE FOR LABORATORY AND MODULES TEACH
Saiful Anwar, Rindi Genesa Hatika, B.Herawan Hayadi................................. 493-498

91. MATERIAL SELECTION ANALYSIS AND MAGNET SKEWING TO REDUCE COGGING TORQUE IN PERMANENT MAGNET GENERATOR
Sepannur Bandri, M. Aldi Tio.................................................................... 499-506

92. COMPARISON OF DECISION TREE ALGORITHM METHOD (C4.5) AND NAIVE BAYES TO IDENTIFY STUDENT LEARNING RESULTS WITH COOPERATIVE LEARNING MODEL
Sri Restu Ningsih.................................................................................... 507-511

93. ONLINE ASSESSMENT TOOLS FOR 2013 CURRICULUM BASE ON INFORMATION TECHNOLOGY
Suartin, Hambali, Oriza Chandra .................................................................. 512-517

94. GAME BASED LEARNING TO IMPROVEMENT TEACHERS KNOWLEDGE FOR TEACHING STRATEGY IN THE CLASS
Suherman................................................................................................. 518-523

95. LEARNING RESPONSE OF JOURNEY LEARNING COOPERATIV LEARNING AND LEARNING MODULE IN EDUCATION MEDIA LEVEL
Suparno, Bulkia Rahim, Zonny Amanda Putra, Junil Adri, Jasman...................... 524-528

96. NEED ANALYSIS APPLICATION ON THE FEASIBILITY STUDY OF THE HYDROELECTRIC POWER SELECTION (CASE IN SOLOK, PESISIR SELATAN AND SIJUNJUNG REGENCY)
Suryadimal, Edi Septe, Wenny Martiana, Fahmi Rizal, Nizwardi Jalinus................ 529-534

97. DEVELOPING SOFT SKILLS LEARNING MODELFOR MECHANICAL ENGINEERING STUDENTS OF VOCATIONAL HIGH SCHOOL
Suryo Hartanto .......................................................................................... 535-538

98. IMPACT OF WORK-BASED LEARNING OF CONCRETE STONE WORK PRACTICE ON DIPLOMA-III CIVIL ENGINEERING STUDENTS
Syafiatun Siregar ....................................................................................... 539-543

99. DEVELOPMENT OF WEB-BASED DECISION SUPPORT SYSTEM FOR SCHOLARSHIP RECIPIENTS SELECTION USING ANALYTICAL HIERARCHY PROCESS (AHP) METHOD
Titi Sriwahyun, Dedi Irfan, Ika Pharma Dewi and Hanny Maharani..................... 544-552

100. EFFECT OF ENGINE TEMPERATURE CHANGES ON INJECTION TIME OF FUEL AND GAS EMISSION OF GASOLINE ENGINE
Toto Sugiarto, Dwi Sudarno Putra, Wawan Purwanto...................................... 553-557
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>101.</td>
<td>EARTHQUAKE AND TSUNAMI DISASTER MITIGATION TRAINING FOR ELEMENTARY SCHOOL STUDENTS IN THE COASTAL AREA OF PADANG PARIAMAN DISTRICT WITH KYOTO INTERNATIONAL DISASTER PREVENTATION SCHOOL METHOD</td>
<td>Totoh Andoyono, Fitra Rifwan, Revian Bodi, Prima Zola, Annisa Prita</td>
<td>558-560</td>
</tr>
<tr>
<td>102.</td>
<td>FUNCTIONAL MEMBERSHIP ANALYSIS OF FUZZY INFERENCE SYSTEM SUGENO IN ANEMIA CLASSIFICATION</td>
<td>Tri Monarita Johan</td>
<td>561-563</td>
</tr>
<tr>
<td>103.</td>
<td>DEVELOPMENTAL OF MEDIA LEARNING BASED ON TUTORIAL VIDEO AT CHARACTER MAKE UP SUBJECT IN SMKN 6</td>
<td>TyasAsih Surya Mentari, MurniAstuti, and Linda Rosalina</td>
<td>564-570</td>
</tr>
<tr>
<td>104.</td>
<td>PSYCHOLOGICAL FACTORS INFLUENCING THE DECISION MAKING OF PURCHASING PRODUCTS VIA ONLINE</td>
<td>Ulfa Annida Damanik, Sri Wening</td>
<td>571-577</td>
</tr>
<tr>
<td>105.</td>
<td>IMPROVING TEACHERS’ PROFESSIONALISM APPROPRIATE TO NEW CURRIRULUM 2017 FOR VOCATIONAL SCHOOLS BY CAPACITY BUILDING AND WORKSHOP ABOUT PREPARING LOCAL GOVERNMENT FINANCIAL STATEMENT; AN EXPERIMENTAL STUDY ON ACCOUNTING TEACHERS’ FROM VOCATIONAL SCHOOLS IN WEST SUMATERA PROVINCE</td>
<td>Vita Fitria Sari, Mayar Afriyenti, Mia Angelina Setiawan</td>
<td>578-585</td>
</tr>
<tr>
<td>106.</td>
<td>THE DEVELOPMENT OF VIT (VOCATIONAL INTEREST TEST) MODEL USING DECISION SUPPORT SYSTEM (DSS) TECHNIQUE</td>
<td>Vitriani</td>
<td>586-590</td>
</tr>
<tr>
<td>107.</td>
<td>ANALYSING INFORMATION SYSTEM OF ACADEMIC SERVICES IN THE UNIVERSITY</td>
<td>Wahyu Prima, Ganefri, Krismadinata</td>
<td>591-595</td>
</tr>
<tr>
<td>108.</td>
<td>RESOURCE SHARING–BLENDED PROJECT BASED LEARNING (RS-BPBL©) MODEL DEVELOPMENT IN VOCATIONAL HIGH SCHOOL</td>
<td>Wahyudi</td>
<td>596-602</td>
</tr>
<tr>
<td>109.</td>
<td>DEVELOPMENT ASSESSMENT MODEL TO HIGH ORDER THINKING SKILL ORIENTATE FOR EVALUATION STUDENT COMPETENCY</td>
<td>Wakhinuddin S, Bahrul Amin, Waskito</td>
<td>603-605</td>
</tr>
<tr>
<td>110.</td>
<td>USE OF GEARBOX VIAR ON FISHING SHIPS</td>
<td>Wakhinuddin S, Donny Fernandez, Andrizal, M Nasir, Rifdarmon</td>
<td>606-609</td>
</tr>
<tr>
<td>111.</td>
<td>THE APPLICATION OF SIMPLE STRAIN GAUGE DYNAMOMETER IN LEARNING STYLE CUTTING LATHE</td>
<td>Wenny Marthiana, Suryadimal, Edi Septe, Duskiardi, Andika</td>
<td>610-613</td>
</tr>
<tr>
<td>112.</td>
<td>DESIGN OF ANDROID BASED INTERACTIVE BOOK IN INTEGRATED ISLAMIC ELEMENTATY SCHOOL OF LAN TABUR PAGARALAM CITY</td>
<td>Yadi, Efan, Sigit Candra Setya</td>
<td>614-617</td>
</tr>
</tbody>
</table>
113. SMART CLASSROOM DESIGNS IN THE SMART EDUCATIONAL ENVIRONMENT
Yasdinul Huda, B Herawan Hayadi ................................................................. 618-626

114. BUILD AND DESIGN OF BUSINESS INTELLIGENCE UNIVERSITY SYSTEM AS
DECISION SUPPORT ACADEMIC
Yaslinda Lizar, Asriwan Guci ........................................................................... 627-636

115. SOIL STABILITY USING CEMENT PCC IN LUBUK MINTURUN PADANG,
INDONESIA
Yocky Syaida Adha Putra, Tengku Ahmad Fauzan Syah .................................. 637-642

116. INFLUENCE THE LEARNING STRATEGY AND ENTRY BEHAVIOR TO YIELD
LEARNING BUILDING CONSTRUCTION AND DRAWING 1 OF STUDENT
Yuwalitas Gusmareta, Fahmi Rizal, Nurhasan Syah .......................................... 643-646

117. IMPLEMENTATION OF DISASTER PREPARED SCHOOL (SSB) IN WEST
PASAMAN DISTRICT WEST SUMATERA PROVINCE
Yuwalitas Gusmareta, NurhasanSyah, Laras Andreas Oktavia, RizkyIndraUtama,
MuviYandra ........................................................................................................ 647-649

118. USING MOBILE TELECOMMUNICATIONS -2000 INTERNATIONAL FOR
ANALYZING TECHNOLOGY NETWORK ERA 4G-LTE
ZulhamSitorus, Ganefri, NizwardiJalinus ......................................................... 650-653

119. FACTORS AFFECTING STUDENTS IN CHOOSING COMPUTER ENGINEERING
DEPARTMENT IN STT PAYAKUMBUH
Zulkifili, Dilson, Rahmad Al Rian ..................................................................... 654-659

120. FACTORS EFFECTING ELEMENTARY SCHOOL TEACHER READINESS ON
IMPLEMENTING CURRICULUM IN WEST SUMATERA
Zuryanty, Hamimah, Mulyani Zein ................................................................. 660-665
THE DESIGN OF THE SIGNAL MEASUREMENT DEVICE OF BODY’S BIOELECTRICAL IMPEDANCE BY USING THREE ELECTRODES

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ABSTRACT: This article aims to design the signal measurement device of body’s bioelectrical impedance (bio-impedance). Previous measurement methods are less effective because they used four electrodes. While this device is using three electrodes. The device consists of three integrated circuits, i.e. stimulate’s circuit, instrumentation’s circuit, and minimum system. The design used three electrodes method which one electrode is mounted on the left shoulder, one electrode on the right shoulder, and another is functionalized as the ground which is mounted between the left and the right shoulder. The measured voltage is represented bio-impedance’s value. Based on the experiment, the device is able to measure bio-impedance’s signal of human’s body. The obtained signal could be used as a control signal.

Keywords: bio-impedance, three electrodes, a control signal, measurement

1. INTRODUCTION

The bioelectrical impedance (bio-impedance) is a passive electrical part found in body tissues. The magnitude of bio-impedance varies because it’s influenced by muscle contraction that occurs in body tissue. The bio-impedance’s measurements can be performed on almost any part of the body as long as the muscles in that part are still functioning or contracting. To measure the magnitude of bio-impedance, the body must be passed a small electrical current through an electrode, then measure the potential difference between two points on the current flowing part. The measured bio-impedance [1] can be known by using Ohm’s law.

\[ Z = \frac{V}{I} \]

Where \( V \) is the voltage and \( I \) is the current and \( Z \) is the body impedance.

The biopotential electrode is an interface between the body and the electronic measuring instrument. This connector is very important because the current flowing body is the currents in the form of ions. While the current that moves on electronic devices in the form of electrons. Therefore, the electrode is a transducer capable of converting ion currents into electric currents. This current conversion is based on the oxidation-reduction reaction. The electrical currents within the metal move electrons to move from the metal surface and caused oxidation reactions that produce cations. This cation undergoes a discharge (reduction reaction) in the electrolyte. The reactions that arise in the anions are similar; anion toward the electrodes surface and oxidized to neutral and gives some electrons to the electrodes [1].

The electronics model of the electrodes can be understood as in Figure 1 [1]. \( E_{cell} \) is half-cell potential, \( C_d \) and \( R_d \) are the impedance of the electrodes, and \( R_s \) is the cable resistance. When this is analyzed, it can be realized that the resistivity of the electrodes will decrease due to the frequency effect, the half-cell potential will also decrease as a result of frequency.

![Mathematical Model of Electrodes](image)

There are two methods of measuring bio-impedance previously, namely bipolar and the tetrapolar electrode. The bipolar method uses two electrodes to flow the current and measure the potential difference, while the second method uses two pairs of electrodes to flow the current and measure the large potential difference. Although bipolar methods are easier, researchers generally [1] [2] [3] [4] [5] [6] [7] used tetrapolar methods in...
bio-impedance measurement because the measured results were better than the bipolar method. The method of measuring the tetrapolar as seen in Figure 2 [8].

![Fig. 2 Four Electrodes Method](image)

The measurement’s method of four electrodes is considered to be less efficient and effective since it used too many electrodes for 1 measurement channel. To that end, this article tried to offer another alternative in measuring body bio-impedance. The measurement’s method used only 3 electrodes that can measure on 2 channel at the same time.

2. METHODS

In general, the bio-impedance’s measurement system consists of a stimulation’s circuit and instrumentation’s circuit. The stimulation’s circuit is a circuit which alternates current source with a frequency of 50 KHz and a maximum amplitude of 0.5 mA. Then, the current will be injected into the body through an electrode. The other part is a series of instrumentation. This circuit is used to measure potential differences in the simulated body. The measured voltage represents the value of bio-impedance [9].

The voltage is amplified by using instrumentation’s circuit amplifiers that have a high common mode rejection ratio (CMRR) capability. Once amplified, the voltage is passed to the band pass filter circuit to take the desired frequency, ie ± 50KHz. Thus, the voltage data will be spared from electromyography (EMG) signal interference ranging from 20Hz to 500 Hz, artificial movement disturbance, and radio wave interference. The output voltage of the filter circuit then goes into the circuit of the voltage rectifier in order to facilitate the microcontroller in retrieving and processing the data. In this articles used 2 series of stimulation and 2 pieces of instrumentation to perform measurements on two channels simultaneously. The system requires three electrodes. The diagram block of the system is showed in Figure 3.

![Fig. 3 Diagram Block of Bio-impedance Measurement System](image)

2.1 Stimulation’s Circuit

This circuit aims to generate an alternating current source with a frequency of 50 kHz and a maximum amplitude of 0.5 mA. The stimulation’s circuit consists of sine wave generator and voltage controlled current source (vccs).

2.1.1 Sine Wave Generator

The sinusoidal signal generating circuit consists of square wave generator circuit, low pass filters, and non-inverting amplifiers. The square wave generator circuit aims to produce a square signal as free running with the addition of setting the frequency of signal output. The desired output frequency of this circuit is 50 Khz. The low pass filter circuit is used to obtain the output of a sinusoidal signal from the square signal input of the square wave generator circuit. The Cut off frequency of this LPF circuit is set to equal the frequency of the signal generated by the square wave generator circuit which is 50KHz. The non-inverting amplifier circuit is used as the voltage amplitude regulator of the sinusoidal signal generated by the low pass filter circuit.

2.1.2 Voltage Controlled Current Source (VCCS)

The function of VCCS’s circuit is to convert a sinusoidal voltage signal into a sinusoidal current signal which will be injected into the patient’s body through the electrode. This circuit is composed of two op-amps that have a bandwidth gain of 3 MHz, low current bias current (50 pA), and high slew rate (10 V/ s).
2.2 Bio-impedance Instrumentation’s Circuit

This circuit is used to measure potential differences in the simulated body. The measured voltage represents the amount of bio-impedance. The instrumentation circuit consists of amplifier instrumentation’s circuit, bandpass filter, AC to DC converter, and differential amplifier’s circuit. The function of amplifier instrumentation’s circuit is to strengthen the measured bio-impedance’s voltages. Bandpass filter served to remove noise and to pass the frequency with a range of 45 kHz to 55 kHz. AC to DC converter aims to convert Ac voltage into DC voltage. The differential amplifier function as a final amplifier before it’s processed by a microcontroller.

The installation and placement of electrodes for measuring bio-impedance are performed on the back/shoulders as it has the most optimal bio-impedance [7]. In addition, the section also provides many alternatives to provide the control signal. Figure 4 shows the positioning of the electrode.

Fig. 4 The positioning of three electrodes

3. RESULT AND DISCUSSION

3.1 The Test of Simulation’s Circuit

3.1.1 The Test of Square Wave Generator Circuit

This circuit serves to generate a square wave with an adjustable frequency. The conducted experiments result that this circuit can generate frequency’s range between 23 KHz and 238 KHz. Since this study required a frequency of 50 KHz. The output signal of this circuit is shown in Figure 5.

Fig. 5 The output signal of square wave generator circuit

3.1.2 The Test of Low Pass Filter

The test of low pass filter circuit is done by providing sinusoidal voltage input with constant amplitude. The frequency of voltage varied from 1 KHz to 500 KHz and measured output voltage using a voltmeter. Figure 6 is graphic of the frequency response of the LPF circuit and the output signal.

Table 1 Result of the test of LPF’s circuit

<table>
<thead>
<tr>
<th>Vin  (Volt)</th>
<th>F in  (Hz)</th>
<th>V out  (Volt)</th>
<th>Gain (V out/V in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>1000</td>
<td>740</td>
<td>1.1923</td>
</tr>
<tr>
<td>500</td>
<td>5000</td>
<td>740</td>
<td>1.1923</td>
</tr>
<tr>
<td>500</td>
<td>10000</td>
<td>720</td>
<td>1.1730</td>
</tr>
<tr>
<td>500</td>
<td>15000</td>
<td>690</td>
<td>1.1442</td>
</tr>
<tr>
<td>500</td>
<td>20000</td>
<td>700</td>
<td>1.1538</td>
</tr>
<tr>
<td>500</td>
<td>25000</td>
<td>680</td>
<td>1.1346</td>
</tr>
<tr>
<td>500</td>
<td>30000</td>
<td>690</td>
<td>1.1442</td>
</tr>
<tr>
<td>500</td>
<td>35000</td>
<td>670</td>
<td>1.125</td>
</tr>
<tr>
<td>500</td>
<td>40000</td>
<td>610</td>
<td>1.0673</td>
</tr>
<tr>
<td>500</td>
<td>45000</td>
<td>510</td>
<td>0.9711</td>
</tr>
<tr>
<td>500</td>
<td>50000</td>
<td>359</td>
<td>0.8259</td>
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<tr>
<td>500</td>
<td>60000</td>
<td>348</td>
<td>0.5269</td>
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<tr>
<td>500</td>
<td>70000</td>
<td>327</td>
<td>0.3144</td>
</tr>
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<td>500</td>
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<td>200</td>
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<tr>
<td>500</td>
<td>90000</td>
<td>131</td>
<td>0.1259</td>
</tr>
<tr>
<td>500</td>
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<td>88.7</td>
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</tr>
<tr>
<td>500</td>
<td>200000</td>
<td>6.38</td>
<td>0.0061</td>
</tr>
<tr>
<td>500</td>
<td>300000</td>
<td>1.74</td>
<td>0.0016</td>
</tr>
<tr>
<td>500</td>
<td>400000</td>
<td>0.814</td>
<td>0.0007</td>
</tr>
<tr>
<td>500</td>
<td>500000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
3.1.3 The Test of Inverting Amplifier Circuit

The function of this circuit is to regulate the amplification of the sinusoidal signal generated by the LPF so that it can easily adjust the signal amplitude desired. In this system, the designed sinusoidal signal generated has a value of 2 Vrms. Figure 7 is the output signal of the inverting amplifier circuit.

3.1.4 The Test of VCCS’s Circuit

The output of this circuit is set to produce a sinusoidal current with a frequency of 50 KHz, as well as a constant amplitude of 0.5mA. With 2V input signal amplitude, the multi-tune is set to have a resistance of 1 KΩ. The test of this circuit is done by using multi-tune of the 5K variable resistor. Table 2 is the result of the test of VCCS’ circuit.

<table>
<thead>
<tr>
<th>Resistance (Ω)</th>
<th>No Load Current (mA rms)</th>
<th>Measured Current (mA rms)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.5</td>
<td>0.499</td>
<td>0.2</td>
</tr>
<tr>
<td>200</td>
<td>0.5</td>
<td>0.498</td>
<td>0.4</td>
</tr>
<tr>
<td>300</td>
<td>0.5</td>
<td>0.497</td>
<td>0.6</td>
</tr>
<tr>
<td>400</td>
<td>0.5</td>
<td>0.496</td>
<td>0.8</td>
</tr>
<tr>
<td>500</td>
<td>0.5</td>
<td>0.495</td>
<td>1.0</td>
</tr>
<tr>
<td>600</td>
<td>0.5</td>
<td>0.494</td>
<td>1.2</td>
</tr>
<tr>
<td>700</td>
<td>0.5</td>
<td>0.492</td>
<td>1.6</td>
</tr>
<tr>
<td>800</td>
<td>0.5</td>
<td>0.49</td>
<td>2.0</td>
</tr>
<tr>
<td>900</td>
<td>0.5</td>
<td>0.49</td>
<td>2.0</td>
</tr>
<tr>
<td>1000</td>
<td>0.5</td>
<td>0.488</td>
<td>2.4</td>
</tr>
</tbody>
</table>

When the variable resistor is not installed, the VCCS’s circuit is only connected to the amperemeter. In the initial conditions, I_out is set to a value of 0.5mA. From the test results, if the resistor value is high, then the error is also high. This indicated that the voltage controlled current source circuit is still not stable enough to produce a constant current with varying loads. This is not a problem in the application of bio-impedance measurement in the back area, because the impedance’s range is not too big which is about 250 - 270 [8].

3.2 The Test of Instrumentation’s Circuit

3.2.1 The Test of Instrumentation Amplifier

This test is performed by measuring the level of linearity from amplification of this instrumentation by using the input of the sinusoidal signal generator function. In the process of the multi-tune’s test is set to have a gain of 10 times, so \( R_{gain} = 2 \times 22kΩ / (10 - 1) = 4.89kΩ \). The test’s result for some input signals is shown in Table 3.

<table>
<thead>
<tr>
<th>( \text{V}_{in} ) (mV rms)</th>
<th>( \text{V}_{out} ) (mV rms)</th>
<th>Gain (( \text{V}<em>{out}/\text{V}</em>{in} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1003</td>
<td>10.03</td>
</tr>
<tr>
<td>150</td>
<td>1536</td>
<td>10.024</td>
</tr>
<tr>
<td>200</td>
<td>2063</td>
<td>10.315</td>
</tr>
<tr>
<td>250</td>
<td>2572</td>
<td>10.288</td>
</tr>
<tr>
<td>300</td>
<td>3059</td>
<td>10.196</td>
</tr>
<tr>
<td>350</td>
<td>3583</td>
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</tr>
<tr>
<td>400</td>
<td>4104</td>
<td>10.26</td>
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<td>450</td>
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<td>10.13</td>
</tr>
<tr>
<td>500</td>
<td>5070</td>
<td>10.14</td>
</tr>
</tbody>
</table>

From the above experimental results can be concluded the amplification of the amplifier instrumentation data is quite linear.

3.2.2 The Test of Band Pass Filter (BPF)

The test on this circuit is performed to see the frequency response of the Band Pass Filter circuit.
The cut-off frequency is between 48KHz and 55KHz, or center frequency is at 50kHz. The input signal used is a sine wave derived from the function generator with an input voltage of 1 Vrms. The frequency varied from 1 KHz to 500 KHz, and the output voltage is measured using an Avometer. The test results from this BPF’s circuit are shown in Table 4 below.

Table 4 The test’s result of BPF’s circuit

<table>
<thead>
<tr>
<th>Vin (Vrms)</th>
<th>fin (KHz)</th>
<th>Vout (Vrms)</th>
<th>Gain (Vout/Vin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0.09566</td>
<td>0.019132</td>
</tr>
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<td>5</td>
<td>20</td>
<td>0.94722</td>
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<td>5</td>
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<td>3.93141</td>
<td>0.786282</td>
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<td>4.42912</td>
<td>0.885824</td>
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<td>1.004984</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>4.54289</td>
<td>0.908578</td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>4.13719</td>
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</tr>
<tr>
<td>5</td>
<td>80</td>
<td>3.87723</td>
<td>0.775446</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>2.02039</td>
<td>0.404078</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>1.37764</td>
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</tr>
<tr>
<td>5</td>
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<td>0.141709</td>
</tr>
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<td>5</td>
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<td>0</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The result of the BPF’s test above showed that the center frequency lied at 50 KHz. This is proven at that frequency the voltage gain is the greatest gain.

3.2.3 The Test of AC to DC Converter

This test is done by providing input to the circuit of 50kHz sinusoidal signal which generated from function generator with some variation of voltage amplitude. The output voltage is a DC voltage is shown by a voltmeter which is then compared with the RMS voltage of its input signal to determine the error of this circuit. The test results are shown in Table 5.

Table 5 The result’s test of AC to DC converter circuit

<table>
<thead>
<tr>
<th>Vin AC (Vrms)</th>
<th>Vout DC (Volt)</th>
<th>error (Volt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.41</td>
<td>0.09</td>
</tr>
<tr>
<td>1</td>
<td>0.93</td>
<td>0.07</td>
</tr>
<tr>
<td>1.5</td>
<td>1.34</td>
<td>0.26</td>
</tr>
<tr>
<td>2</td>
<td>0.95</td>
<td>0.05</td>
</tr>
<tr>
<td>2.5</td>
<td>2.48</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>3.04</td>
<td>0.04</td>
</tr>
<tr>
<td>3.53</td>
<td>3.23</td>
<td>0.27</td>
</tr>
<tr>
<td>4</td>
<td>3.65</td>
<td>0.35</td>
</tr>
<tr>
<td>4.5</td>
<td>4.13</td>
<td>0.37</td>
</tr>
</tbody>
</table>

3.2.4 The Test of Differential Amplifier Circuit

This circuit is used to adjust the DC voltage output from the AC to DC converter so that the value will vary from 0-5 Volts. Thus, the output of this circuit is a DC voltage with a maximum voltage of 5 Volts and it’s ready to be inserted into the ADC microcontroller.

3.3 The Body Bio-impedance Measurement

This measurement is intended to determine the magnitude of impedance changes on the back/shoulders. The measurement was made by moving the right and left shoulders from the normal position up to the maximum and recorded the changes in voltage that occur. The test was conducted on five samples. The impedance is obtained by dividing that voltage by a large flow of stimulation. Table 6 shown the measurements on the right and left shoulders.

Table 6 Result of measurements on the right shoulders

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Measured Impedance ( )</th>
<th>Impedance Change ( )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>Contraction</td>
</tr>
<tr>
<td>1</td>
<td>Yudi</td>
<td>137.0832</td>
<td>152.4007</td>
</tr>
<tr>
<td>2</td>
<td>Dharma</td>
<td>196.0295</td>
<td>203.6045</td>
</tr>
<tr>
<td>3</td>
<td>Andi</td>
<td>164.7954</td>
<td>175.9647</td>
</tr>
<tr>
<td>4</td>
<td>Ahmad</td>
<td>178.5674</td>
<td>188.4387</td>
</tr>
<tr>
<td>5</td>
<td>Robi</td>
<td>184.6490</td>
<td>189.6852</td>
</tr>
</tbody>
</table>

Table 7 Result of measurements left shoulders

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Measured Impedance ( )</th>
<th>Impedance Change ( )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>Contraction</td>
</tr>
<tr>
<td>1</td>
<td>Yudi</td>
<td>154.8362</td>
<td>162.8298</td>
</tr>
<tr>
<td>2</td>
<td>Dharma</td>
<td>174.8294</td>
<td>178.7382</td>
</tr>
<tr>
<td>3</td>
<td>Andi</td>
<td>139.2847</td>
<td>145.8345</td>
</tr>
<tr>
<td>4</td>
<td>Ahmad</td>
<td>156.2193</td>
<td>163.7301</td>
</tr>
<tr>
<td>5</td>
<td>Robi</td>
<td>129.8453</td>
<td>139.3493</td>
</tr>
</tbody>
</table>

From table 6 and 7, it’s known that the bio-impedance measurement system is designed to measure the body’s bio-impedance value for all samples tested. Table 6 is the measurement result on the right shoulder and Table 7 is the measurement result for the left shoulder. There is a change in the value of bio-impedance in normal circumstances compared to muscles when contract. The test results also show that the value of bio-
impedance when the muscle contracts larger compared to normal condition. On the right shoulder, the changes in bio-impedance values occurred between 5.0362 Ohm and 15.3175 Ohm. While on the left shoulder the change in bio-impedance values that occurred between 3.9088 Ohm and 9.504 Ohm. The changes in bio-impedance values also caused the changes in measured bio-impedance voltages which will be used as a control signal in a system.

4. CONCLUSION

The design of body bio-impedance measurement system with three electrodes methods successfully done. This device is able to measure the body's bio-impedance signal on two channels simultaneously. There is a change in the bio-impedance value of the body when muscle tissue contracts compared to normal circumstances. On the right shoulder, an average change in body bio-impedance value of 9.7938 Ohm, and on the left shoulder of 7.0934 Ohm. The changes in body bio-impedance values are proportional to the result of the changes of bio-impedance voltage. The voltage changes that occur can be used as a control signal in the system.

5. REFERENCES