Secure Data Communication on ARM using Embedded 'C'

S.H.V Prasada Rao, B.Rajesh, P.Kanakaraja

Abstract-*The encryption standards such as DES (Data Encryption Standard), AES (Advanced Encryption Standard) and EES (Escrowed Encryption Standard) are widely used to solve the problem of communication over an insecure channel. With advanced technologies in computer hardware and software, these standards seem not to be as secure and fast as one would like. In this paper we propose a fast and secure encryption algorithm using substitution mapping, translation and transposing operations. Like one's compliment methodology the proposed symmetric encryption technique has two advantages over traditional schemes. First, the encryption and decryption procedures are much simpler, and consequently, much faster. Second, the security level is higher due to the inherent poly-alphabetic nature of the substitution mapping method used here, together with the translation and transposition operations performed in the algorithm. In this paper, the encryption and decryption procedures are explained and the performance is compared with popular encryption algorithms.*

Keywords-Cipher text; Decryption; Encryption; Plaintext; Secret key, mode switch, GSM modem, Siren

I. Introduction

In open networked systems, information is being received and misused by adversaries by means of facilitating attacks at various levels in the communication [1]. Data encryption is sought to be the most effective means to counteract the attacks [2]. There are two classes of encryption in use, which are referred to as i) Symmetric-key encryption using secret keys and ii) Asymmetric-key encryption using public and private keys. Public-key algorithms are slow, whereas Symmetric-key algorithms generally run 1000 times faster [3]. Symmetric-key cryptography has been -- and still is – extensively Used to solve the Traditional problem of communication over an insecure channel [4]. The encryption standards such as DES (Data Encryption Standard) [5], AES (Advanced Encryption Standard) [6], and EES (Escrowed Encryption Standard) [7] are used in Government and public domains. With today's advanced technologies these standards seem not to be as secure and fast as one would like [4]. Time Dependant Multiple Random Cipher Code [8] is a non- Feasted Symmetric-key encryption algorithm using random numbers. Performance comparison of popular symmetric-key encryption algorithms found in literature [9] indicates that Blowfish is faster compared to DES and AES. High throughput encryption and decryption are becoming increasingly important in the area of high-speed networking [10].

Manuscript received on August 2014

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Fast encryption algorithms are needed these days for the secure communication of high volume information through insecure channels. In this paper, a new symmetric-key encryption algorithm for secured message communication over insecure channels is presented. It is a direct mapping poly alphabetic Symmetric-key encryption algorithm. Here, we use direct substitution mapping and subsequent translation and transposition operations using X- OR logic and circular shifts that results in higher conversion speed. The block size is 128 bits (16 characters) and the key size is also 128 bits (16 characters). A comparison of the proposed encryption method with DES and AES is shown in table. 2.

The rest of the paper is organized in the following sections. In section 2, the encryption process is explained and in section 3, decryption process is explained. Performance is evaluated in section 4 and conclusions are made in Section 5.

II. The Encryption process.

A. Nomenclature

P – Plaintext
C – Cipher
text K – Secret
key
C_{L1} – Level-one cipher text
P (i) – i th plaintext character in input plaintext character block

C (i) – ith cipher text character in a block

C_{L1}(i) – ith level-one cipher text character in a block M[i][j] – Element of matrix M with row i and column j

A(i) – Element of Array *A* with index *i*			
K(i) – ith character of secret key, *K*			
$^{K}ts\_n$ -- Sub-key for translation in nth round			
Ktp_n 0, *Ktp_n1, Ktp_n2, Ktp_n3*	--	Sub-keys	For
transposition in the nth round			

B. Encryption steps.

The encryption, C = E (K, P), using the proposed encryption algorithm consists of three steps. The first step involves initialization of a matrix with ASCII code of characters, shuffled using a secret key, K. This initialization is required only once before the beginning of conversion of a plaintext message into corresponding cipher text message. The second step involves mapping, by substitution using the matrix, each character in every block of 16 characters into level-one cipher text character. The third step involves translation and transposition of level -one cipher text characters within a block, by X-OR and circular shift operations, using arrays, in 8 rounds. Fig.1 shows simplified block diagram of the encryption scheme.

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C. Matrix for substitution mapping.

A matrix M with 16 rows and 95 columns initialized with ASCII codes of characters using secret key is used for mapping the plaintext characters into level-one cipher text characters. During encryption, a block of 16 plaintext characters in the message is taken into a buffer. The ASCII code of the character P (i) is Obtained. From this ASCII code, 32 is subtracted. The resulting integer is used as column number j of ith row of the matrix M. The element contained in this cell which is an ASCII code of a character, is taken as the level-one cipher text character C_{L1}

(i) corresponding to the plaintext character P (i). In this way all the characters in a block are mapped into level-one cipher text characters and all plaintext character blocks are mapped into level-one cipher text character blocks.

D. Matrix initialization.

A matrix M with sixteen rows and ninety five columns is defined. Columns in every row of the matrix is filled with ASCII codes of characters starting from BLANK (ASCII = 32) in column zero to '~' (ASCII = 126) in column ninety-four representing elements of the matrix.

A 16 character (128 bits) secret key K, with key characters K(0) through K(15), is used for encryption and decryption. The ith row of the matrix is given an initial right circular shift, as many number of times as equal to the ASCII code of (i+1)th key character to shuffle the contents of the matrix M, for i = 0 to 14. For example, if K(1), is 'a' whose ASCII code is 97, row 0 of the matrix M is right circular shifted 97 times. If K(2) is 'h' whose ASCII code is 104, the second row of the matrix M is right circular shifted 104 times and so on. The row 15 of matrix M is right circular shifted as many number of times as equal to ASCII value of the key character K (0). Further, the ith row of the matrix is given a second right circular shift as many number of times as equal to ASCII (K(i)) to shuffle the contents of the matrix M, for i = 0 to 15. For example, the row 0 of M is right circular shifted as many number of times as equal to the ASCII value of key character K(0). The row 1 of the matrix M is given a right circular shift as many number of times as equal to the ASCII value of the key character K(1) and so on. Code.3 shows this second circular shift operation applied to the rows of matrix M.

E. Substitution mapping procedure.

A given message is broken into blocks of sixteen plaintext characters P(0) through P(15). Plaintext character P (i) is taken and a number j is calculated such that j = (ASCII code of plaintext character P (i) – 32). This number, j, is used as column number of the matrix M. Using j as column number we proceed to find the element in the ith row of the matrix M.

This element (ASCII code of a character) is used as level-one cipher text character C_{L1} (i) for a given plaintext character P(i). For example, for the plaintext character P(0) in a block, i = 0, j = (ASCII code of plaintext character P(0) – 32) is used as column number of row 0 of the matrix M to obtain level-one cipher text character corresponding to P(0). Similarly for character P(1) in the plaintext character block, i = 1 and j = (ASCII code of plaintext character P(1) – 32) where j is used as column number of the row 1 of the matrix to obtain level-one cipher text character corresponding to P(1). In this way, all the 16 plaintext characters in a block are mapped into 16 level-one cipher text characters denoted by $C_{L1}(i)$, i = 0 to 15. The characters of level 1 cipher text character block (C_{L1} (0) through C_{L1} (15)) are transferred to a 16 element array A1.

F.sub-set key generation.

One set of eight sub-keys K , K , K ……....K are generated ts_0 ts_1 ts_2 ts_7 using the secret key K such that: Kts_n = characters in columns

0 through column 15 in row n of matrix M concatenated. These keys are used in translation rounds. Another set of sub-keys K_{tp_n0}, K_{ps_n1}, K_{tp_n2} and K_{tp_n3} are generated such that K_{tp_n0} = character of matrix M with row number n and column number 0.

Here, each key is a character represented by the corresponding element in the matrix M. These keys are used in transposition rounds.

G. Translation and Transposing.

Eight rounds of translation and transposition operations are performed on the level 1 cipher text character block. The translation operations are done using X-OR operation performed on the cipher text character block using sub key, K_{ts_n} in the nth round. The translated cipher text character block is transposed using four arrays whose elements are circular shifted using

sub-keys K_{tp_n0}, K_{tp_n1}, K_{tp_n2}, K_{tp_n3} used in that round. These operations make the resulting output cipher text characters extremely difficult to decrypt by any adversary without having the secret key. The translation and transposition produce the effect of diffusion.

1. Translation of cipher text characters.

The contents of array A_1 is X-ORed with sub key K_{ts_n} in the nth round. The 16 characters of each block of cipher text are X-ORed with 16 characters of sub key K_{ts_n}

2. Transposing of cipher text characters.

The X-ORed level -one cipher text characters available in array A_1 are bifurcated and transposed using four arrays. For the nth round, array A_1 is right circular shifted as many number of times as equal to the integer value of Ktp_n0. After this operation, the first eight elements of A_1 (left most elements) are transferred to another array A_2 having 8 element positions. Then, A_2 is right circular shifted as many number of times as equal to the integer value of K_{tp_n1}. The other eight elements of the array A_1 (rightmost elements) are transferred to another 8 element array A_3 which is left circular shifted as many number of times as equal to integer value of K_{tp_n2}. Then A_2 and A_3 are concatenated and transferred to the 16 element array A_1. This 16 element array, A_1, is right circular shifted as many number of times as equal to the integer value of K_{tp_n3}. After this operation, the contents of A_1 represent the cipher text characters in a given block. The elements of array A_1 are moved to the cipher text block C(0) through C(15). The cipher text blocks are used to create the output cipher text message file.

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III. The Decryption process.

The decryption algorithm performs the reverse operations of encryption such that P = D (K, C). It is done in three steps. Here, cipher text character C (i), in blocks of 16 are processed using arrays and matrix. The first step involves initialization of a matrix with ASCII codes of characters, shuffled using the secret key. In the second step, the cipher text characters are de-transposed using circular shift operation of array and de-translated by X-OR logic using sub-keys in multiple rounds. With this operation we get back the level-one cipher text characters. In the third step, these level-one cipher text characters are inverse-mapped into plaintext characters using the matrix. In the decryption algorithm, sub-keys are generated from the secret key in the same way as in the case of encryption algorithm.

A. Matrix initialization.

An identical matrix M, used for mapping the plaintext characters into level-one cipher text characters, is used here for inverse mapping of the level-one cipher text characters into plaintext characters during decryption. At the decryption site, this matrix is created using the secret key K in the same way as in the case of encryption.

B. De-transposing of cipher text characters:

The cipher text character block from the cipher text file is brought in to a 16 element array A_1. For the n^{th} round, array A_1 is left circular shifted as many number of times as equal to the integer value of K_{tp_n3}. After this operation, the first eight elements ofA_1 (left most elements) are transferred to another array A_2 having 8 element positions. Then, A_2 is left circular shifted as many number of times as equal to the integer value of K_{tp_n2}. The other eight elements of the array A_1 (rightmost elements) are transferred to another 8 element array A_3 which is right circular shifted as many number of times as equal to integer value of K_{tp_n1}. Then A_2 and A_3 are concatenated and transferred to the 16 element array A_1. This array is left circular shifted as many number of times as equal to the integer value $^{of\ K}tp\_n0$.

C. De-translation of cipher text characters:

The contents of array A_1 is X-ORed with the bits of sub key K_{ts_n} in the nth round. After this operation, the contents of the array A corresponds to the level- one cipher text character block corresponding to the one obtained after the mapping operation done at the encryption side using the matrix. The contents of array A_1 is moved to level 1 cipher text block, C_{L1}.

D. Inverse mapping using matrix:

If C_{L1} (i) is the level-one cipher text character in a block, the inverse mapping is such that P (i) = char ((column number j of ith row of matrix M where C_{L1} (i) is the element) + 32). For example, let the 1st level-one cipher text character, C_{L1} (1), in a block is '#'. We proceed to search '#' in the matrix M to find the column number j in the 1st row where C_{L1} (1) = M [1] [j]. Then we determine the character whose ASCII = (j + 32) which gives the plaintext character P (1) corresponding to C_{L1} (1). Let the 2nd level-one cipher text character, C_{L1} (2), in a block is '%'. We proceed to search '%' in the matrix M to find the column number j in the 2nd row where C_{L1} (2) = M [2][j]. Then we determine the character whose ASCII = (j + 32) which gives the plaintext character P(2) corresponding to C_{L1}(2). In this way we can inverse map every cipher text character in every block into plaintext characters to get back the original message file.

IV. Performance evaluation

Performance comparison of various popular secret key algorithms, such as DES, AES and Blowfish running on a Pentium-4, 2.4 GHz machine, discussed in the literature [9] shows that Blowfish is the fastest among these algorithms.

The throughputs of these algorithms are respectively 7,988 bytes/sec, 5,326 bytes/sec and 10,167 bytes/sec. The proposed Symmetric-key Encryption algorithm is subjected to performance evaluation using a Pentium-4, 2.4 GHz machine. Execution time taken by the algorithm was measured using a plaintext file and the throughput calculated. The time between two test points in the algorithm during execution was measured with the help of system clock. The number of bytes (in the plaintext file) required for an execution time of one second during encryption was ascertained. Table.1 shows the comparison of performance of this encryption algorithm with the performance of popular secret key algorithms given in [9]. The throughput of Blowfish algorithm is only 10,167 bytes per second whereas this encryption algorithm provides 81,674 bytes per second. Thus this Encryption algorithm is 8 times faster than Blowfish algorithm.

Plate.1 shows a plaintext message file used for encryption. Plate.2 shows the cipher text message file generated using the proposed encryption scheme. Plate.3 shows the plaintext message recovered from the cipher text message using the proposed decryption scheme.

CCCCCCCCCCCCCCCC
CCC aaaaaaaaaaaaaa
BBBBBBBBBBBBBB
bbbbbbbbbbbbbb
111111111111111
222222222222222

$$$$$$$$$$$$$$

Plate.1: Plaintext message used for encryption.

\rm]a i5sNz {z < <R.-aC (2 Z4ZU} gCsn^a h4rM {t {= #/aB+ 5[5 T~h b} Ma0yEC~

Kj VSc~Na3xDB} Dk W mHx*-JRTk Ve7I

Plate.2: Cipher text generated from the message.
CCCCCCCCCCCCCCCC

aaaaaaaaaaaaaa
BBBBBBBBBBBBB
BB
bbbbbbbbbbbbbb
111111111111111

222222222222222

$$$$$$$$$$$$$$

Plate.3: Recovered message after decryption

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Table.2: Comparison of proposed encryption algorithm with DES and AES

Encryption Algorithm	DES	AES	Blow fish	**Proposed Encryption**
Throughput	7,988	5,326	10,167	**81,674**
Bytes/sec				

V.Working principle:

Industrial wireless transmission has arrived providing clear and significant advantages. Nevertheless, security is always an important issue and a question often asked is, "Will information be secure when broadcast via Data-Link Group wireless modems?" The answer can be found in understanding the technologies employed in these products and, to that end, this report will provide the understanding needed.

Data Encryption and Error Detection:

SRM Series information (modem specific and user data) exchanged between the modems is compressed, encrypted using a Substitution Dynamic Key and checked with one or more 32-bit CRC (Cyclical Redundancy Check) words. The dynamic key is changed more than 100 times a second and is generated based on network dynamics. The CRC error detection and correction, along with data encryption, ensures the data gets through securely and without corruption or is rejected.

Wireless Network Configuration:

There are two modes of operation for a Series network of radios, point-to-point and point-to-multipoint. Each will be approached separately.

Point-to-Point Operation:

In this mode, connection configuration is achieved by call number addressing. Each modem has a unique call number imbedded within its processor that cannot be changed or duplicated. A wireless network is composed of one Master, one Remote and optionally, one or two Repeaters. Each modem in the system is configured to communicate with specifically addressed modem(s) and thus forms a "closed system" in that no other modems can participate in the conversation. This is extremely secure especially when considering data injection.

Data encryption/decryption:

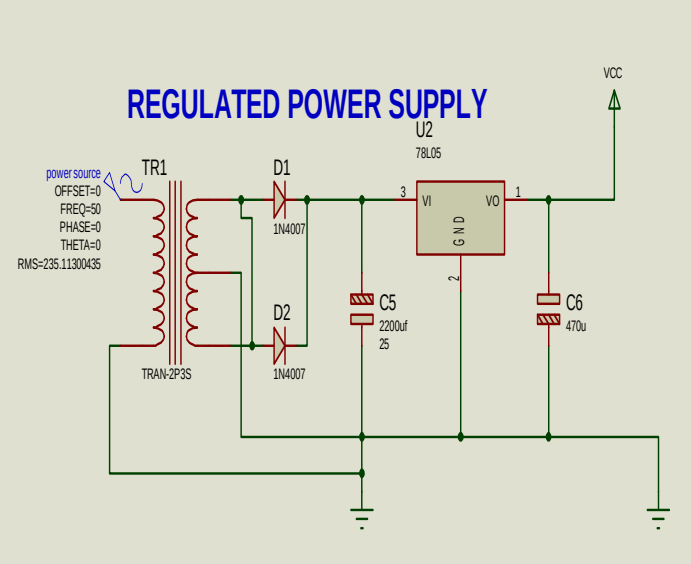
A data encryption/decryption IC is a specialized integrated circuit (IC) that can encrypt outgoing data and decrypt incoming data. Some such devices are intended for half-duplex operation (in which input and output do not occur simultaneously), and others are designed for full-duplex operation (where input and output can occur simultaneously).

Encryption is the conversion of data into a form, called a cipher, that cannot be understood by unauthorized people. Decryption is the process of converting encrypted data back into its original form, so it can be understood. Encryption and decryption should not be confused with encoding and decoding, in which data is converted from one form to another but is not deliberately altered so as to conceal its content.

An integrated circuit, sometimes called a chip or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. These devices can perform dozens of tasks in electronics and computing.

Power supply:

we are using hear full wave rectifier (FWR) for source voltage with linear voltage regulators for controller purpose LM7805 means it is a fixed positive +5v supply for TTL logic level design The construction of regulated power supply using FWR as shown below circuit respectively.



Circuit diagram:

A) AT89C52 Transceiver station:

Here we are implementing secure data communication in bi-directional protocol with half-duplex data transmission one side we are using The basic standard controller MCS51 family AT89C52 based design and another one we are implemented advanced processor 32-bit level ARM7 family LPC2148 controller respectively here the constructional diagram of the AT89C52 transceiver circuit as shown below.

B) ARM7 (LPC2148) Transceiver station:

The latest processor ARM7 family LPC2148 processor design it is a 32-bit level processor to use the one of the transceiver station in our design in this number of individual modules are inbuilt incorporated such as ADC, DAC, PWM, SPI, TWI (I2C) USB CONTROLLER that's why the processor technology is advanced and high speed devices for effective design purpose respectively. The constructional circuit diagram as shown in below figure respectively.

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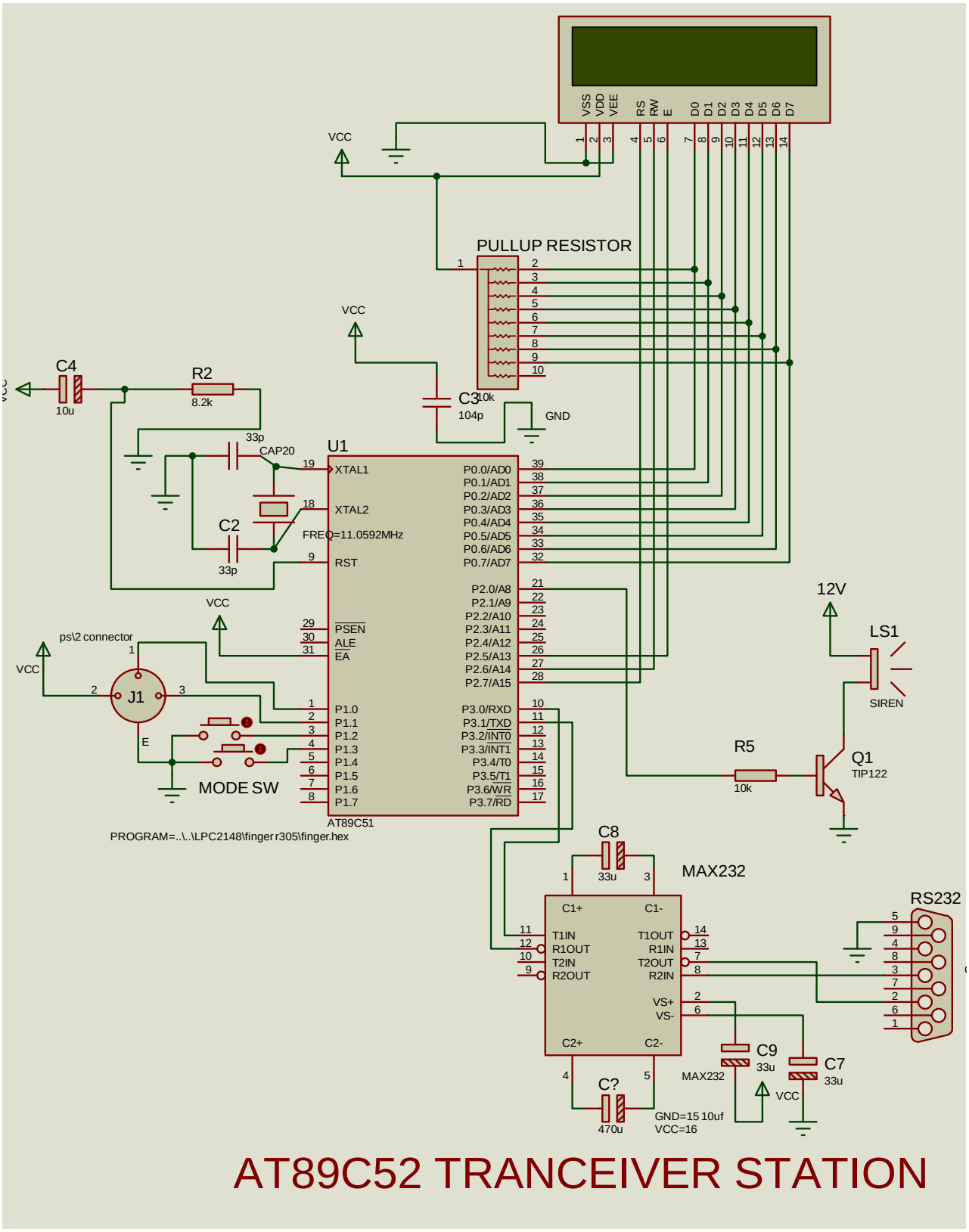

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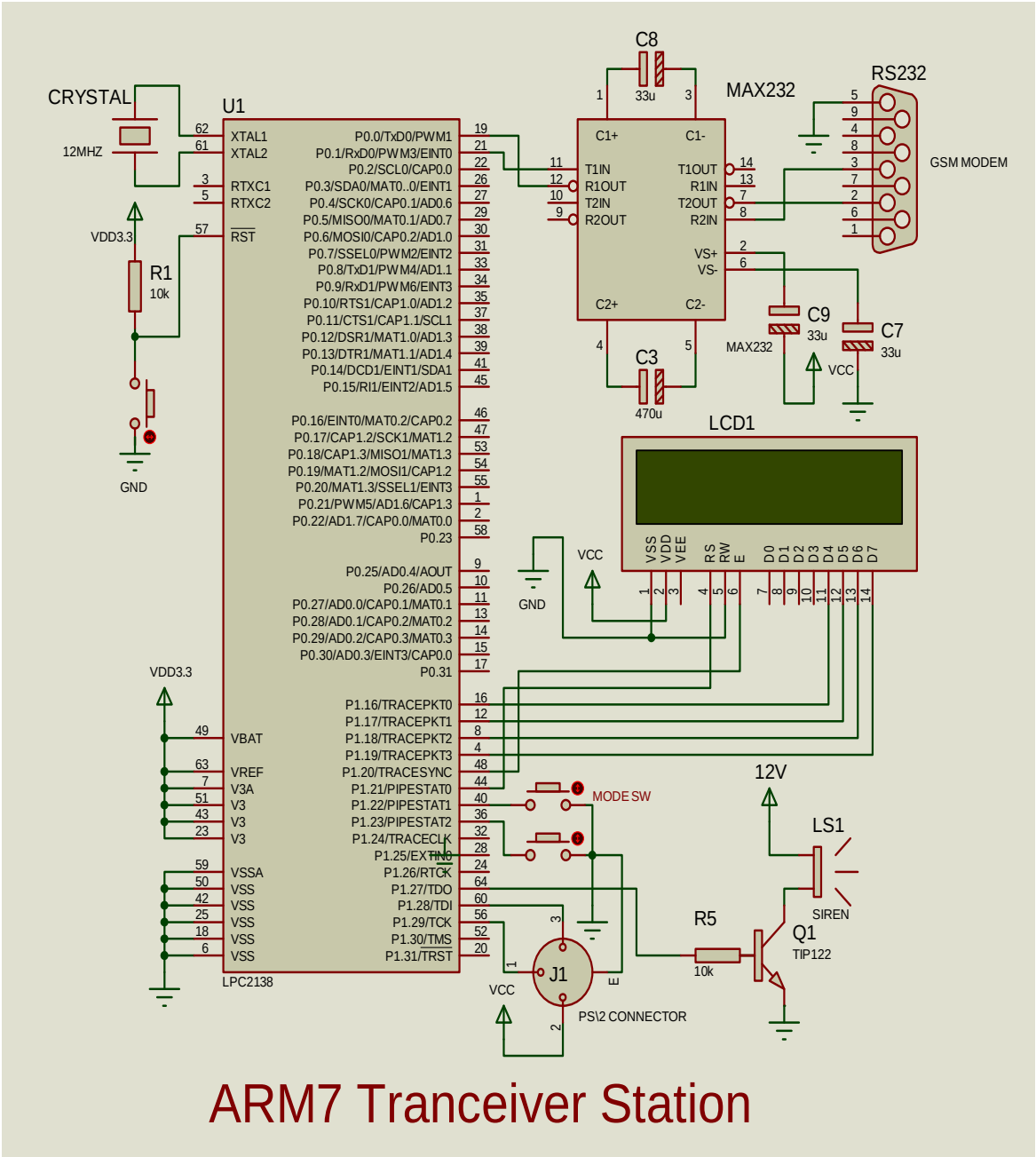

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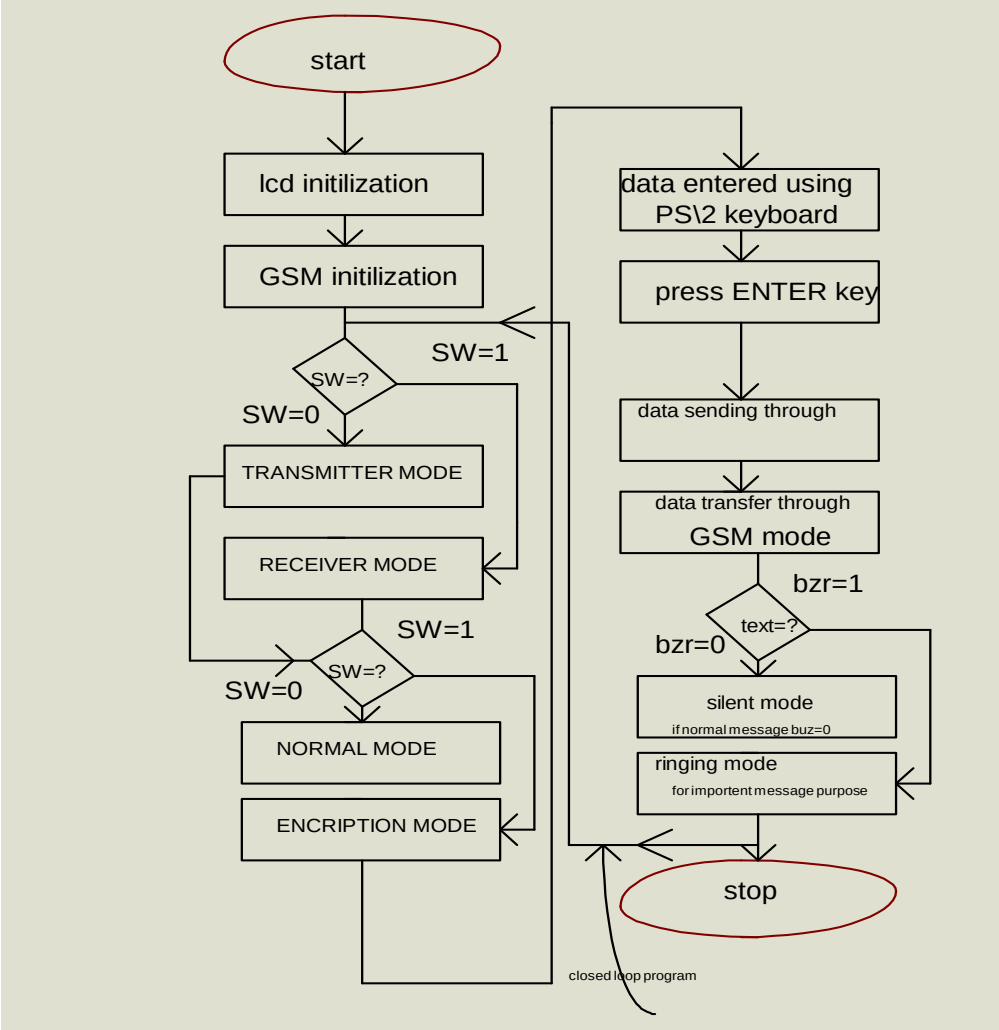
C) SOFTWARE Algorithm:



VI. Conclusion

The Encryption algorithm, presented above, is a simple, direct mapping algorithm using matrix and arrays. Consequently, it is very fast and suitable for high speed encryption applications. The matrix based substitution resulting in poly alphabetic cipher text generation followed by multiple round arrays based transposing and X-OR logic based translations give strength to this encryption algorithm. The combination of poly alphabetic substitution, translation and transposition makes the decryption extremely difficult without having the secret key.

Decryption of cipher text messages created using this encryption is practically impossible by exhaustive key search as in the case of other algorithms using 128 bits secret key. The cipher text generated by this algorithm does not have one to one correspondence in terms of position of the characters in plaintext and cipher text. This feature also makes decryption extremely difficult by brute force. The performance test shows that this encryption is a fast algorithm compared to the popular Symmetric-key algorithms. We are planning a cryptanalysis to determine the strengths and weaknesses of this algorithm. Also, we are trying an extension of this algorithm to include image files by suitably changing the matrix size and elements.

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